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Enabling Communication and Collaboration by Building an Infrastructure for a more Accurate and Effective Information Flow

A Case Study of the New Product Development Process at Volvo Construction Equipment

Master's thesis in Industrial Engineering and Management with emphasis in Quality and Operations Management

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DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE

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ABSTRACT

Communication, collaboration, and information are crucial elements for companies' success but are often the root cause of errors in projects. The larger the company is the more complex the information and communication flow will be. At the same time, more and more data are available for companies which increase the risk of overloading information that can end up with important data/information being lost or hidden in an overflow of documentation, or even in not using any of them.

The aim of this research was to identify important factors and flaws in communication and collaboration in the New Product Development process to investigate the possibility to build an infrastructure that can support the data/information flow as well as to investigate if a general visualization tool could be implemented and applied to all cases at Volvo Construction Equipment. The research involves the three main departments of the company: Operations, Technology and Purchasing, and different functions within them. Since the scope of the Masters' Thesis is quite wide, a mix of business research methods and the Six Sigma methodology was applied using both quantitative and qualitative approaches that followed the DMAIC cycle. The business research approaches were used for data collection that were analyzed and served as a base for answering three research questions.

The findings of the research show that there are several different factors and flaws that influence the possibility of building an infrastructure such as organizational structure, accessibility to the systems, amount of standardization, what communication channels that are used, the informal and formal knowledge structures, transferring knowledge, what storage system for information sharing is used, and how to measure performance in order to be able to improve continuously. The literature as well as responses from survey and interviews indicated that it was not possible to use one single visualization tool to meet all different demands that could be implemented. That would result in a huge and costly visualization tool where data/information could be lost or hidden inside the tool. The researchers found that the most crucial elements for a visualization tool to be successful is that it must fulfill a purpose, present the right information as well as enabling the user to transfer the information into knowledge. Therefore, the different features used in a visualization tool will vary from situation to situation. Some of the desired features that arose from Volvo Construction Equipment were planning and Virtual Reality. The researchers advised the company to further investigate if a Kanban Board and Virtual Reality could be the visualization tools needed for the company.

Keywords: Information Flow, Communication, Collaboration, New Product Development, Knowledge Sharing, Visualization, Six Sigma, DMAIC, Quality Indicators, Standardization, Infrastructure.

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Gothenburg, June 2021

Karen and Lovisa

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List of abbreviations

Volvo CE	
VPS	
NPD	New Product Development
RQ	
DMAIC	Define, Measure, Analyze, Improve, and Control
TQM	
QMS	Quality Management System
WIP	Work-in-Progress
VOP	Voice of the Process
VOC	Voice of the Customer
PDSA	Plan, Do, Study, Act
AIM	Affinity Interrelationship Method
SIPOC	Supplier, Input, Process, Output, and Customer
Т тар	
СТQ	Critical to Quality
P-map	Process map
MSA	Measurement System Analysis
VSM	Value Stream Map
DPMO	Defects per Million Opportunities
FMEA	Failure Modes and Effect Analysis
DFMEA	Design FMEA
PFMEA	Process FMEA
SD	Supplier Development
SDE	Supplier Development Europe
QA	Quality Assurance
APQP	Advance Product Quality Planning
PPAP	Production Part Approval Process
SAFe®	Scaled Agile framework
VR	Virtual Reality
FEM	Finite Element Method

1. INTRODUCTION

In this first chapter the background, the aim of the master's thesis, and the research questions will be introduced. Finally, the limitations of the research will be presented.

1.1 Background

Communication, collaboration, and information is often the root cause of errors in projects. The larger the company is, the more complex the information and communication flow will be. Industries are moving towards Industry 4.0, which will increase the amount of data available for companies. The data by itself is not useful, it has to be transformed into information, which in turn becomes knowledge that is used as a base for decisions. There will be a risk of overloading data and ending up with not using any of them, therefore it is important to investigate and standardize the information flow and build and infrastructure that supports it. This will allow the company to use the right data at the right time.

Volvo Construction Equipment (Volvo CE) is a part of Volvo Group and develops, manufactures, and markets equipment for construction and related industries. Volvo CE is among the world's leading manufacturers of wheel loaders and articulated haulers, as well as manufacturers of excavation equipment, road development machines and compact construction equipment. The company is represented worldwide in different locations in Europe, the Americas, Asia Pacific, and China. The company has more than 14,600 employees from 85 different nationalities. Volvo CE has 265 dealers represented in 180 markets globally. The headquarters are located in Gothenburg, Sweden, and there are factories in Sweden, France, Germany, US, Brazil, India, China, and Korea. In Sweden, the factory is located in Arvika, as well as the Operations department, but other departments and functions are located in Eskilstuna, Hallsberg, and Braås.

Volvo CE is moving towards Factory 4 Tomorrow which is a combination of Industry 4.0 and Lean methodology which results in a new version of the Volvo Production System (VPS). In the New Product Development Process (NPD), they have started the journey to implement Agile methods. With this in mind, they need to identify and improve their information flow. Today they are struggling with the mismatch in the information flow and cross-functional work. One reason is that the departments are located in different cities therefore, the communication and collaboration between those are insufficient and complex, but there are several other factors affecting the information flow. For instance, the quality engineer providing his/her report and the production manager giving his/her feedback, they are using different languages and visualizations that they think the other department needs.

The problem has been defined by Elisa Zanelli in her report "Decrease the risks of product failure by managing the complex information flow in a Welding fabrication industry" as well as measured and analyzed by Evdoxia Glykeria Panatzi's report "Increased productivity by improved information flow in the NPD Process" and Gaia Santoni's report "Standardized cross-functional communication as a Robust design tool". They all conclude that there are flaws in the communication and that this is affecting the quality, time to market and costs. To these it can be added that these flaws would also have a negative effect on the customer's perceived quality and returning rate. Small improvements will certainly have a positive impact on different stages of the NPD process and on the final results. These studies can serve as a good foundation to continue searching for a solution. However, the results have not been implemented since the solutions are not compatible with Volvo CE's software and useful guidelines are missing. There has also not been a continuous follow-up of their work since there is not a perfect organizational role yet that can own and cultivate possible solutions. To conclude, Volvo CE is in need of connecting these studies and implementing tools that could be used in their daily work.

1.2 Aim

The aim of the report is to identify important factors and flaws in communication and collaboration in the NPD process in order to investigate the possibility to build an infrastructure that can stimulate and support the data/information flow. The aim is also to investigate if a general visualization tool can be implemented and applied to all cases at Volvo CE. This research will result in an analysis of the way-of-working and recommendations about features and possible areas of use for a visualization tool. It is also important to provide the company with useful guidelines in order to be able to continue working in the implementation of a visualization tool that can be used in their daily work, and to consider the need of finding or creating an organizational role that will follow up the work and make sure that the improved suggestions will be carried out.

1.3 Specification of issue under investigation

The following research questions are going to be investigated in order to accomplish the aim of this master's thesis.

RQ 1: What important factors and flaws in communication and collaboration are important to consider when building an infrastructure that can support the data/information flow?

RQ 2: Is it possible to facilitate the information exchange by using a visualization tool that is useful for all users?

RQ 3: What kind of features are important to include in a visualization tool?

1.4 Limitations

In this subchapter the limitations of the study will be established. Limitations are important in order to limit the scope of the project/research. The study needs to be manageable by the researchers and clear boundaries need to be set up.

The investigated problem can be divided in two parts. The first one is related to the quality of the information flow and the second part is about the infrastructure, which makes the communication and collaboration possible. Both parts are important in order to have a well working information system and therefore they are included in the scope of the study. The focus of the research is going to be put on the NPD process in the industrialization phase of Volvo CE.

The researchers have drawn some limitations regarding some knowledge management assumptions such as that the employees have the knowledge needed to perform their job and are aware of their own roles and responsibilities, therefore this will not be included in this study. In order to know how well the information process works this can be evaluated at the end of each milestone or at the end of the project. By evaluating information processes important improvements can be identified. The researchers have decided to exclude the current evaluation process from this study since the researchers are constrained by time, but it is recommended to include this in future research.

2. METHODOLOGY

In this chapter the chosen methodology will be presented. The researchers decided to use a combination of business research methods and Six Sigma methodology to be adapted to fit the aim of this investigation. In the following sub-chapters, the research and strategy approaches as well as the chosen methodology will be discussed in detail. The ethical considerations will be briefly explained and the validity and reliability for quantitative research as well as the trustworthiness and authenticity for qualitative research will be presented in regard to this study.

2.1 Research Approach

There are three logical reasoning approaches in business research: deductive, inductive, and abductive. All of them are used to make logical conclusions and to build theories. This study will make use of an abductive approach because it allows the researchers to have a holistic view, analyze the issues from multiple perspectives and move back and forth in the process, which is an advantage when working with Six Sigma tools. Abductive thinking is based on a pragmatist perspective and attempts to explain empirical phenomena found through observations and/or experiences and build and test theories based on the findings (*Bell, Bryman, & Harley, 2019*). A big advantage with an abductive approach is that it overcomes the drawbacks of the other two approaches. In a deductive approach you can only dismiss or approve the theory and there is a risk of falsifying the theory. Meanwhile, in an inductive approach it is not clear how much data that is enough to build the theory and as a result the theory can remain untested (*Bell, Bryman, & Harley, 2019*). Shortly, the deductive answer the why question, inductive the what and abductive try to answer both, and at the same time create space to generate new theories, see Figure 1. The use of an abductive approach gives the researchers more flexibility to change the theoretical framework before, during or after the research process (*Dubois & Gadde, 2002*).



Figure 1: The three research approaches (Jokhio & Chalmers, 2015)

2.2 Research Strategy

In order to state the research strategy of this study, the ontological and epistemological considerations must be understood and established. Ontology deals with the study of existence while epistemology handles the means and conditions for knowledge (*Bell, Bryman, & Harley, 2019*).

There are two ontological points of view; Objectivism and Constructionism. The most appropriate position for this study is the one called Constructionism which implies that organization and culture do not constrain social beings, instead these are formed by the actions and interactions of individuals and are subject to changes. This position is the most suitable since it is closely associated with a pragmatist perspective which the abductive approach is based on (*Bell, Bryman, & Harley, 2019*).

The epistemological considerations guide the researchers in which way the research will be conducted. The aim of this study requires a mixed epistemological position between Positivism and Interpretivism that is called Pragmatism. Pragmatism implies the use of methods of natural science for objectivity as well as grasping the subjective aspects of social interaction. It relies on abductive reasoning, which allows combining methods from both quantitative and qualitative research strategies, see Table 1 (*Morgan, 2007*). As mentioned in 2.1 Research Approach, this study is using an abductive approach therefore pragmatism is the most suitable choice. By integrating the different perspectives of both epistemological positions, a more holistic view can be achieved.

	Qualitative Approach	Quantitative Approach	Pragmatic Approach
Connection of theory and data	Induction	Deduction	Abduction
Relationship to research process	Subjectivity	Objectivity	Intersubjectivity
Inference from data	Context	Generality	Transferability

Table 1. A Pragmatic Alternative to Key Issues in Social Science Research Methodology (Morgan, 2007)

The quantitative research will be used to get an overall perspective of the information flow in the company and be able to get numerical data to be measured, meanwhile the qualitative research will be conducted for a deeper understanding of the underlying factors. The tools that will be used in this study will be presented in the following section.

2.3 Business Research Method

The business research method will be one of four mixed methods presented by Bell et al. (2019) called convergent parallel design. A convergent parallel design has the aim of comparing or merging the analyses of the quantitative and qualitative data in order to capture the whole picture,

see Figure 2. In a convergent parallel design, both methods are of equal weight. This design was selected to be the most suitable since it tries to capture the strength of both methods and by that avoid the weaknesses (*Bell, Bryman, & Harley, 2019*). This research method is thereby suitable



Figure 2: Convergent parallel design (Bell, Bryman, & Harley, 2019)

for the chosen abductive research approach.

In quantitative research information is collected and transformed into data in order to be quantified and analyzed. Researchers usually state a hypothesis or hypotheses (or research questions) to be tested as a starting point that can be supported or disproven after the analysis. But stating a hypothesis is not mandatory in quantitative research and the researchers have the option to freely collect data concerning the investigated issue before stating the research questions (*Bell, Bryman, & Harley, 2019*). Quantitative research subsumes methods as surveys which are going to be applied in this study.

In qualitative research the research questions tend to be an outcome of the study rather than preceding it, but this point of view is disregarded by some authors (*Bell, Bryman, & Harley, 2019*). Nevertheless, the research questions can be preliminary stated keeping them open to changes according to the authors' findings. Qualitative research includes research methods such as qualitative interviews, ethnography/participant observations, focus groups, etc. that will be used during the course of this study.

2.4 Six Sigma Methodology

Six Sigma is a systematic method used in industry for process improvement and new product and service development. It is based on scientific methods and relies on statistical methods. Linderman, Schroeder, Zaheer, and Choo (2003) affirm that Six Sigma still *"lacks theoretical underpinning and a basis for research other than "best practice" studies"* (p. 193), for that reason the researchers decided to combine foundations of business research and Six Sigma methodology to have a more solid academic study. Six Sigma is applied in practice and is seen as a problem solving and improvement approach. One method for process improvement used in Six Sigma is the DMAIC cycle which consists of five steps; Define, Measure, Analyze, Improve, and Control (*Linderman, Schroeder, Zaheer, & Choo, 2003*). The DMAIC is an effective method even called metaroutine to use for changing established routines or designing new ones and for variation

reduction (*Schroeder, Linderman, Liedtke, & Choo, 2008; de Mast & Lokkerbol, 2012*). Therefore, this is an appropriate method to use in this research.

The Define phase aims to identify the right underlying problem. This is done by zooming out in order to get an overall view and looking into different perspectives that involve all the different stakeholders. The Measure phase has the purpose to identify the current state and find the baseline to measure their performance in relation with the identified customer needs. This phase provides the researchers with sufficient information about the process and prepares for the next phase where the root causes can be searched for. The Analyze phase also tackles the problem by analyzing the collected data about the process using statistical tools. In the next phase Improve, the gained knowledge in the previous phases is used to try finding possible solutions by optimizing the outputs meaning reducing or even eliminating variation. In the final phase Control, these solutions that have been implemented on a pilot basis in the previous phase, are tested to prove their efficiency and maintain the gains in the long term by implementing control tools (*Carleton, 2018*).

Figure 3 shows the five phases of the DMAIC method. These phases do not follow a cascade approach, instead they can overlap each other, and the process can be iterative. The DMAIC phases are briefly described here, the different tools will be described in depth in the Theoretical Framework, the process of the Define and Measure phases will be portrayed in the Empirical Findings and the Analyze phase will be presented in the Analysis chapter.



Figure 3: DMAIC cycle

As mentioned above, the DMAIC cycle is not a straightforward process, meaning that the researchers will be moving back and forward in the different phases. For that reason, it is not sure that all phases are going to be accomplished in this research. The main focus will be on the Define, Measure and Analyze phases since the problem is quite complex and no baseline had been determined before, this is the reason why it is important to focus on these three phases. This does

not mean that the last two phases will be left aside. Depending on the study progress the Improve and Control phase will be handled.

2.5 Data Collection

As mentioned before, a mix of quantitative and qualitative methods will be used. These methods will be described in detail in the following sub-chapters.

2.5.1 Surveys

Quantitative surveys are used to get numerical data that can be quantified and measured in order to determine statistical results. Surveys enable the researchers to reach out to a larger number of respondents and therefore gives an opportunity to reach border insights about the information flow and find possible measures and/or indicators. In order for these measures to be valid and reliable it is important to choose the proper population sampling. But there are also other factors affecting the validity and reliability of the study that will be discussed in another chapter.

A proportional representation of employees of the involved departments is desired, for this means a Stratified Random Sampling is the best option. Stratified random sampling is a type of probability sample that stratifies the population by a criterion, being the chosen criterion for the strata in this case departmental membership. The advantages of choosing this kind of sampling are getting a more accurate representation of the desired population by reducing bias in the sampling selection as well as having the possibility of using several stratifying criteria if needed (*Bell, Bryman, & Harley, 2019*). Nevertheless, there is always a risk of having different kinds of sampling errors that will be presented later.

2.5.2 Literature review

A literature review is crucial for postgraduate dissertation since it justifies the research questions and builds the research design. It should include subjects like; the theoretical area that is already known, is there any inconsistencies relating to this area, relevant concepts, and theories. In a literature review it is also important to identify the knowledge limit in the area (*Bell, Bryman, & Harley, 2019*). According to Bell et al. (2019) there are two approaches to execute a literature review: systematic and narrative. The systematic is an approach that has an organized way of choosing and using the literature and is a cornerstone of evidence-based approach. Meanwhile, the narrative is less structured and is more diverse/expansive in the scope. The narrative approach tends to be more applicable in research that is based on interpretive epistemology and use of qualitative methods (*Bell, Bryman, & Harley, 2019*). As mentioned above this research is using a pragmatic approach, therefore the narrative approach is approach is that it is more suitable for the DMAIC method where you do not know the outcome and therefore the literature can change during the process.

2.5.3 Semi-structured interviews

To collect the qualitative data, semi-structured interviews were chosen since those allow the interviewer to be able to compare answers from different interviews but also gives the freedom to have different discussions with the respondents. The interviews will be carried out in a mix of structure and unstructured character with prepared questions, these prepared questions do not need to be followed strictly. An advantage with semi-structured interviews is that it enables follow-up questions as well as the interviewee can bring up new ideas and views about the problem (*Bell, Bryman, & Harley, 2019*).

In order to make sure that the semi-structured interviews cover the topic and help answer the research questions an interview guide will be used. An interview guide consists of prepared questions that the interviewer can ask but does not need to be constrained to. It is important that the questions in the interview guide are asked in a relevant language to the interviewee. The interview guide follows a general sequence presented by Robson (1993), see Figure 4.



Figure 4: Interview sequence (Robson, 1993)

Although a generalized picture is not possible to get from a qualitative approach, the researchers want to capture a holistic view and therefore want to interview employees involved from different departments. Therefore, a generic purposive sampling is the most suitable since it enables the authors to choose the interview objects in a strategic way and the different criteria that is relevant to answer the research questions. One form of purposive sampling, that is called snowball sampling, will be used. In order to reach out to the right people, already established contacts are going to be utilized to point out relevant respondents (*Bell, Bryman, & Harley, 2019*).

2.5.4 Ethnography/participant observations

To further collect qualitative data, observations will be conducted. Ethnography and participant observations is a method where the authors are joining a process or group and observe what happens in order to understand the problem from an insider's point of view. This method is used to gain understanding of organizations work culture and entities which will be of great importance in order to understand the communication and information flow. A full-scale ethnography will not be possible because it will require too much time spent in an organizational setting, therefore a micro-ethnography observation will be done in the form of a Gemba walk in the Arvika facility (*Bell, Bryman, & Harley, 2019*). Gemba walk is a tool from Lean and Six Sigma that aims at watching how the process is done and talking with those who do the job in order to understand the process (*Mann, 2005*). The focus in the observation will be on understanding how the process

works as well as to see how people interact with each other and how well the communication channels work.

In an observation it is important to consider what role the observer will have, according to Bell et al. (2019) there are four roles; Complete participant, Participant-as-observer, Observer-asparticipant and Complete observer, see Figure 5. Since it will be a micro-ethnography it will not be possible to take a role as a complete participant or participant as observer, and a complete observer has a risk of missing important information since you do not interact at all. Therefore, the role of observer-as-participant will be used in this study. This will allow the researchers to interact and to ask questions during the observation. The sampling of this observation will be a purposive sampling in the form of snowball sampling. The snowball sampling in combination with convenience sampling is according to Bell et al. (2019) the most common one for ethnographic research.



Figure 5: Role of observer (Bell, Bryman, & Harley, 2019)

2.5.5 Focus group

Focus group is a qualitative method for interviewing two or more participants at the same time. But the aim of this method is not sparing time or getting individual opinions, instead the focus is put on exploring a specific topic in depth, being carried out by interactions and discussions between the group members. A focus group is usually run by a moderator(s) or facilitator(s) that guides the session but does not interfere with the group's interactions (*Bell, Bryman, & Harley, 2019*).

The researchers will use the focus group technique in order to test the suggested features and areas of use of a visualization tool obtained from the results of the gathered data from the quantitative and qualitative methods. This will be done in order to validate the results and/or make appropriate changes. The participants will be chosen strategically from the involved departments.

2.6 Ethics of the Research

It is very important when conducting a business research study to be aware of the ethical principles and legal considerations that should be taken into account in order to make informed decisions about ethical issues. The researchers agreed on maintaining a stance of ethics in accordance with Universalism that states that *"the ethical precepts should never be broken" (Bell, Bryman, &*

Harley, 2019, p. 111). These principles and other considerations will be described in the following sub-chapters in regard to this study.

2.6.1 Avoidance of harm

It is important to avoid harm as it can affect participants' development, self-esteem, career and/or future employment. In order to protect the participants, the identities and records of individuals should be maintained as confidential. This means that the authors need to make sure that respondents' identities cannot be discovered unless permission to do so has been given. In the survey it will be easier to keep the records and findings anonymized, since it is a quantitative method, according to Bell et al. (2019) it is more of an issue to keep it anonymized in the qualitative methods especially when care has to be taken with regard to possible identification of departments, individuals, and places. Therefore, it is important that the authors take this into consideration when conducting the qualitative methods.

2.6.2 Informed consent

The ethical principle of voluntary informed consent aims to provide the potential participants/respondents with sufficient information about the research topic to be able to decide if they wish to participate in the study or not. The decision must be freely taken after a well-informed consideration without coercion of any kind (*Bell, Bryman, & Harley, 2019*).

In the course of this study the participants will be informed about the nature/aim of the thesis work verbally and/or in a written form. The participants will be asked for permission to be recorded when being interviewed/observed, consent will also be asked in order to eventually quote them when writing the findings and their wish will be respected. They will also have access to the final written report.

2.6.3 Privacy

Linked to the informed consent is the third ethical concern that is about the privacy issue. The researchers have no special right to intrude on a respondent's privacy, what is considered as privacy is up to each individual to decide (*Bell, Bryman, & Harley, 2019*). Therefore, the researchers need to make sure that each respondent has the opportunity to refuse to answer questions if they do not feel comfortable answering them and the possibility of declining findings that they perceive as invasion of privacy.

2.6.4 Preventing deception

This ethical principle handles the matters of dishonesty when conducting and/or presenting the research. The participants are deceived when they are not fully informed of the purpose of the study and/or are led to believe something that is not true (*Bell, Bryman, & Harley, 2019*).

Deception is completely unethical and unacceptable and can damage the trust between the partners. The reserachers intend to avoid deception of any kind when conducting the study.

2.6.5 Legal considerations

Some legal considerations regarding the data management must be taken into consideration. National and EU legislation about data protection will be respected. Other legal considerations as copyright or intellectual property is owned by Volvo Group according to the signed contract.

2.7 Reliability and Validity for Quantitative Research

It is important to evaluate the research in order to confirm the quality and use of the findings. In quantitative research the criteria for evaluation are reliability and validity. These criteria will be further explained below.

2.7.1 Reliability

In quantitative research it is important to make sure that the study is reliable, meaning that it should be repeatable. Using the same methods under the same circumstances should lead to the same result then the study is stable and reliable. To ensure that a study is reliable there are three prominent factors that need to be considered: stability, internal reliability, and inter-rater consistency (*Bell, Bryman, & Harley, 2019*).

With stability the question about how the measure is stable over time is considered. One of the most common ways to test is to use the test-retest method meaning that the same sample is tested on two occasions this should lead to high correlation. High correlation will imply that the measure is stable (*Bell, Bryman, & Harley, 2019*). Since the authors are constrained by the time to completion of this master thesis a retest is difficult to implement and suggest that a retest is done in the near future.

Internal reliability handles the issue about the degree of relatedness of indicators. It is important to make sure that the questions that are used to form an indicator are coherent to each other, otherwise there is a risk of mixing different concepts and analyzing something else. A way to measure the coherence is to use Cronbach's alpha which calculates the average of all possible splithalf reliability coefficients. The coefficient alpha is between 1 and 0 where 0.80 and above is an acceptable level (*Bell, Bryman, & Harley, 2019*). The test can be done using a computer program as JMP.

Lastly, inter-rater consistency is about stability in the decisions. The problem can arise when there are more than one observer and there is a high degree of subjective judgement involved e.g., decisions made about how to categorize items. One way to measure inter-rater consistency is to use Cohen's kappa which measures the agreement over the coding of items by two people. The

coefficient is similar to Cronbach's alpha; the closer to 1 the higher the inter-observer consistency (*Bell, Bryman, & Harley, 2019*). Cohen's kappa will be applied.

2.7.2 Validity

It is also important in quantitative research to make sure that the study is validated, meaning that the indicators should measure the concept. There exists four forms of validity: measurement-, internal-, external- and ecological validity. In quantitative research the focus is on measurement validity which measures social scientific concepts. Measurement validity reflects on how the measures really measure the concept. When measuring validity there are many aspects such as face-, concurrent-, predictive-, convergent- and discriminant validity to be considered (*Bell, Bryman, & Harley, 2019*).

When developing a measure, face validity should be considered and could be established by testing the questions on other people to see if they understand the concept. These people should have experience or expertise in the field and determine if the measures seem to reflect on the concept *(Bell, Bryman, & Harley, 2019)*. In order to ensure face validity, the authors will send the survey to the thesis supervisor who will act as the expert in the field and determine if the survey seems to reflect the concept.

The concurrent validity deals with the issue of factors that can differ and its relevance to the concept. For example, people tend to answer questions differently depending on their mood (*Bell, Bryman, & Harley, 2019*). For this study about information and communication employees may perceive the communication flow as non-functioning and will answer questions differently from people that perceive it as working. Therefore, it is important to identify these correlations.

In predictive validity future criterion measures are used rather than contemporary ones. To test the predictive validity the survey can be sent out some months or years after to compare the answers from the survey that was done. Another way to test predictive validity is to include questions about an ideal future scenario (*Bell, Bryman, & Harley, 2019*). This way is preferred by the researchers.

Convergent validity is about comparing measures through other methods. For example, if the survey measures how much time employees spend on meetings a way to validate the measures in the survey is to track and observe the employees schedule (*Bell, Bryman, & Harley, 2019*).

Discriminant validity intends to ensure that the indicators measure different things and do not overlap each other (*Bell, Bryman, & Harley, 2019*). Testing discriminant validity is very important in order to guarantee the distinctiveness of the analyzed measures and the authors intend to test it using the one proposed by Little, Kluemper, Nelson and Gooty (2012).

2.8 Trustworthiness and Authenticity for Qualitative Research

According to Bell et al. (2019), an alternative criterion is proposed by Guba (1985) for evaluating qualitative research that differs from the quantitative view of validity and reliability. They argue that there is not one single reality for the social world but there could exist several ones to be discovered by the researchers (*Bell, Bryman, & Harley, 2019*). The trustworthiness of the qualitative research will be briefly explained in terms of credibility, transferability, dependability, and confirmability.

2.8.1 Credibility (parallels internal validity)

To ensure the credibility of the findings the researchers must make use of a canon of good practices when conducting the research as well as seeking confirmation from the participants to corroborate that the social reality(s) has been correctly understood by the authors (*Bell, Bryman, & Harley, 2019*). This respondent validation is intended to be done in a focus group at the end of the study by presenting the proposed solution and findings. Another convenient method to ensure credibility is called Triangulation which is commonly used in quantitative research but that is also very useful to cross-check results from both quantitative and qualitative research (*Bell, Bryman, & Harley, 2019*) which is the case the researchers will encounter.

2.8.2 Transferability (parallels external validity)

Opinions diverge about how to apply transferability in qualitative research since this is usually related to deeper studies of subjective character which differ substantially from quantitative ones that focus more on the breadth rather than the depth. This issue makes it quite difficult to transfer that specifical reality to other contexts. Some researchers such as Geertz (1973) argue that a detailed description of the case should be provided while Guba and Lincoln (1994) disagree with that because that could generate sources of criticism and judgement about the transferability of the findings (*Bell, Bryman, & Harley, 2019*).

2.8.3 Dependability (parallels reliability)

Dependability can be understanded as a parallel to reliability in quantitative research, which means if the findings are trustworthy enough to be applied. For that means, the adoption of an "*auditing*" approach is suggested by Guba and Lincoln (1994) which implies keeping records of all the steps of the research process in order to be audited by a peer (*Bell, Bryman, & Harley, 2019*). The researchers rely on the assigned supervisor and examiner from Chalmers to serve as an "auditor" to guarantee the dependability of this thesis work.

2.8.4 Confirmability (parallels objectivity)

Confirmability aims to a high degree to make sure that the researchers maintain objectivity when conducting the study without allowing personal values, conflict of interests or own points of view

influence the applied methods and findings that derive from these (*Bell, Bryman, & Harley, 2019*). The researchers aim to preserve the objectivity of the study and rely on the "auditor" to point out if the confirmability of the study is at risk.

2.8.5 Authenticity

Authenticity is a criterion presented by Guba and Lincoln (1994) that deals with the social and political impact of the research. The researchers are obligated to objectively present different points of view and empower the participants through a better understanding of the situation to take actions that can derive into positive changes (*Bell, Bryman, & Harley, 2019*).

3. THEORETICAL FRAMEWORK

This chapter will cover the literature review that serves as a base or theoretical framework to this research. First, a brief review of the Total Quality Management's cornerstones will be presented, followed by an introduction to different procedural models as Waterfall and Agile, and Push and Pull approaches. The Six Sigma methodology with emphasis in concepts as Voice of the Process and Voice of the Customer, and the DMAIC cycle's different phases and tools that are applied in this master thesis will be also briefly described. Finally, general concepts within communication, knowledge and information sharing, and visualization will be explained.

3.1 The cornerstones of Total Quality Management

The concept of Total Quality Management (TQM) can be defined as a set of continuous efforts to satisfy, or even better exceed, customer needs and expectations by applying values, methodologies and tools that would lead to lowering costs and diminishing resource consumption. TQM can also be seen as a holistic framework to which different methodologies can be applied (*Bergman & Klefsjö, 2010*). Bergman and Klefsjö (2010) present a model where they introduce important values that need to be present and interrelate in order to serve as a basis to accomplish the means of TQM. It is called the cornerstone model of TQM presented in Figure 6 below.



Figure 6. The cornerstone model of TQM (Bergman & Klefsjö, 2010)

The presented values, even called cornerstones are focus on customers, base decisions on facts, focus on processes, improve continuously, let everybody be committed, and committed leadership. These values are fundamental in any quality effort and should not be neglected. The following paragraphs are based on the definitions given by Bergman and Klefsjö (2010).

Focus on customers is placed in the middle of the model since identifying and fulfilling customer needs and expectations are central aspects in TQM. It is important to highlight that both internal and external customers are equally important and need to be satisfied.

Base decisions on facts is another important cornerstone that implies making decisions wellsustained by numerical and/or verbal data/information that have been properly analyzed, and not on random factors. There are several statistical tools that help in gathering, structuring, and analyzing data, such as the Seven Improvement Tools and the Seven Management Tools which are intended to be used for numerical and verbal information, respectively.

Focus on processes is about understanding processes' inputs and their transformation into outputs that satisfy the needs of the customers by creating value in the form of goods or services. In general, three kinds of processes can be differentiated: Main, Support and Management processes.

Improve continuously is another important element that implies striving to become better while using less resources. A basic rule says, according to Bergman and Klefsjö (2010), that *"it is always possible to improve products, processes and methodologies while using fewer resources, i.e., to achieve higher quality at lower costs"* (p. 44). The Six Sigma methodology is very well suited to accomplish continuous improvements.

Let everybody be committed deals with creating conditions to facilitate the personnel being committed to quality work. It is important to encourage a good cycle where the employees are trusted by the managers and responsibilities and authority are delegated, these make people feel empowered and appreciated which increases the intrinsic motivation that is needed to feel commitment, pride, and perform better. Job satisfaction is crucial to achieve high quality. This principle must apply even to the suppliers that should be involved in the quality work.

Committed leadership is a crucial factor for any quality effort to succeed and must be practiced on all levels of an organization. Committed leaders encourage a culture of sustainable quality improvements, learning, teaching by example and giving support to their staff and quality initiatives.

As one of the cornerstones states, the decisions must be supported by facts in terms of numerical or verbal information/data. Utilizing quality indicators is a way of providing the required base for a more thoughtful decision making. These indicators are extensively used in healthcare and to some extent in manufacturing. The literature provides several definitions, one of them is given by Vuk (2012) who defines them as, "Quality indicators are one of the quality management system (QMS) tools to monitor and control efficiency of the system key segments, while the results collected serve as a basis for implementation of corrective measures and continuous quality improvement." (p. 24). Vuk (2012) explains that quality indicators can be classified in several ways depending on their intended purpose, or in line with the chosen quality model, they could be divided into structural, process or outcome indicators. They also must possess a number of attributes such as measurability, reliability, and validity (Vuk, 2012).

3.2 Waterfall vs Agile procedural models

In new product development or project management, there exist different types of procedural models. A procedural model is characterized by organizing and/or standardizing the methods and tools into project phases or processes (*Thesing, Feldmann, & Burchardt, 2021*). According to Thesing et.al. (2021) there are two different procedural models: plan-driven models and Agile methods. The plan-driven model follows the classic Waterfall process, and the Agile method is more iterative or test-driven such as Scrum or Lean-Kanban. More in detail of each of these will be presented in 3.2.1 and 3.2.2. A combined or hybrid approach will be briefly presented in 3.2.3.

3.2.1 Waterfall procedural model

The traditional Waterfall model was founded by Royce in 1970 and is known for the well planning and structuring of projects. The steps or process phases are supposed to be executed in a sequential series of steps. Where the next step only starts if the previous is considered as finished (*Cocco, Mannaro, Concas, & Marchesi, 2011*). The phases are planning, design, development, testing and deployment and they are followed in that order, the next phase only starts when the previous one is approved to be finished or ended. This methodology requires defining the scope or requirements in the beginning of the project and then implementing a plan that the project group will follow as accurately as possible (*Cocco, Mannaro, Concas, & Marchesi, 2011; Thesing, Feldmann, & Burchardt, 2021*). According to Thesing et al. (2021) due to the fact that the expected result is defined in the beginning, this enables the project to work in a goal- and plan-oriented manner. The Waterfall approach has often stated work packages, responsibilities, and deadlines, which provides the project with stability and structure (*Thesing, Feldmann, & Burchardt, 2021*).

3.2.2 Agile procedural model

Agile has become more and more popular and originated in 2001 in the software industry as a response to the inflexible methodology (*Cocco, Mannaro, Concas, & Marchesi, 2011*). Compared to the Waterfall model the Agile approach does not focus on planning and following it as accurately as possible, instead the team develops solutions step by step. Agile does not follow the classical linear approach; it is more like multiple iterations and is seen as a more test-driven approach. The project is broken down to smaller cycles and the result of every cycle is presented to the customer. This means that an Agile way of working includes the customer in the development process and the reason for it is that the customer or the user has general requirements but are not able to specify them in detail in the beginning of the process. The Agile approach is beneficial to use when the outcome of the project is unclear. It is also seen as a more flexible approach than the Waterfall model due to the fact that change requests are more important to achieve than following the initial plan. The flexibility to change enables companies to react quickly to changes. (*Thesing, Feldmann, & Burchardt, 2021*)

According to Cocco et al. (2011) two process tools focusing on pull scheduling and iterations used in Agile are Scrum and Lean-Kanban. Scrum got its name after Takeuchi and Nonaka (1986) suggested implementing a "rugby approach to managing new product development" making a parallel or comparison to the movement known as scrummage in which the rugby's team members meet to agree on their next movements (Cooper & Sommer, 2016, p. 518). Scrum can be seen as an Agile framework that can be used in different contexts as it breaks down the work into a list with smaller activities that is done in a prioritized way given by the Product Owner. Scrum is organized in three formalities: Sprint Planning, Daily Scrum Meetings and Sprint Review (Cocco, Mannaro, Concas, & Marchesi, 2011). In the Sprint planning session, the sprint goals are decided, and a sprint backlog is developed. The sprint backlog is a list of features or increments that aim to be developed during the sprint that usually takes between two to four weeks in length. The daily Scrum is a stand-up fifteen minutes meeting where team members share quick updates on the project status, what has been done in the last 24 hours and what they are going to do until the next daily scrum. At the end of the sprint a Sprint or Retrospective Review is held in order to make an evaluation of the sprint results to ensure that the project is going forward, set new goals for the upcoming sprint and make recommendations for improvements. (Cooper & Sommer, 2016)

Lean-Kanban is a tool that likewise Scrum breaks down the work into smaller work items, those work items are described on a card. Each card is put on a board called Kanban board in order to make the work more visible and understandable. On the board the work in process (WIP), assigned work, priorities and bottlenecks are also presented. The aim with a Kanban board is to visualize the process for the team members in such a way that they only focus on what needs to be developed in order to optimize the process and reduce lead time. (*Cocco, Mannaro, Concas, & Marchesi, 2011*)

Both of the Agile procedural models mentioned above are aiming to adapt quickly to changes by using iteration and feedback loops. According to Cocco et al. (2011) Lean-Kanban has shorter feedback loops and works more continuously and smoothly since this Agile process can release products anytime and does not need to wait until the end of an iteration to release or make changes like Scrum.

3.2.3 Hybrid procedural model

A third procedural model can be considered which consists of a combination of the Waterfall plandriven process model and Agile principles. According to Thesing et al. (2021) the so-called Hybrid approaches combine the advantages of both methods by applying the Waterfall model when planning the overall structure of the project but managing certain parts or sub-projects using Agile principles. This allows the project team applying Agile principles to have richer communication, shorter feedback cycles and be more adaptable to changes while still being a part of a classical Waterfall procedural model (*Thesing, Feldmann, & Burchardt, 2021*). Stage-Gate is a popular Waterfall approach that is a registered trademark in the US and Canada. It usually consists of five stages and five gates where the result of each stage is evaluated when reaching the respective gate and the decision to Go, Kill, Hold or Recycle is taken before moving on to the next stage (*Cooper & Sommer, 2016*). Cooper and Sommer (2016) argue that a hybrid Agile-Stage-Gate model is appropriate to use in projects with high uncertainty that demand for experimentation, failing and learning quickly in order to make incremental product versions with high customer involvement from very early in the project.

3.3 Push and Pull Approaches

The Push and Pull Approaches originated in the field of supply chain management but are currently used in many other fields. According to Liberopoulos (2013) different definitions can be found in the literature and have changed through time, but these can be grouped in three general definitions that are going to be quoted.

Definition 1: "A pull system initiates production as a reaction to present demand, while a push system initiates production in anticipation of future demand."

Definition 2: "In a pull system, production is triggered by actual demands for finished products, while in a push system, production is initiated independently of demands."

Definition 3: "A pull system is one that explicitly limits the amount of WIP that can be in the system, while a push system has no explicit limit on the amount of WIP that can be in the system." (p. 213).

WIP is an acronym for Work-in-Progress. Bergman and Klefsjö (2010) make reference to two terms, the Technology Push and the Market Pull which combination according to the authors can lead to success as several successful examples have shown.

A Pull Approach model for Quality Assurance that can be applied to the information flow has been developed by Ericson Öberg (2016). The model is based on lean concepts and was originally developed for evaluation of welds. It proposes to address the WHO, WHATs and HOW before taking any action and aims to focus on the customer's or users of the data's needs, this allows to define the information needs in advance and proceed in accordance with those needs based on facts. The model is presented in Figure 7.


Figure 7. Pull Approach Model for Quality Assurance (Ericson Öberg , 2016)

3.4 Six Sigma

According to Bergman and Klefsjö (2010), Six Sigma can be considered as a methodology within the general TQM framework. Six Sigma originated in the USA around 1985 as a response to the growing competition and/or rivalry from the Japanese industry (*Linderman, Schroeder, Zaheer, & Choo, 2003; Hahn, Hill, Hoerl, & Zinkgraf, 1999*). According to Hahn et al. (1999), Six Sigma is described as a systematic method for product and process improvements. The methodology has a customer centric view and base the goal setting on customer requirements (*Linderman, Schroeder, Zaheer, & Choo, 2003*). Six Sigma developed from the quality engineering field and has, according to de Mast and Lokkerbol (2012), incorporated methods from statistical quality control, Total Quality Management and Taguchi's off-line quality. It is therefore seen as a structured method that bases decisions on data and metrics in each step of the process. This is strengthened by de Koning and de Mast (2006) who argues that Six Sigma is about improving product quality and/or process quality.

Furthermore, de Koning and de Mast (2006) argues that Six Sigma offers a wide range of tools and techniques both statistical and nonstatistical. Therefore, one of the main advantages is that the methods are flexible, since the tools and techniques can be adapted to a wide range of complex problems. Meanwhile, the method is less applicable to problems where the solution is already known (*de Mast & Lokkerbol*, 2012).

Six Sigma differs from TQM because it has a stronger focus on the problem definition and has different problem-solving methods like for example DMAIC cycle or Design for Six Sigma

(Barone & Lo Franco, 2012). Despite what method and tools that are used the most important is to clearly define the problem, until that is done a solution cannot be offered (Linderman, Schroeder, Zaheer, & Choo, 2003). One of the most well-known problem-solving methods used in Six Sigma is the DMAIC-cycle, which is an acronym for Define, Measure, Analyze, Improve and Control (Linderman, Schroeder, Zaheer, & Choo, 2003; de Mast & Lokkerbol, 2012). Another method is the one called Design for Six Sigma which is used in incremental product design and includes the following steps: Define, Measure, Analyze, Design, and Verify (Linderman, Schroeder, Zaheer, & Choo, 2003). These problem-solving methods follow foreseen steps that all include a set of tools that can be used. The method also enables cross-functional work since it creates a need to involve different people from different departments in order to solve the underlying problems (Schroeder, Linderman, Liedtke, & Choo, 2008). The DMAIC cycle will be described more deeply in sections 3.4.2.1 to 3.4.2.5.

3.4.1 Voice of the Process and Voice of the Customer

According to Hammersberg (2020), The Voice of the Process (VOP) and the Voice of the Customer (VOC) are two central concepts that are extendedly used to optimize the performance of a process or operation. It is important to understand the difference between these two concepts. The VOC can be defined as the customer's specifications, goals, and requirements, and since one of the most central cornerstones of TQM is to Focus on Customers, it is fundamental to understand the customer needs, what it is expected to accomplish, in order to focus on the right things and not in making the wrong things right. The VOP is not the same as the VOC. The VOP provides information about the process behavior and helps to distinguish between noise, which is natural variability in the system, and real changes or signals (*Hammersberg, The natural behaviour of the process. In the Voice of the Process, 2020).* If the process of natural behavior is not understanded it is very difficult to meet the demands of the customers (VOC) and optimize the process (*Hammersberg, The natural behaviour of the process, 2020*). According to Danielsson and Holgård (2010), the process cannot be controlled using the specifications (VOC), but these must be aligned with the VOP.

Figure 8 shows the difference between VOP and VOC. In a process, product, or operation the VOC provides the specification limits (UPL, LSL) while the VOP provides the Control limits (UCL, LCL) which are clearly not the same. The objective is to maintain the process or operation in relation to a performance target inside the control limits and be able to identify predictable and non-predictable causes of variation to improve the process by tweaking it or reengineering it according to the situation. (*Danielsson & Holgård*, 2010)



Figure 8. VOP vs. VOC (Hammersberg, Basic improvement set-up. Control Limits (CL)#Specification Limits (SL), 2020)

3.4.2 DMAIC

The most widely used framework in the Six Sigma methodology is the one called the DMAIC cycle (*Learn about Quality - Six Sigma, 2021*). As it was mentioned before, DMAIC is an acronym that stands for its five phases: Define, Measure, Analyze, Improve and Control. The DMAIC cycle has its origins on the PDSA (Plan, Do, Study, Act) cycle that was developed by Walter A Shewhart. A variety of tools such as the Seven Improvement Tools and the Seven Management Tools are used during this sequence of operations for the improvement work (*Bergman & Klefsjö, 2010*). In the following sections the different phases of the DMAIC cycle and some of their tools will be presented.

3.4.2.1 Define

Define is the first phase in DMAIC-cycle and the purpose is to identify the problem and the underlying reasons for it, define which process needs to be improved and goals to achieve. The key process metrics should be defined and used as a guidance to selection and goal settings in the project (*Snee, 2004*). It is also important to define the stakeholder(s) and their perspectives in order to know who is affected by the problem. In the Define phase the team members are selected, and their roles and responsibilities are set (*de Koning & de Mast*, 2006). According to Carleton (2018) in The Black Belt Memory Jogger, the Define phase aside from the above mentioned also include defining customer needs (VOC), identifying benefits for the business, deciding change management strategy, defining project scope, and determining boundaries for the project.

It is crucial that the underlying problem is identified otherwise the solution will not be useful and new problems will occur and it will have an impact on the result of the rest phases. Therefore, the Define phase is the most important phase since it will affect the rest and thereby the outcome of the project (*Barone & Lo Franco, 2012*). According to Hild, Sanders and Ross (1999), there are three common mistakes in process and/or product improvement projects: Starting with having a solution to the problem, using existing historical data to solve the problem, and starting by deciding technical or statistical tools to use that the team thinks will solve the problem. These mistakes are of great importance to consider during a Six Sigma project and especially in the Define phase. The Define phase should only result with a common understanding of the problem and goals not a solution (*Snee, 2004*).

In the Define phase there is a mix of tools that can be used. For example, for analyzing qualitative data (AIM, SIPOC), guiding and/or structuring the process (T-map, Project Charter), brainstorming (Is-Is not matrix) and scoping (Effective Scoping, SIPOC).

AIM

The Affinity Interrelationship Method (AIM) is a structured tool for analyzing qualitative data for complex problems that enable people to discuss, analyze and create a consensus to the problem and causes of it (*Barone & Lo Franco, 2012*). It is a beneficial tool to use for analyzing complex problems since it is a combination of the 7 management tools, the affinity diagram, and the interrelationship diagram (*Alänge, 2009*). The method's basic ideas were developed by professor Kawakita Jiro in the 1960s and are known as the KJ-method. In 1989 Professor Shoji Shiba introduced the 19 step-by-step approach to KJ in the field of Quality Management that served as inspiration to the AIM (*Alänge, 2009*).

AIM is a step-by-step guide consisting of a total of ten steps. These steps are going to be described according to Alänge (2009). The first step is brainstorming over a statement or situation that is stated in a question form. The people in the group quietly and privately answer the questions with one or two sentences on a post-it. This is done without talking or responding to each other's notes. When everyone has written all the notes the answers are read out loud and placed on a board so everyone can understand, if it is something unclear the group together add or change the note. This is a crucial step in order to secure the quality of the data by clarifying the meaning. When that is done the team groups the notes so that the ones that are similar to each other or deal with the same issue are grouped together. When the grouping is done, it is time to give them a title. Higher levels of grouping can be done always following the affinity principle, lonely wolves are allowed. When the grouping is completed, the groups are connected by arrows that visualize the cause-and-effect relationship. An arrow cannot point in two directions. The final layout of the groups can be rearranged to facilitate the understanding. Then each team member rates the groups with points or colors that represent the points: Red=3 points, Blue=2 points and Green=1 point. This is done to understand which issues are more important and need the most consideration. Lastly, a final answer to the opening question is written down, this is done by considering the most important groups titles and their interrelationships. (Alänge, 2009)

This tool allows people to brainstorm about a problem, establish a common understanding and prioritization of the data. When there are a lot of critical issues and a need for finding cause-and-effect relationships AIM is a good tool to use (*Barone & Lo Franco, 2012; Alänge, 2009*).

T map

A thought map or T map is a way of structuring a project with a set of questions throughout the process that has the purpose of guiding team members through the process of improvement (*Hild, Sanders, & Ross, 1999*). Thought maps can be constructed to fit the project since there are no stepby-step instructions on how to construct one. The idea with T-map is that you ask a question to gather information and then you ask another question to get more information and so on. A thought map enables one to deal with multiple approaches or paths at the same time and the most suitable solution is selected (*Hild, Sanders, & Ross, 1999*). Since Six Sigma is not a straightforward process sometimes it could be hard to plan in detail when each step is supposed to be done and therefore planning tools like Gantt Chart can be hard to follow. T map could in these cases be used as a planning tool, by setting up a couple of questions that should be answered in each phase. The questions do not need to be answered in a sequence; they are more a guideline on what needs to be done. What is good to take into consideration is that the T map is only as good as the information captured. (*Hild, Sanders, & Ross, 1999*)

Is-Is-Not Matrix

According to Andersen and Fagerhaug (2006), the Is-Is not Matrix is a structured brainstorming tool to clarify the problem and the possible causes. The goal with this tool is to distinguish between what is the problem and what is not. The benefits with this tool are that by comparing Is with Is not, it gives you a faster overview of where the focus should be on, and where to start. It also creates a better understanding of the root causes and is a help to define the boundaries of the project, meaning what is not the problem and shall not be included. (*Andersen & Fagerhaug, 2006*)

The design of the matrix can be different but should include questions about what occur, what objects are affected, what are the specific defects or problems, where geographically they take place, when they occur, the extent of the problem(s), who is involved and when they were first detected.

Scoping tools

Scoping the project is an essential part in the Define phase and it should lead to clear goals that are measurable. The scoping works as a guidance through the project and therefore it has a huge impact on the outcome of the Six Sigma project. A precise scoping will enable the team to stay within the guideline (*Lynch, Bertolino, & Cloutier, 2003*). Two examples of scoping tools are SIPOC and Effective Scoping which will be described below.

SIPOC

SIPOC is an analyzing tool from TQM that is applicable in Six Sigma, and it is an acronym for: Supplier, Input, Process, Output and Customer (*Brown, 2019*). The tool enables people to have a shared understanding of the process from plan to the delivery that is used as a first definition of the process (SIPOC MAP). The tool is useful in the beginning of an improvement project in order to identify relevant components. According to Brown (2019), the simplicity of adapting the tool and the rapid way of getting an overview of the process is what makes the SIPOC so popular.

The tool often consists of five boxes for each letter that has their purpose. The supplier aims to identify who provides the input, a question to answer is: Is there any link between supplier and specific input. In input, the focus is to identify the inputs to the process. What key inputs exist, materials, information, products etc. are necessary for the process to work. The process is about finding what activities are used in the process, where it starts and stops. In output, the final product, service, or solution should be identified and answer the question of what comes out of the process. The customer step focuses on identifying who will benefit from this output (*Silverstein, Samuel, & DeCarlo, 2012*). According to Silverstein et al. (2017), the important questions to consider are presented in Figure 9.

SIPOC	Questions	Quick Tips		
Supplier	Who is the supplier?	Consider person, department, or organization.		
Input	What are the inputs into the process?	Consider materials, equipment, procedures, people, and policies.		
Process	What are the actions necessary for each step in the process?	Include an action (verb) and object (noun) for each step.		
Output	What is the final product, service, or solution provided to the customer?	Identify the specific item that is provided to a specific customer.		
Customer	What is the person, group, or process that will be using or benefitting from this output?	Link a specific output to a specific customer.		

Figure 9. SIPOC questions to consider (Silverstein, Samuel, & DeCarlo, 2012)

Effective Scoping

Effective Scoping is a tool based on experiences using SIPOC created by Peter Hammersberg, a senior lecturer at Chalmers University of Technology. According to Zanti (2015), the main goal with this tool is to determine the measurement system and to create consensus. This tool enables you to zoom out and get a more holistic view of the problem and/or process and it creates a pull approach. Effective Scoping enables the project team to identify if the current measurement system can measure the improvement or if new measurements need to be implemented. The tool consists of nine steps divided into three sub-groups: focus the output, what to improve and focus the manning. In the output the goal is to identify who the customer is, what comes out of the process, in what context it will be used and what is required of it (list of big Y or customers' requirements).

In the output it is important to understand **what** the process, product or organization does and not **how**. In focus on what to improve the goal is to identify the objective with the project before manning and the questions to answer here are; what measure should be improved, what is the baseline, can that precise output (y) be measured and what cannot be lost in the processes (Y). In the final sub-group focus on the manning; the goal is to identify where the change can be made, what inputs are supplied, from who are supplied and what does the system require of the input. (*Zanti, 2015*)

Effective Scoping uses the same or similar questions as SIPOC, the difference is the order of it and according to Zanti (2015), this makes a huge impact on the outcome. As mentioned above, the Effective Scoping creates a pull approach rather than a push approach as the SIPOC does. The push approach can develop a mindset that only fixes problems rather than challenging the problem and therefore not finding the root cause(s). By creating a pull approach, it is more likely to find the root causes (*Zanti, 2015*).

Project Charter

Snee (2004) defines the Project Charter as a tool to define what should be included and not in the project. The customer needs, scope, goals, and criteria should be defined. Team members and deadlines can also be decided in a project charter. The project charter can be seen as a summarizing result of the Define phase. One advantage with doing a project charter is that it creates a consensus and common approach to the project. It works as a contract between all stakeholders, so everyone knows what to achieve (*Snee*, 2004).

3.4.2.2 Measure

In the Measure phase the purpose is to define and make sure that you have the right metrics. In this phase the process' output to be improved is decided based on customer requirements and project objectives (*Snee, 2004*). One or more characteristics regarding the product or process should be chosen, this is called response variables and is often concerned with what is most important for the customer called critical to quality (CTQ). Also, the influenced characteristics or resources should be identified, this is called input variables (*Barone & Lo Franco, 2012*). The Measure phase also includes data collection of current status in order to determine and evaluate the current situation (*Snee, 2004*). The data collection and chosen measurements should be emphasized on the purpose from the Define phase. It is beneficial if the measurements provide the project group with detailed information that is enough to evaluate the performance and make improvement decisions (*Barone & Lo Franco, 2012*).

In this phase there are a lot of tools that can be used and according to Snee (2004) some common tools to use in the Measure phase are: Process map (P-map), Measurement System Analysis (MSA), capability analysis, control charts, Cause and Effect diagram also known as fishbone or Ishikawa diagram, and Cause and Effect matrix. However, the main purpose with these tools is

according to Barone & Lo Franco (2012) "Measure the process to satisfy customer needs; develop a data collection plan; collect and compare to determine issues and shortfalls" (p. 13).

According to Carleton (2018) the Measure phase can be considered complete when "the team has enough understanding of the process and the performance gap to start looking for root causes in the Analyze phase" (p. 55). Some tools that can be used in the Measure phase are process mapping, value stream mapping, data collection template that results in a data collection plan, etc. (Carleton, 2018).

Process map

A process map defines the flow of activities in a process both the input and outputs. It is a graphical map that visualizes the complexity of the process and identifies the value as well as the non-value adding activities. It also identifies the key inputs going into the process and the key outputs *(Carleton, 2018).* Carleton (2018) states that a process map can be used to (p. 57):

- "Review the process with the team to ensure everyone is on the same page."
- "Check for areas where it may be useful to collect data."
- "Look for obvious disconnections, non-value-added steps, and quick wins." and
- "Help generate a list of potential root causes in the Analyze phase."

Value stream mapping

A value stream map (VSM) aims to reduce lead time and waste by identifying long term improvements. It also helps the company to identify problem areas and map future states in order to reduce waste. A VSM identifies both the material flow and the information flow and according to Carleton (2018) it also identifies: "*Process steps, Waste, Lead time, How flow is driven, Performance measures, such as cycle time, wait time, inventory, work in process, defect rates, Opportunities for improvement*" (p. 63).

Data collection plan

What data to collect can be tricky, especially in these days where the availability of data is high thanks to digitalization. Therefore, it is important to have a data collection plan. A data collection plan enables the team to know what data to collect, so the right data are collected in the right way. It should include the scope of the measure, meaning what should be included and not, as well as the measurement process to ensure consistency and reliability. All information should fit in one page document that describes; what, where, when, who and how to collect the data. (*Carleton, 2018*)

3.4.2.3 Analyze

In the Analyze phase the purpose is to evaluate and analyze the collected data from the Measure phase. With help from statistical methods, causes of defects, variation, stability, trends of the process or product and performance evaluations based on DPMO (defects per million opportunities) the data are analyzed in this phase. The analysis can provide important information for setting improvement targets and to prioritize the opportunities (*Barone & Lo Franco, 2012*). In this phase the root causes of the problem are often identified and two of the most used tools in this phase are Multi-Vari studies and Failure Modes and Effect Analysis (FMEA) (*Snee, 2004*).

3.4.2.4 Improve

The purpose of the Improve phase is to decide what to change in the process based on the findings from the Analyze phase in order to improve the performance. It is only in this phase where the improvements are done, the DMA phases are supported with facts in order to be able to find improvements and the C phase aims to control that the improvements actually work (*Snee, 2004*). In the Improve phase it is common to use the improvement measures 7QC tools. The activities in this phase should eliminate variation and enable the company to implement the solutions (*Barone & Lo Franco, 2012*).

The Six Sigma methodology offers a selection of improvement tools such as the Failure Mode and Effect Analysis (FMEA) which aims to identify all that can fail in a process, their causes, and impact on the customer. FMEA is a good tool to assess and manage risks. There are several types of FMEA, such as Design FMEA (DFMEA) and Process FMEA (PFMEA). The difference between these two is that in a PFMA the process is broken down in steps while in a DFMEA the components in a product are considered (*FMEA*, *DFMEA*, *PFMEA*, *and FMECA: An Overview of FMEA Types*, 2018).

3.4.2.5 Control

The last step of the DMAIC is the Control phase and the purpose of this step is to ensure that the implemented improvements meet the desired level of performance. By using statistical process control tools like control charts, it is possible to monitor the results from the improvement. After a while, the process could need some adjustments or it could be that the improvement is not meeting the desired level at all and then it is necessary to review the DMAIC phases again (*Snee, 2004; Barone & Lo Franco, 2012*). Therefore, according to Barone and Lo Franco (2012), it is important in this phase to "control process variation to meet requirements; develop a strategy to monitor and control the improved processes; implement the improvements of system and structures" (p. 15). According to Barone & Lo Franco (2012), another activity in this phase is what they called institutionalization which seeks to update the processes that have been affected by the Six Sigma product. It could be for example an updated flow chart, new documents, or estimation of annual savings. Lastly, the results should be shared within the organization (*Barone & Lo Franco, 2012*).

3.5 Communication

Communication has a huge influence on an organization's success and is therefore an important activity to consider. Internal communication is providing employees with necessary information about work tasks, organization etc. (*Berger, 2008*). According to Berger (2008) right communication can motivate and create engagement and is seen as a basis for individuals in the organization. In the internal communication inside organizations there are multiple different channels that can be used. What channels that are used will have an impact on the relationships and the employees' satisfaction, which will affect the company's effectiveness and success (*Tkalac Verčič & Špoljarić, 2020*).

The digitalization has increased the amount of communication channels and modern organizations are often using multiple channels in order to satisfy the employees' needs *(Tkalac Verčič & Špoljarić, 2020)*. Dévényi (2016) defined two main categories of communication channels: written and oral. Written channels include letters, reports, bulletin boards, email, Internet, manuals posters etc. *(Dévényi, 2016; Berger, 2008)*. These channels are according to Dévényi (2016) beneficial to use for routine information that is clear since the communication is tangible and verifiable. Oral channels include for example face-to-face communication, phone conversations, focus group and online meetings *(Dévényi, 2016; Berger, 2008)*. The benefits with oral communication are that the people exchange information and are able to respond immediately. However, the disadvantage is that people must be available, and that the information often needs to pass multiple people, the more people involved the more complex the oral communication will be *(Dévényi, 2016)*. Oral or face-to-face communication is according to Tkalac Verčič and Špoljarić (2020) better to use when transferring symbols, while data and written communication are better to use for information.

When talking about communication channels, the richness is often used to compare the different channels. Richness is defined according to Smith, Patmos, and Pitts (2018) as the ability to communicate information, handle several suggestions, feedback, and personalize. The rich media use both nonverbal and verbal cues (*Tkalac Verčič & Špoljarić*, 2020).

Some of the written and oral communication channels are further described below.

Face-to-face

Face-to-face is presented as the richest communication channel as it enables suggestions, interaction, and information at the same time (*Smith, Patmos, & Pitts, 2018*). The face-to-face communication also enables people to discuss complex information due to the high personal focus.

Email

Emails are according to Smith et al. (2018) based on text and could be seen as a leaner channel of communication. Email is an effective communication channel for that reason it is perceived as medium communication (*Lee, Kozar, & Larsen, 2005*). Some advantages with email is that it gives

a continuity in conversations, and it is always available for the sender. A disadvantage with email is the absence of personalization (*Smith, Patmos, & Pitts, 2018*).

Instant messaging

Similar to Email, Instant messaging is a textual communication form. The difference is that it is possible to see when people are available or not, which enables direct contact and/or response. This communication channel has low costs and allows rapid feedback and engaging informal conversations (*Smith, Patmos, & Pitts, 2018*).

Phone call

Phone calls are a communication channel that gives instant information if both parties are available at the same time (*Hinds & Kiesler*, 1995). According to Smith et al. (2018) it allows greater exchange of social information. One disadvantage is that it is not possible to send out mass information or messages as easily as the other communication channels (*Smith, Patmos, & Pitts, 2018*).

Digital/Video communication

Digital or video communication offers interactions to a greater extent than the previously mentioned communication channels. It is similar to face-to-face interaction, but it is performed digitally, this offers more people the opportunity to engage in the communication than for example phone calls. It can work as the closest replacement when face-to-face communication is not available (*Smith, Patmos, & Pitts, 2018*). Video conversations are often seen as medium in richness (*Tkalac Verčič & Špoljarić, 2020*).

The choice of communication channels are influenced by for example organization size, culture, and employee's qualifications (*Dévényi*, 2016). Depending on which communication channel that is chosen there will be different results in engagement and response time (*Tkalac Verčič & Špoljarić*, 2020). Tkalac Verčič and Špoljarić (2020) argue that organizations that use rich media will have a more symmetrical and effective communication since it allows immediate dialogue and feedback. However, the organization should not be limited to only verbal communication channels, since the different channels are used for different tasks (*Tkalac Verčič & Špoljarić*, 2020). Similar to this, Smith et al. (2018) argue that organizations should offer multiple communication channels and face-to-face opportunities to their employees in order to align and enable cross-functional work. This would improve the employee's perception of feeling connected and informed (*Smith, Patmos, & Pitts, 2018*). The best way to know which communication channels lead to higher satisfaction is according to Tkalac Verčič and Špoljarić (2020) to ask the employees and listen to their response. Tkalac Verčič and Špoljarić (2020) further state that "Unacceptable channels will lead to unsuccessful communication." (p. 6).

3.6 Knowledge Sharing

This subchapter covers general definitions of knowledge and information sharing and why those concepts are important to be taken into consideration. Lee and Yang (2000) state that "*Information is data organized into meaningful patterns*" (p. 783), meaning that information can be for example measurements, raw data, statistics, calculations, reports, etc.

The data or information is transformed to knowledge when a person uses, understands, and applies the information to a specific work task. Knowledge is therefore more than just information; it is an observation of objects, and it is individual. One person's knowledge could be someone else's information. This means that one person can interpret and transform information into knowledge at the same time someone else can try to interpret the information but do not understand it, in that situation the information will be just information. Knowledge is therefore depending on the individual that is using the information. (*Lee & Yang*, 2000)

Tacit and Explicit Knowledge

Knowledge is often divided into two categories: tacit and explicit. Tacit knowledge can be defined as things that are not possible to be explained or transferred to another person in an easy way (*Lee & Yang*, 2000). Polanyi (1962) explains that "*There are things that we know but cannot tell*" (p. 601), so the tacit knowledge is connected to the individual skills which cannot be easily shared or standardized. According to Lee and Yang (2000) this could be defined as the know-how knowledge. The explicit knowledge is easy to communicate and transfer from person to person. One example of explicit knowledge is technical documents. The explicit knowledge can be transferred in manuals and/or standardized in order to share with others (*Lee & Yang*, 2000).

Both tacit and explicit knowledge can transform in four different ways from: tacit to tacit (socialization), explicit to explicit (articulation), tacit to explicit (combination) and explicit to tacit (internalization) (*Nonaka*, 2007). According to Nonaka (2007) the most powerful transfer from an organization point of view is when tacit and explicit knowledge interacts since it leads to new knowledge for the company. To convert tacit knowledge can be tricky since it means that you find a way to express the inexpressible, the most frequent way of doing it is according to Nonaka (2007) *"the store of figurative language and symbolism that managers can draw from to articulate their intuitions and insights"* (p. 9). Nonaka (2007) further explains that a better way to do it is by using redundancy since it encourages communication and creates a "common cognitive ground" (p. 14). Because of the overlapping of information, it is easier to see what colleagues are struggling with to write down and it also spreads the explicit knowledge in the organization (*Nonaka*, 2007).

The tacit and explicit knowledge can be connected to two organizational structures: formal and informal. Formal structure is connected with explicit knowledge which means that people can access knowledge easily. Meanwhile, informal structures or organizations work with a lot of tacit knowledge, for example in innovation projects (*Lee & Yang*, 2000). The informal is according to Lee and Yang (2000) often shared by face-to-face communication. It is important to have in mind

that people rely on different types of knowledge in order to solve problems and therefore need different structures. People that work with a lot of explicit knowledge will require more documents or reports in order to make decisions, meanwhile a person that works with a lot of tacit knowledge will require more face-to-face communication or meetings in order to make a decision (*Lee & Yang*, 2000). Knowledge is then embedded in networks that are enveloped by members, division, structure, and tasks (*Argote & Ingram*, 2000). According to Argote and Ingram (2000) the division network acts like a divider that decides which member or division is going to perform the different assignments and the knowledge of the individual that possesses the experience of performing the task is embedded in the network as well.

Knowledge transfer

Knowledge storage capacity is owned by an organization and is their memory and ability to store and reuse information. It should support employees with for example routines and structures of information (*Lee & Yang*, 2000). According to Lee and Chang (2000) it is crucial for organizations to have a good system for storing and reuse information and knowledge, if the system is poor the overall knowledge will not reach their fullest potential.

The process of transferring knowledge is crucial for sustaining competitive and organizational performance. A transfer is considered done when one department or group is influenced or tries to apply another groups' information (*Argote & Ingram*, 2000). According to Argote and Ingram (2000) the problem arises on an individual level and transfers to higher levels such as other departments or divisions. They further argue that knowledge transfer can be measured in changes in knowledge or changes in performance. One challenge is that the tacit knowledge is hard to measure since it is seldom written down in reports that are often used to measure knowledge. For tacit knowledge it is better to use performance-based measurements (*Argote & Ingram*, 2000). The knowledge transfer can occur both explicitly and implicitly. In an explicit way it occurs when a function communicates an improvement potential with another function. In an implicit way it can occur by its function being unable to explain the knowledge or information that they have acquired (*Argote & Ingram*, 2000).

Argote and Ingram (2000) stated that there are factors that affect the knowledge transformation "...such as the reliability of the source, predicted difficulty of transfer during the early initiation stage, whereas factors that affected the execution of transfer, such as the recipient's ability to absorb knowledge, affected difficulty during the implementation phases" (p. 161). Another finding from Argote and Ingram (2000) was that knowledge transfer is accomplished easier in organizations that are in superordinate relationships like an alliance or franchise than in independent organizations or functions.

3.7 Visualization

Visualization can be described as a graphical representation of information that is presented in a way to enable a common and better understanding so that the user can transfer it to knowledge. If that is not achieved the visualization has failed (*Iliinsky & Steele*, 2010). Alhadad (2018) argues that the purpose of visualizing data is to support understanding and create a shared view. It is important to consider which type of data visualization to use in order to transfer the information to knowledge since the wrong one can cause false interpretation of the data. Therefore, it is beneficial to perform data visualization and analyses together at the same time to get a comprehensive view of the results (*Alhadad*, 2018). A good computer-based visualization should enable the user to get an overview, zoom out and zoom in to get details, and filter information according to the needs of the user, with interfaces that allow performing all these actions (*Ware, Chapter 10 Interacting with Visualizations, 2004*).

There are multiple ways of visualizing data and visualization tools. What is important to always consider when choosing the way of presenting it is; what is the intended message and context of use. With the intended message it is important to consider what knowledge that is wanted to convey, what do you want to tell with the visualization. This message should not be determined in a rush since it is a critical step in order to create a good visualization. Once it is determined it is important to consider how the visualization is intended to be used. When the message is clearly defined it is easier to select what data to include in the visualization and not in order to decide what context to use. It could be to reveal what is already known or present the unknown (Iliinsky & Steele, 2010). An effective visualization is therefore built on a clear goal and/or message that is designed as straightforward as possible. It is important to not have too much information in the visualization and only what is necessary, because more or too much information will result in a longer time for the user to find and understand the desired message (Iliinsky & Steele, 2010). According to Alhadad (2018) having overload of information is one of the factors that could lead to visual clutter, the other is lack of a structure for representation of data. Rosenholtz, Li, Mansfield, and Jin (2005) define clutter as "the state in which excess items, or their representation or organization, lead to a degradation of performance at some task" (p. 761). Visual clutter is not only wrong from an aesthetic point of view, but also the confusion that having too many objects may cause is the problem (Rosenholtz, Li, Mansfield, & Jin, 2005).

Another important issue when talking about visualization that is usually forgotten is color blindness. There is as much as 10% of the male population and 1% of the females that suffer from some form of color blindness. This means that they are not able to distinguish red and green colors, which creates a new kind of disability among some of the users when using color coding for presenting information (*Ware, Chapter 4 Color, 2004*). So, when developing a visualization tool, color blindness is an important issue to be considered.

Furthermore, Eppler and Burkhard (2007) mention that an effective transfer of knowledge through visualization has five questions that should be considered:

- "1. What type of knowledge is visualized (content)?
- 2. Why should that knowledge be visualized (purpose, km process)?
- 3. For whom is the knowledge visualized (target group)?
- 4. In which context should it be visualized (communicative situation: participants, place/media)?
- 5. How can the knowledge be represented (method, format)?" (p. 113).

As mentioned, there are multiple ways of visualizing data, some of the most basic and famous ones are flow charts, bar, line, scatter, and pi graphs. This way of presenting data is good if you have common visualization problems, but they are limited to a specific type of data. Benefits with these ways of visualizing is that it is easy to create and familiar to people. The disadvantages with those are that they are not so flexible and only suits specific data (*Iliinsky & Steele, 2010*).

Visualization can improve the knowledge on both personal, team and organizational level and according to Eppler and Burkhard (2007) there exists something called knowledge visualization, the difference from data visualization is that it tries to visualize knowledge in terms of both tacit and explicit. Knowledge visualization therefore aims to create or transfer knowledge from one person to another form for example insights, perspectives, opinions and/or predictions. There are multiple tools to use but some examples are conceptual diagrams such as Porter's five forces, knowledge maps or sketches. These tools' purpose is to communicate and trigger discussions about the problem or topic (*Eppler & Burkhard, 2007*).

Both Iliinsky and Steele (2010) and Alhadad (2018) mention some advice in order to make the visualization more effective, these recommendations are summarized below:

- Have important information bigger, bolder, brighter, or more detailed.
- Have less important information presented with less intense colors or lighter lines.
- Use axes in both qualitative and quantitative data.
 - Qualitative axes can be defined as unranked or unordered areas or groupings.
 - Quantitative axes provide information and support search for relevant values.
- If the information can be used independently, slide along relevant divisions, divide larger datasets into multiple similar or related visualizations.
- Apply standard representations and conventions for example representations for element symbols and/or directions.
- Avoid judging proportions if there are more than three cumulative categories.
- Avoid using visualization if it requires comparison across multiple graphical representations.

4. EMPIRICAL FINDINGS

In this section the selection of departments and functions that will be included in this research will be presented, followed by actions in the Define and Measure steps of the DMAIC cycle.

4.1 Geographic limitations of departments and functions

Volvo CE is an international company located in different parts of the world and has a hierarchical structure with many levels. Therefore, it will be necessary to do some geographical limitations and focus on some specific structural levels to scale down the complex hierarchical structure in order to be able to handle the problem during this thesis course. This thesis will investigate the problem in the NPD process where the three involved departments are: Operations, Purchasing and Technology. It means that sales regions Asia, Europe & International, and North America will not be included. The following departments: Legal, Communication; Finance, Business Development and Digital & IT, Human Resources; and Quality, Safety and Environmental Care will also be excluded since they are not directly involved in the NPD process. Figure 10 shows a simplified organizational structure where green represents the departments included in the report and red represents the ones excluded. These three departments are divided into functions, the ones that will be included in this report are illustrated in Figure 11. The limitation in Operations will be on a national level in Sweden, Purchasing will be limited to Europe and Technology will be limited to product platform wheel loaders and haulers. These limitations are going to serve as a base for sampling purposes in both quantitative and qualitative data collection.



Figure 10: Simplified Organization Structure Volvo CE



Figure 11. Extended organizational structure of chosen functions.

*Disclosure: This is not the complete organizational chart. It only shows the researchers' selection of functions in each department.

4.2 Define

The aim with Define is to identify the underlying problem, define improvement activities and opportunities as well as internal and external requirements. Another important thing to identify in the Define phase is the scope and boundaries for the project. For this project at Volvo CE the Define phase consisted of an AIM workshop, T-map, Is-Is not Matrix, Effective Scoping and lastly the scope and boundaries were defined in a Project Charter. All of these actions will be described below.

4.2.1 AIM

An AIM workshop was conducted in order to get a shared understanding of the problem and to make sure that everyone shared the same understanding. The AIM was done digitally by Teams and the participants were the authors, their supervisor from Chalmers university, the industrial supervisor and two other persons from Volvo CE. The meeting lasted for two hours where people first quietly answered on post-its the question: What outcome do we want to achieve with this master thesis? Then the answers were read out loud and explained. This procedure was done together during that meeting. The remaining steps were done separately by the authors in a program called Miro. The AIM was conducted in Swedish, and the authors translated it to English. When the AIM analysis was completed, it was sent out to the participants, and they gave some input back. This led to some minor changes of the AIM.

In total there were 41 notes written down, these were grouped into 14 sub-groups. One of the notes did not fit into any of the sub-groups so that one was left aside as a lonely wolf, this was: Ways to handle different degrees of maturity in different departments/areas. Those 14 sub-groups were divided into three main groups: Communication and collaboration, Master thesis workers expectations and Desired outcome. Three of the sub-groups did not fit into these groups and were not suitable together so these were left without a main group, the three were: Connect missed links in previous master thesis, Potential research areas and Future assignments/employment opportunities. A summarized result showing the sub-groups (pink notes) and main groups (blue notes) is presented in Figure 12.

Communication and collaboration was the group that got the most points (6), followed by Master thesis workers expectations (4) and Desired outcome (2). In the group Communication and collaboration, there were four sub-groups; good communication between Chalmers and Volvo to increase knowledge exchange, good collaboration between master thesis workers and stakeholders to achieve optimal result, map the complexity of communication to facilitate information management, and emphasize the importance of a pull mindset at Volvo CE to optimizes resources. Looking into the relationships, the communication and collaboration affect the desired outcome and potential research areas. Meanwhile, it is affected by; master thesis workers' expectations and ways to handle different degrees of maturity in different departments/areas. By this it could be

concluded that optimal cooperation and communication as well as the necessary conditions on site are crucial to accomplish the desired outcome. The full AIM is found in Appendix A.

AIM EXPECTATIONS

Optimal cooperation and communication as well as the necessary conditions on site are crucial to accomplish the desired outcome.



Figure 12. Summarized result of the AIM workshop

4.1.2 Thought Process Map

Since DMAIC is an iterative cycle which often requires the team to move back and forward in the different phases, a T-map was conducted with questions that needed to be answered. This map is used to see that information that is needed is gathered and is also used as a planning tool to know what to do next. But the main purpose was to gather information, analyze and then ask new questions to gather more information.

The T-map was structured by the five steps of DMAIC and their goals in each phase. Instead of writing questions in the T-map some activities were written down in a bullet list, these activities should gather data in order to achieve the goals. The goals and activities can be found in Figure 13. The activities were based on some questions and the aim was to come up with questions during

the activities. What is important to mention is that these activities were just some suggestions and were not written in stone. As with any other plan, it is just a plan not more, not less. It needs to be flexible to change and adaptable to external circumstances.



Figure 13. T-map DMAIC

4.1.3 Is-Is not Matrix

To brainstorm what the problem could be and not in a structured way, an Is-Is not Matrix was conducted. The goal with the tool is in the end to be able to distinguish between what is and is not the problem. Statements from meetings and emails were analyzed and put into the matrix and gave the researchers a quick overview. While conducting the matrix it was clear that the researchers lacked some information and therefore the Is-Is not matrix was sent to the industrial supervisor at Volvo CE in order to get feedback and more input where gaps had occurred. Some questions from the T-map were also sent in order to gather more information and get a more accurate view.

From the Is-Is not matrix the objective of the problem was decided to be the information flow between different departments and the involved functions were Technology, Operations and Purchasing. The specific defects or problems were identified as insufficient or unclear communication, rework in terms of new meetings, lack of common way of working, lack of common language and/or understanding of each other, and lack of visualization, but there were not caused by the employees' lack of knowledge or not knowing their own role and responsibilities. The identified problems are recurrent and varies from project to project, and the extent of the problem is unknown. By doing the matrix it is possible to set some boundaries like the problem seems to be national, and therefore the international relationships will not be investigated, meaning that the focus will be to investigate the problem on the departments located in Sweden. It did not seem to be a problem in the internal sub-departments, this will not be totally excluded since it could not be proved at this stage, but the main focus will not be on that. The findings from the Is-Is not matrix can be found in Appendix B.

4.1.4 Effective Scoping

After the Is-Is not matrix there was a need to zoom out in order to get a holistic view of the problem and also to determine the measurement system, when the objective of the problem was determined there was a need to understand what the process output is. Therefore, effective scoping was conducted. The goal with effective scoping was to identify the current measurement system and see if a new measurement system was needed in order to solve the underlying problem. It enabled the authors to create a pull approach which was desirable.

When using the effective scoping tool, the researchers must always start identifying the output of the process. With the use of the information from the AIM, emails, and digital meetings, it was possible to identify two important perspectives: the quality of the information and the infrastructure that enables communication. Both perspectives are needed, therefore it was decided to use two outputs:

- 1. Information/knowledge in terms of CAD drawings and reports
- 2. Infrastructure to facilitate information and knowledge exchange

Based on the output six potential improvements were discovered:

- Y1: Productivity in the industrialization phase
- Y2: Delivery precision of information
- Y3: Quality of information
- Y4: Improve common way of working (routines)
- Y5: Improve common language
- Y6: Clear visualization

These improvements need to be measured but those kinds of measurements of the information flow do not exist in the company. Without measurements it is not possible to either evaluate the current status or the improved one. Therefore, there was a need to establish new measurements or small (y)s, in order to be able to measure the defined outputs. Suggestions of six new measurements were:

- y1: Lead time between milestones/meetings' hours
- y2: Response time
- y3: Quality index (usability, clarity, etc.)
- y4: Degree of consciousness of common way of working
- y5: Degree of collaboration
- y6: Degree of own understanding

The next step was to identify the baseline of the (y)s or facts behind the problems, in other words the data that was needed and could be trusted and how to get it. The affected people were the same as those defined in the Is-Is not matrix, namely Operations, Technology and Purchasing departments but also end customers.

Then the underlying system that builds up the (y)s was identified to be the information flow. The final steps were to identify the process's inputs and their suppliers. Finally, what the system requires of the inputs were clarified. The complete Effective Scoping table can be found in Appendix C.

4.1.5 Project Charter

When the AIM, T-map, Is-Is not matrix and Effective Scoping were conducted the authors had enough information to do a project charter. A project charter is like a tender of what the project promises as well as what the project is not about. The project charter was filled out and sent to the industrial supervisor at Volvo CE for feedback and approval from their site. The project charter was used later on as a guide on what to do in the next phases and was seen as a short summary of the Define phase. The delivery affected was defined as a mismatch in the information flow and cross-functional work, insufficient and/or complex communication, and collaboration between departments. The actual baseline was established to be a vague standardization of interaction channels and infrastructure between involved departments in the feedback loops, and the measures to improve were divided into realistic and best-case goals. The realistic goal was to find key factors affecting the information flow and develop a visualization tool; meanwhile, the best-case goal was to test and implement a standardized information flow method and a visualization tool. The complete project charter can be found in Appendix D.

4.2 Measure

In the Measure phase the purpose is to make sure that the right metrics are defined. Since new measurements were found in the Define phase, it places higher demands to control these. To make sure that the right data were collected a Data Collection Plan was applied, see Appendix E. In accordance with the Data Collection Plan the authors could confirm that there was a need for collecting both quantitative and qualitative data. The quantitative data will enable the authors to get a general view of the problem, meanwhile the qualitative data will give a better understanding of the reasons behind. The quantitative data were collected by a survey and the qualitative data were collected by in-depth interviews, observations, and a focus group. These will be deeply described in 4.2.1, 4.2.2, 4.2.3 and 4.2.4.

4.2.1 Survey

In order to collect quantitative data a digital survey was decided to be constructed. The first thing to consider before constructing questions was to establish the goals for the survey and those were to measure the satisfaction level of the information sharing, and the communication and collaboration between departments and functions. After that the sample was selected, the target sample was decided to be people that were involved in a project, it could be all from manager, team members to support functions. It was decided that the more people the better the result would be, since the larger the sample size is the less sampling error may occur and give the possibility to make generalizations. The intention was to have a probability sample of stratified random type where the stratifying criterion was departmental membership (*Bell, Bryman, & Harley, 2019*). Therefore, the survey was sent out by the industrial supervisor to managers on all the divisions working with projects. The managers were then in charge of sending out the survey to their employees in their respective departments. This was done because the response rate would probably be higher if the survey came from the managers and not a student. It was also decided to send the survey via email due to the speed of sending and response.

The survey questions were constructed with the mindset of keeping it as short and simple as possible with only must-know and useful questions. An information text was placed in the beginning of the survey explaining who the authors are, what the purpose of the survey was, what information that was desired and what it was going to be used for.

Due to the established goal four major sections were used in the survey besides demographic information; these sections were:

- Information Process
- Communication and Collaboration between Departments,
- Degree of own understanding
- Improvement Potential.

In all of the sections, a mix of types of questions were used. In order to make an effective survey, some response variables, explanatory variables, and stratification were used. The survey was built up to have easy and pleasant questions in the beginning, the most important ones in the middle, and in the end, there were the most difficult questions. In the survey the rating scale was chosen to be 1 to 5. Emotional charged words tried to be avoided in the questions and there was no use of two questions in one in order to make it easier for the respondent. The survey was sent to the industrial supervisor at Volvo CE who tested the survey in order to make sure that the right language was used, that the questions were understandable and that the survey was not too long. He came with important feedback that led to some changes and adjustments to the survey before the final version was sent out by mail with a link to the survey.

The first part of the survey was the demographics, where there were in total six stratification questions about:

- Gender
- Age
- Working role
- How long they have been working for the company
- Which NPD phases they were involved in
- How many times they had visited the Arvika factory

The second section of the survey was the information process where there was a mix of stratification and response variables, in total there were seven questions and one follow up question in this section. The goal with these questions was to get a holistic view of the information process. Two questions were about estimating the time spent on following up meetings and each communication channel. On the first one there was a time span of times per month; less than 1, 1-2, 3-4 and 5 or more. The second one had four options 0, 4, 6 or 12 hours, the goal with this question was to be able to do a 3-point estimation using the response from the participants. There was one question about what communication channels were used, and then a question about the respondent's perception of those, this one was with the selection of retain, replace, or make more effective. There was also a question where the respondents had to rate their priorities between speed, searchability, and structure, another question about rating the standardization of the information flow and lastly, a question about delivering in time with yes, no, and sometimes as alternatives, where negative or sometimes answers led to another section with a why question for giving reasons for that.

The third section was the biggest one in the survey, and it was the communication and collaboration between departments. In this section, the harder or more sensitive questions were

placed. The goal with this section was to get a deeper understanding of the connection between departments, how and when they communicate with each other and how they perceive it, there was a mix of response variables, explanatory, and stratification questions. Initially, twelve departments were identified as usually involved in projects, therefore the questions in this section were divided into these twelve departments. In total there were twelve exact same questions for each department, but in the first question of each department the respondent got the question if they collaborated or had communication with that department, and they could answer yes, sometimes, and no. If the answer were yes and sometimes, they would get the twelve questions, but if they answered no, they were moved on to the next department. In this way, it was ensured that those who responded to the questions actually had a collaboration with the department. The first question aimed to establish the time span for getting information from the correspondent department, the second question searched for the channels used, the third question aimed to find out the frequency of the communication per month. The next nine questions were rating questions using the scale 1 to 5. Four of those questions aimed to find out how useful, important, understandable, and reliable the information from the specific department was, to be able to measure a quality index that includes all these factors. The other five rating questions were about how much new knowledge they get, if they share a common way of working, how well the collaboration works, if they share a common language, and finally how well they understand the role and responsibilities of that department.

The fourth part of the survey were two questions with the purpose of seeing the degree of their own understanding. The goal with this section was to see how the degree of their own understanding was and to map out what departments need information from each other. The first question in this part was a multiple-choice question about what departments the respondent thought needed information from them, and the second one was a rating from 1 to 5 about how well they understood what information others needed from them.

The last part of the survey was improvement potential with a total of 10 explanatory variables questions. There was a mix of rating and open questions. This section was the only one with open questions where the respondents could freely answer, the reason for that is that open questions are difficult to analyze in a quantitative way and therefore they were used as little as possible. However, in the improvement potential it was of highest interest to get the respondents perspective on what could be improved and therefore some of the questions were constructed to be open. There were three questions about standardization and improvements in the communication, and six questions about a potential visualization tool, three of them were rating questions using the scale 1 to 5, one open question where the respondents could write what kind of features they would like to have in a visualization tool, and two yes, no, or maybe questions regarding a concrete example of a visualization tool developed by Gaia Santoni in 2019. The final question of the survey aimed to find out the respondent's interest in participating in additional activities such as in-depth interviews and/or a focus group.

4.2.2 In-depth interviews

In order to collect qualitative data, it was decided to conduct in-depth interviews. The goal with the interview was to get a deeper understanding of how the information flow goes, why it is like it is and what could be improved. Therefore, a semi-structured interview guide was prepared to make sure the interviews covered those areas and to be able to compare the answers.

In resemblance to the survey, the focus was on people who worked in projects in some way, but to be able to compare the answers it was decided to use a stratified sample rather than a random one and choose people that worked or had some connection to a specific project. The goal was to target key persons from all the involved departments, and contacts to possible interview objects were given by the industrial supervisor. This specific project is called L-350 and involves people from Operations, Technology, and Purchasing. The selected employees were contacted by email with short information about the thesis, the interview, why they were contacted and asked if they were interested in participating. If they gave their informed consent, an interview time was booked.

A semi-structured interview guide was constructed following Robson (1993) interview sequence with two introduction questions that aimed to be easy to answer on. The first one was to present themselves, their location, and their role at the company, and the second one was how often they visit the Arvika plan. These warm-up questions were followed by the main body of the interview that consisted of fifty questions organized in four sections: working procedure and information process, communication and collaboration between the departments, capability, and improvement potential. The complete interview guide can be found in Appendix F.

In the working procedure and information process, general questions with the intention to get a describing view of their working procedures and the information flow, were made. But there were also questions about their view of standardization as well as different information systems used inside the company. In the communication and collaboration section, the questions were more regarding how they communicate with each other. There were also more specific questions both general but also in regard to the L-350 project, as well as questions about communication loss and eventual problems. In the third section capability, there were mostly questions regarding the specific L-350 project. The aim of this section was to see how the quality of the information sharing has been and how they have perceived the project. The last section of the body was improvement potential. Similar to the survey, the aim was to find out the participants' view about future improvements, if there was a need for a visualization tool and what kind of features this tool should include. At the end of the interview, the interviewees were given the opportunity to add freely some additional information or ask questions.

A total of fifteen interviews were made. The interviews lasted from 40 to 120 minutes, where most of them lasted for 90 minutes. Both the researchers participated in the interviews, one held the interview and the other one took notes. Due to COVID-19 pandemic and since the interviewees were located in Arvika, Eskilstuna and Braås, and the researchers were in Gothenburg, all of the

interviews were conducted remotely using Teams. The interviews were conducted both in Swedish and English. At the beginning of each session, the interviewees were informed about the intended use of the interviews' results, their anonymity, and were asked for their consent to record the sessions. The recordings were later transcribed by the authors. The interviewees were given the opportunity to respond freely without time limitations and could skip questions or refuse to answer if they so desired. The use of a semi-structured interview guide gave the researchers the advantage to adjust the questions, skip them if they were already answered in previous ones, or add additional follow-up questions to clarify the answers if required.

4.2.3 Observations

A three-days long visit to the Arvika plant was performed by the researchers in order to get a better understanding of the operations, products, and processes. The visit was planned to happen earlier during the Define phase, but it had to be postponed due to the COVID-19 situation in the region, the visit could finally be safely arranged during the Analysis phase. Since the Six Sigma methodology is not a straightforward process it is possible to make iterations and reflect upon what has been done and move back and forward between the different phases. During the first day a guided Gemba walk around the whole factory was done where the researchers had the opportunity to observe the different manufacturing operations in all three lines of products: Medium, Large and Heavy. The heavy products were of special interest since the L-350 model has been the focus of attention in this master thesis project. It was possible to talk with some of the workers who explained some of the processes. The level of competence in their respective areas was high. The researchers were also able to try the cabin of a L-350 wheel loader (see Figure 14), it was a powerful experience that added a touch of reality to the project, since until then talking about information and communication flow only via Teams was a little bit subjective but been able to see the results and try a heavy wheel loader gave the researchers another perspective, a better understanding about what can be accomplished by everybody's efforts.



Figure 14. The researchers trying a L-350 wheel loader at the Arvika factory.

During the second and third days at the Arvika plant, the researchers were able to participate as observants during a couple of meetings with the possibility to ask questions if it was required. The aim was to observe how the participants interacted with each other. The first meeting was the longest one, where important issues about planning activities in different projects were discussed, the meeting was cross-functional and included people from all the three departments. The second meeting the researchers attended was a short one called pulse meeting that takes place every morning and lasts between 5 to 10 minutes. In this meeting issues or problems regarding the daily activities and status of the production are presented by the respective responsible persons. More than fifty people attended that meeting that is actually open to all since it gives a good overview of the current status and what needs to be done. All meetings are conducted via Teams or Skype due to the pandemic situation, and the majority of people are working from home.

Another important observation was made by the researchers while visiting the offices regarding the currently used visualization channels. A lot of important information concerning the production is visualized in big whiteboards and monitors at the offices next to the factory, that allows the engineers to have an overview of the current status before entering the plant (see Figure 15). This information is also possible to be acquired digitally.



Figure 15. Different ways of visualizing information at the Arvika plant

4.2.4 Focus Group

The researchers conducted a Focus Group during the second day of the visit to the Arvika factory. There were five participants from Operations that were chosen from different functions and that had not participated in the interviews. The participants' background is presented in Appendix H. There were four participants physically present and the fifth one joined via Teams. The researchers served as moderators and did not participate in the discussions. The participants were encouraged to use their creativity. The dynamics was as follows: First, a short introduction of the master thesis was done, followed by individual presentations. Then the goal of the session was established, which was to get an understanding of what features could be used in a visualization tool, and in what areas was possible to use it. Then, a warm-up exercise was conducted where the participants could freely discuss what kind of visualization tools they were used to using in their daily work. Until here all five participants discussed together. After that the participants were divided into two groups, a group of three in place, and a second group of two, with one person online. The goal of dividing the group was to facilitate communication in smaller groups where everybody could contribute. This was followed by three rounds of about 20 minutes each. The groups were provided

with post-it notes where they could summarize their discussions, one idea per post-it note. During the first round, the participants freely discussed the two questions that were the goal of the session. In the second round the participants discussed the responses to the same questions obtained from the quantitative and qualitative analysis, after they finished each round, they placed the post-its in a previously prepared flipchart stand. Finally, during the third around the participants presented and discussed their answers. Figure 16 shows the participants in action both physically and digitally.



Figure 16. Focus Group in action

The results of the Focus Group will be presented in chapter 6.3.

5. ANALYSIS

This chapter will cover the Analyze phase of the DMAIC cycle in terms of the analysis of the quantitative and the qualitative data. The quantitative analysis is based on the Google Form responses and also using the JMP software. The qualitative analysis was made by sorting out all the answers from the interviews into different categories in four Excel tables. These categories were department and function affiliation in the columns, and different sections inspired by the interview guide in the rows, some sections comprised several questions. This way of treating the data facilitated the comparison of the different answers. The quantitative analysis is presented in 5.1, and the qualitative analysis in 5.2.

5.1 Quantitative Analysis

In this section the analysis of the quantitative data gathered through the digital survey is going to be presented. The analysis is based on 23 responses from Volvo CE employees. The response rate has not been as high as expected due to different circumstances such as problems with Volvo's intranet firewall that blocked the access to the Google Forms survey; this problem was resolved after a while. Another problem has been some resistance and unwillingness to participate because of high workload and/or problems with understanding some of the questions, clarifications were made by request.

5.1.1 Stratification questions

Figure 17 shows the compiled demographic data from the respondents. From the responses it can be concluded that the majority (78.3%) of the population are men, 91.3% are between 36 and 60 years old and most of them have senior experience, meaning 11 or more years working at the company with almost 35% that have been working for more than 21 years. This is a good indicator that the obtained data is reliable since the majority of the respondents are very experienced and can base their answers on facts.





Figure 18 shows the department affiliation of the respondents, 58% are from Technology, 8% are from Operations and 34% are from Purchasing. We can conclude that Technology is overrepresented while Operations is underrepresented, Purchasing on the contrary, represents a third of the total.



Figure 18. Department affiliation

Looking into which phase the respondents were involved in, the majority of people were involved in the Final development with 20 of the 23 respondents involved in this phase, followed by detailed

development (B-release) and the industrialization (P-release and SOP) both with 19 of the 23 respondents, see Figure 19. There were five respondents that were involved in all phases, 3 from the GPE platform, 1 from UPP and 1 from Quality.



Which phase (s) of the develoment process are you involved in?

Moving on to how many times the respondents have visited the Arvika plant, there were 30,4% who never had visited the plan facility in a year span, 39,1% had visited the plan one to three times, meanwhile there was 21,7% that stated that it was their location, see Figure 20.



5.1.2 Information process

The questions in this section covered how the information is acquired, the time spent in order to get it and if the deliveries are made in time. The aim was to get a holistic view about the information process, different communication channels and their effectiveness and the respondents' priorities.

It was of interest to know how much time the participants spent on follow-up meetings in regard to projects. In Figure 21, it is shown that the majority of the respondents spend more than 1 time

Figure 19. Level of involvement in a project

per month participating in follow-up meetings, more than 60% have more than 3 and of those as much as 39.1% have 5 or more follow-up meetings per month.



Figure 21. Time spent on follow-up meetings.

It could be seen from the survey that the majority of the respondents collect the information they need from email (95.7%), see Figure 22. The second most common way to collect information was by setting up meetings (82.6%). Another common way was to use SharePoint (82.6%) and personal communication like ad-hoc or by talking when seeing each other at the coffee machine (60.9%). Surprisingly, there were five respondents (21.7%) who sometimes need to guess since they are not able to collect the data in another way.

How do you get the needed project information to perform your work tasks?



Figure 22. Channels used for data collection.

The time spent on each communication channel can be seen in Figure 23. The question was divided so the respondents could estimate the time spent using zero, four, six or twelve hours on each communication channel. If they did not use it, they were asked to put zero or leave it blank. The aim of the question was to see if there were some communication channels that were standing out and to do a three-point estimation.



Figure 23. Time spent on each communication channel.

Three-point estimation is a tool to estimate the expected amount of time spent or cost (E) based on three values: the optimistic (O), pessimistic (P) and the most likely (M). The formula for this estimation is E=(O+4M+P)/6 and the standard deviation of the PERT distribution is Standard Deviation=(O-P)/6. For this case, the three-point estimation would be 6.67 hours with a standard deviation of 1.33, the lower and upper boundaries on one to three standard deviations can be found in Table 2. By using the responses from the survey, the three-point estimation was calculated for each communication channel, the responses used were four, six and twelve since the blank or zero was considered as the respondent not using that communication channel. The average of the total amount of response for four, six and twelve hours was used in the calculation, the formula was E=(O/R+4M/R+P/R)/6 and the estimated time spent of each communication channel are presented in Table 3.

Most of the communication channels are inside the boundaries for 1-standard deviation (68,3%) except; ask superior, reuse, and guess, those are inside 2- standard deviation (95,5%). What can be seen from Figure 23 is that most of the respondents spend four hours on the communication channels. There were only six (email, phone call, ad hoc, set up meeting, SharePoint, and own experience) of the nine communication channels they spent six hours, and in three of those (email, set up meeting and SharePoint) some spent even twelve hours. What can be concluded is that the most communication channels are the ones they spend most time on, as mentioned before these were email, set up meeting and SharePoint.

Range	Probability	Lower boundary	Upper boundary	
1- standard deviation	68.3%	5.34	8	
2- standard deviation	95.5%	4.01	9.33	
3- standard deviation	997%	2.68	10.66	

Table 2. Standard deviation for communication channels

	Optimistic (O) 4h	Most likely (M)	Pessimistic (P)	Responses (R)	Estimate time
		6h	12h		spent (E)
3-point	1	1	1	-	6.666666667
Email	16	4	1	21	7.714285714
Phone call	8	2	0	10	8
Ad hoc	12	1	0	13	5.538461538
Set up meeting	12	3	4	19	6.736842105
Set up meeting	5	0	0	5	4
SharePoint	13	3	1	17	7.411764706
Own experience	11	2	0	13	7.076923077
Reuse	11	0	0	11	4
Guess	6	0	0	6	4

Table 3. Three-point estimation for the communication channels

In the survey it was also a question about how well these communication channels work in regard to what they want to retain, make more effective or replace. In Figure 23 the result is presented. There were divided opinions on most of the channels for example email, that was the most commonly used channel, had equal response on retain and make it more effective. Eight respondents wanted it to stay as it is, eight wanted it to be more effective and four were willing to replace it, see Figure 24. What stands out is that the majority wants to replace guess and make both SharePoint and meetings more effective. Own gained experiences was the channel that most people wanted to retain as it is.



Retain, Make more effective and Replace

Figure 24. Evaluation of the communication channels.

The respondents got the possibility to rate their priorities in the communication process in an ascending order from 1 to 3, the given alternatives were speed, searchability and structure. Speed was seen as the most important factor in the communication process where 14 respondents rated it as a 3, see Figure 25. As shown in Figure 25, searchability was the second most important and structure the least important.


Please rate your priorities in the communication process in ascending order (1, 2, 3).



It was also of interest to find out the respondents' perception of how standardized the information flow was. The result shows in general that the majority of the respondents (more than 65%) consider that the information is very low standardized, while 21.7% think that it is standardized enough. Only 13% think that the information is good standardized (see Figure 26).





Another important aspect was to find out if the expected deliveries are made on time in order to move on to the next gate. The result shows that the majority of the respondents sometimes or never deliver their part on time (73.9 %), where it was mostly sometimes delayed (69,6%), see Figure 27. The next question tried to capture the reasons for that overwhelming result. The result is based on 17 answers which represent 73.9% of the respondents who answered that they cannot deliver on time. The most common reason was that they missed information from other departments (76.5%) and that the required information was not delivered on time (70.6%), see Figure 28. Some of the respondents had misinterpreted what information was needed (41.2%) and some needed to prioritize other tasks (41.2%). In this question it was possible to come up with other reasons than those stated, it appeared in total four new reasons; task was more difficult than expected, technical support is not seen as business critical during project time, poor project planning and always late in projects which makes my work impossible sometimes.



Can you deliver your part in time in order to move to the next milestone?

Figure 27. Ability to deliver on time.

Why can you not deliver on time?





Figure 28. Reasons for not delivering on time.

5.1.3 Collaboration and Communication

The goal with this section was to get a holistic view of the collaboration and communication between the different departments. Twelve departments were considered. Figure 29 shows the respondents' collaboration with the respective department. It can be observed that the Technology departments (GPE Platform, WLO Engineering, Product Maintenance & NPD, AH Engineering) are those that are required the most, followed by Operations (Quality, Assembly, Production) while Purchasing is the one that is less required by the other departments. The data were analyzed in JMP in order to clearly visualize the relation between the respondents' department affiliation and their collaboration with other departments. The result can be seen in Figure 30.









Collaboration between departments vs. What department are you working in?

Figure 30. Collaboration between departments vs. department affiliation

Figure 31 shows how long time takes for each department to deliver the information that other departments require from them. A quick overview shows that it takes between 1 to 3 working days in most of the cases for other departments to get what they need. In general, it can be said that the Technology departments are the ones that require most time to deliver the information that is required from others. The Fabrication department within Operations is the one that has the quickest response, in general Operations' responses take 1 to 3 days or less.



Time duration to get information from the departments

Figure 31. Time duration to get information from the departments.

In this section there was also one question about which communication channels they in general use, a similar question was conducted for each department and the result is presented in Figure 31. The most common communication channel in general was as mentioned e-mail followed by meetings. When looking into the different departments it was different for different departments. In the departments where a lot of collaboration was needed like GPE their emails were used as much as meetings, this also occurred for the Product maintenance & NPD, see Figure 32. The most used communication channel with Assembly were meetings. Casual encounters occurred quite frequently with GPE platform, Product Maintenance & NPD (10), closely followed by Assembly. In this question the possibility to add communication channels used was open and three options came in; Visit, go and see and chat. Visit and go and see are similar to each other so they were put together as one whereas chat was put on its own. Go and see occurred when collaborating with Quality (2), Production Engineering (2), Logistic (1) and Purchasing (1). The suggestion chat was done mainly with Technology departments; GPE platform, Product Maintenance & NPD and WLO Engineering.



Communication channels

Figure 32. Communication channels used between departments.

Figure 33 shows a compilation of four variables that were considered to compose the common quality indicator. The variables are how useful, how important, how understandable, and how reliable the information received from the different departments is. The acquired data are analyzed in the JMP software and an indicator for each variable is obtained. The indicators are given by the mean of all the answers for the respective question.

Useful: 3.92 Importance: 3.938 Understandable: 3.81 Reliable: 3.77

From those indicators it can be concluded that the quality of the information has an acceptable level. The common Quality indicator is 3.85 which is given by the mean of the four components.



Figure 33. Quality indicators

The next five questions were analyzed in JMP. The aim was to find indicators about how much new knowledge they gain from the information they receive from the different departments, if they share a common way of working, how well the collaboration works, if they share a common language and/or understand each other, and finally how well they understand the role and responsibilities other departments have. The results can be seen in Figure 34. The found indicators for the different categories are the following:

New knowledge: 3.525 Common way of working: 3.178 Collaboration: 3.716 Common language: 3.572 Understand roles/responsibilities: 3.783



Figure 34. Additional indicators

5.1.4 Degree of own understanding

In this section of the survey the aim was to see to what extent they know what other departments need from them. It was divided into two questions, which department needs information from the respondent, and how well does the respondent understand what others need from the respondent. What is observed is that Product Maintenance and NPD is the department that needs most information from others (77.3%) closely followed by the GPE platform (72.7%), see Figure 35. It is also clear that the Technology departments are those where the most information is required (Product Maintenance and NPD, GPE platform, WLO engineering etc.) In this question it was possible to add other departments if the researchers had missed some, it came in three suggestions: Global Competence Development (Service School) plus sister departments on other sites (e.g., Hameln, Konz, Changwon), mainly internal DEnSE (Germany and Sweden), and Commodity Buyer and Commodity Manager. Except for the three suggestions, Fabrication seems to need the least information (22.7%) closely followed by Logistic and Purchasing Sweden (27.3%).

Which departments need information from you?

22 responses



Figure 35. Departments that need information.

Moving on to how well they think they understand what others need from them, 44.7% of the participants understand well (4 in a scale from 1 to 5) what others need from them, see Figure 36. A majority of the participants (91.3%) have a good understanding of others' needs and only 8.7% perceive that they have a low understanding. The curve in Figure 36 is skewed to the right which means that the majority feels confident in the degree of their own understanding in regard to what is expected from them.

How well do you think you understand what information other departments need?





The data were analyzed in JMP (see Figure 37), and it was possible to get an indicator:

Degree of own understanding: 3.565

It can be observed that despite the fact that the common indicator is quite good, there are some differences between departments, especially in Supplier Development (Purchasing) and UPP (Technology) where the answers fluctuate a lot.



Figure 37. JMP analysis Degree of own understanding

5.1.5 Improvement potential

In the improvement potential section questions concerning standardization potentials, improvements on the current situation and how a visualization tool might help are presented. There were four open questions where the respondents could write the response, three rating questions and two yes, no, maybe questions. The open questions aimed to find out what need to be improved and what features they want to see in a potential visualization tool.

Standardization

The first open question intended to capture what could potentially be standardized in the respondents' work through the respondents' general suggestions. There were in total 13 responses to these questions, with one that replied that he/she did not know. The responses were first analyzed in text mining in JMP, and it turned out that parts and projects were the most common words followed by needed, status and data, see Figure 38. These words give a hint of the content of the answers. The responses were organized in Table 4 by dividing them in three areas: Project status/plan, Infrastructure, and Other. Since project was one of the most common words one cluster

was named project status/plan, where five responses were given to that subject. It can be concluded that there is a need for more standardization when it comes to where the critical parts are, project status, expectations concerning deliveries and what and when employees need to communicate with others. The responses regarding the infrastructure of the information sharing were about the need for having the same setup in SharePoint, meetings, and way of planning, all documentation should be stored in Windchill, there is also a need for data maintenance and accuracy, and that more standardization in general is needed. In Other there were three responses that did not fit in the other groups or together, these were more specific suggestions about how to grow in the company, minimize the distance between functions and the need to always get answers from emails.

Project status/plan	Infrastructure	Other
More specific, when and what, I need to communicate to others.	Same setup of SharePoint (folders), same type of meetings and way of planning	Development contribution for become Technical Support Expert
More open which work that is ongoing	All documents needed placed in Windchill in the machine structure	Minimize the distance between us.
Scheduled de-briefing with project managers to know both current status and needed status from a project demand point of view.	Data maintenance, Organizational accuracy, Data Sharing	To always get an answer from the responsible person/recipient of the email
Rules/expectations concerning deliveries.	More standardization needed.	
For example, a dashboard with all concerned new parts, visualized, and easily followed during the project and its activities. Available for all in the project. Where do we have the critical parts? What parts are not in line with the plan etc. Have we captured the scope; do we miss parts?		

Table 4	Potential	information	that can	he	standardized
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Figure 38. Text cloud - Possible standardization in today's communication

Unnecessary

In order to find what could be improved a question about which steps were unnecessary or could be removed from the communication process was asked. There were in total ten responses, two replied that they did not know. The question was analyzed in text mining in JMP, and it found 41 terms where the word meeting was occurring three times, email two and none two. The text cloud shows words that occur, the more frequently the bigger. For this question, the word meetings is the biggest one, followed by emails, none, need and work, see Figure 39. This gives a hint that many responses were concerning meetings. Therefore, when clustering the responses meetings was chosen to be one of the clusters, the other one was communication issues, see Table 5. Four of the responses concerned meetings, for example that information meetings were unnecessary, meetings with more discussion than conclusions and speculations. In the communication issues, four answers concerning different problems in communication were clustered, such as lack of response or sending emails with attachments.

Table 5.	Unnecessary/Removable	Steps
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Meetings	Communication issues
Information meetings	When we need to involve the person's manager to push them to reply
Large work meetings that do not need my work	None, since lack of communication is a current problem
Meetings with more discussions than conclusions. That every participant sees their contribution and that the scope is clear.	People not answering emails
Speculation, personal agendas, not being prepared or not have correct competence	Sending emails with attachments

problem participant manager information sending see lack attachments conclusions **S** far since agendas largepush ear discussions answering competence people know communica correct preparedcontribution mind current scope reply nothingpersonal speculation

Figure 39. Text cloud - Unnecessary/Removable Steps

Free up most time

Another question concerning the current status and what could possibly be improved is the question in regard to what would free up most time for the respondents. This was as the previous question an open one, where the respondents could write freely. In total there were sixteen replies to this question. The question was analyzed in the text mining in JMP, where information was the biggest word and therefore, the most common one, followed by project and meetings, see Figure 40. After a look at the words in the text cloud the answers were clustered by the authors, in total there were six categories (meetings, emails, cross functional work, project scope, infrastructure/standardization and other), see Table 6. In meetings there were four responses mostly about the unnecessary information meetings and the effectiveness of the meetings. In emails, there were two responses where they expressed the need for a better debriefing of the information in order to avoid unnecessary emails and an excess of emails with all kinds of information. Cross-functionality was also mentioned as a way of saving time when everybody knows what kind of information to deliver and the planning and follow up works effectively. The project scope was also considered important where the respondents wished for a manageable and well-defined scope of the project with defined activities. A common standardized infrastructure where the information is stored in the right status and right place was mentioned as well. Other wishes as minimizing distance to facilitate the communication and removing language barriers were also expressed.

Meetings	Less info meetings	Unnecessary meetings. No information-No meetings.	Effectiveness of meetings	Focus on the agenda, fact-based discussions
Emails	Scheduled de-briefing with project managers to know both current status and needed status from a project demand point of view. That would give less mail conversations just to try and understand what is needed and when it's needed.	All information coming by email with a lot of words.		
Cross-functional work	Cross-functional planning and continuous follow up (to see that no critical delivery falls behind)	If we had a true cross functional work process where we do not have to ask for the information we need, but we are remembered and delivered the info we will need during the specific project phase.		
Project scope	Defined project contribution activities	That the scope is manageable. Resources secured to		

Table 6. What would free up most time.

	for Tech Support Experts	decide scope. That we follow the process and do not take shortcuts. That will in the end cost more in money and time.		
Infrastructure/ standardize	Documentation in the right status and in the right place on the right time	A common system where information is stored so me and anyone else can find it.	Standardization of the work in NPD.	
Other	To be able to read information when I have the time and interest of reading	Answers to questions	Minimizing distance reduces meeting hysteria in the calendar.	Remove language barriers.



Figure 40. Text cloud - What could free up most time.

Visualization tool

The next three questions were also analyzed in JMP. The aim was to test how likely it was that the potential users wanted/were going to use a visualization tool for communication, how useful a visualization tool could be to get a better understanding of issues/problems and finally, their perception of the visualization tool's capability to improve the common language/understanding of other departments. The results are shown in Figure 41. Three indicators could be found as follows.

Willingness to use a visualization tool for communication: 3.565 Useful to get a better understanding of problems: 3.782 Visualization tool can improve the common language/understanding: 3.478

The indicators in general show a good level of acceptance but looking at Figure 41 it is obvious that the opinions differ quite a lot, especially in the departments with a higher number of respondents. This shows that there is skepticism around how beneficial incorporating a new

visualization tool could be. The reasons for that can vary and are difficult to identify only based on the quantitative data, the qualitative data may provide a deeper understanding.



Improve common language/understanding of other departments

Features

The next question was about what kind of features they would like to see in a visualization tool, the question is open in order to not limit the respondents' imagination. They have the freedom to write answers to the question. By being a wide-open question, it could also hinder some respondents from knowing what to answer. In total there were 13 people that answered this question where four of them did not know what to answer or did not know what a visualization tool was. The rest of the replies were divided into two topics: project status and functions, see Table 7. In Project status suggestions concerning cost saving, status of project, effect on delays and following up were collected. In Functions the desirable features concerning the function of the

Figure 41. Perception of the potential of a visualization tool

visualization tool were sorted out, examples that came up were use of colors, different filters and use of CAD models. The responses were analyzed in text mining in JMP, and they resulted in a text cloud, see Figure 42, the more often a word occurs the bigger the word is in the text cloud. This gives an indicator of words and thereby what is important to consider in a visualization tool, the words project, tool and visualization are the biggest ones. However, since it only analyzes the words and not complete phrases, it does not give the full picture of the meaning of them. Therefore, the table was constructed to give a bigger understanding of what is needed.

Project Status	Functions
Potential cost saving VS potential total added cost if not working as planned.	Filter for function dependent information
Status of project and what is primary action for the project right now	It should be adaptable so depending on which area you are working at you probably are more interested in a specific area and not everything
Effect on end user or end product to highlight chain effects of delays	Colors to get an easy overview
When deciding supplier and price, when we discuss details, both with production engineering, designers and suppliers	Full cad-model visualization
Should be rather easy for project management to follow up what needs more focus at the moment etc.	No double documentation

Table 7. Desirable features divided by Project Status and Functions

production effects discuss status saving moment want people supplier familiar depending focus now delays deciding dependent prefer function communication challenge user adaptable colors skype 💟 chain full total documentation etc cad action driven information effect used added also engineering planned filter interested everything designers highlight meetings suppliers product details management VS double right price today follow primary overview needs rather skilled specific

Figure 42. Desirable features to have in a visualization tool.

Lastly, Figure 43 was presented to the respondents in order to capture if this way of presenting information would help to increase their understanding and make their work easier. The picture is borrowed from Santoni (2019). Figure 44 shows the responses to these questions. To the first

question only 3(13%) of the respondents considered that their understanding was increased, the rest responded maybe or no to the same question (60.9% and 26.1% respectively). The same result applies to the second question, meaning that only 3 persons thought that their work would be easier using the presented visualization tool. The fact that 14 persons (60.9%) answered "maybe" to the question could be due to different reasons such as not being able to understand the example, not knowing the facts behind, etc., the researchers can only speculate about it, but there might exist potential in this kind of visualization tool if the prospective users could understand it better and see the benefits. It might be also possible that the visualization tool is useful for some departments but not for all of them and could be more customized including other features such as the ones suggested by the respondents in the previous question.





Would this way of presenting process information increase your understanding? Would this visualization tool make your work easier? 23 responses 23 responses

No







Figure 44. Responses in regard to example of visualization tool

5.2 Qualitative Analysis

In this chapter the analysis of the qualitative data is presented in three main categories: Working procedure and Collaboration and Communication processes, Capability, and Improvement potential. These three categories are based on the body of the interview guide, the difference is that working procedure and collaboration and communication are analyzed in one, in the interview guide there were two separate sections. As it was mentioned before, there were conducted 15 interviews with people from different departments (3 Operations, 9 Technology, 4 Purchasing) that are connected to the L-350 project in one way or another, see Appendix G. One of the interviewees had another role now but was apart in the L-350 so this person responded for two different roles in two different departments. Another one was working in two roles. In total, the qualitative data was gathered from 14 functions from the three main departments Operations, Technology and Purchasing.

5.2.1 Working procedure and Communication and Collaboration process

In this section the results from the questions about working procedure and the collaboration and communication process will be presented with the aim of capturing the interviewee's perception of the current work procedure in regard to the information process and the communication and collaboration between departments and functions. The results are divided and analyzed by department and therefore presented below in 5.2.1.1 Operations, 5.2.1.2 Technology and 5.2.1.3 Purchasing. Lastly, the perception of the current information systems will be presented in 5.2.1.4.

5.2.1.1 Operations

In this section the answers from interviewees that work in Operations will be presented. The section is divided into first describing the working procedure, followed by the communication and collaboration between departments, standardization and lastly responses in regard to the L-350 project are analyzed. In Operations there were a total of three interviews done with people from different functions.

Working procedure

In this section the perception of the working procedure will be presented. The working procedure and the information process in Operations seems to be quite similar between functions, they are following the Project Steering Model (PSM), but the work tasks differ. The Logistics department is dealing with questions or tasks regarding location for new parts, making sure they are coming in at the right time and packaging. They are reporting to the head project manager on a weekly basis, and they also have weekly meetings inside Logistics where they follow up the different tasks that need to be done so that the project can go on. The interviewee mentioned that *"we also have a communication plan, where we describe how we inform and communicate the project, for*

stakeholders and minor stakeholders as well." Furthermore, the interviewee showed the PSM structure and explained how it worked in the different steps, see Figure 45. The PSM model is a steering model mainly used in Operations. In the Assembly and Fabrication, it was more about tendering, planning, and delivering the right machine on deadlines. In Quality it was more about measuring and quality assurances. All three departments are heavily involved in the prototype buildings. There could be some waiting time between different approvals or gates such as feasibility approval, but that was understandable since it is important to make the right decisions. Otherwise, there was no major waiting time, if there were some other operations tasks to perform while waiting.



Figure 45. PSM Flow (PM Academy, PPM Training, 2016)

One of the interviewees was more of a support function for the project and this person perceived that the process of information could be improved, often the information was missed to send to this function as well as they were not invited to meetings where they might have got important information. The interviewee stated that *"if you are curious and if you are sort of you want to know more, then you can always ask and you will get the information, but it is not like you can wait for the information as a support function,"* and *"the main target of the information is often not the support function but sometimes the support functions needs the information as well."*

Two of the interviewees were not heavily involved in the project; one was a recipient of the project, and the other was acting as a support function. Therefore, they had a hard time explaining the timeline of the project. It was also one of the reasons why they did not think the general information about the project was for them, they were more interested in the specific detailed information that concerned them. The third interviewee agreed on this point and mentioned that *"There might be some background information maybe that could be maybe not necessary...But some are of course*

important to have. "They all had the same opinion that general information is good and probably necessary for some people, but they sometimes felt like that was the only information given which was a concern for them. One of the interviewees mentioned "So, to have general information is very good because people that are interested in the general state of the project can listen, but while you have that you cannot forget to sort of pinpoint or attack the proper information group with more detailed information. Because if you assume that everyone gets answers from the general project information then you will not be effective in the project work."

Besides from focusing on two much general information, some mail conversations were seen as unnecessary and time consuming for one of the interviewees. It was concerning all mails that were not target for that specific person in his/her role, and those mails that could have been solved by a phone call, the interviewee said that "Some mails are just mails, you could say that some of the mails could be excluded and solved with a phone call instead, but in general people have bad memory that's why we send mails because then we have it in writing. But if you are not the target of the information that is quite a huge waste." These kinds of mails were something that the interviewee felt that could be removed from the process.

They had different views on what was valuable or important, one thought the feasibility study was very important to spend time on in order to make sure they are doing the right things. Another thought that the Product Criticism and P-FMEA were very valuable since it is in those where problems are brought up. This person also mentioned Virtual Reality (VR) as an upcoming tool that is very helpful, the interviewee stated that "*I also think that we did this VR, we went in in a VR environment and looked at how we could assembly and so on. That was very useful for my co-workers and me.*" The third interviewee mentioned the importance of sharing obvious plans with the correct info to the correct receiver, this included meetings. This in order to avoid having people that are not related to the subject of the meeting or include them in the right time when their topic is brought up. Furthermore, the issue of prioritizing was brought up from the support function point of view since they need to deal with their daily work and support the project as well. It could sometimes be a very high workload and hard to know what to prioritize. The interviewee would appreciate if some people in his function were dedicated to the projects, this person said, "So I would say that to create the most valuable for the project you should have assigned people with assigned roles not only from a project point of view."

Communication and collaboration

In this section the analysis of the collaboration and communication will be presented. According to the three interviewees the collaboration was perceived to be cross functional and with most of the departments, one of them stated that "We of course have to cooperate with everyone about the things we do" and another one said, "I had a lot of contact with a lot of different people, since a lot of different materials need to be measured, evaluated, looked at drawings and so on, and so on." The things that made the interviewees from Operations most proud were when they solved problems cross-functionally and got feedback both external and internal. How often they

communicate as well as how often they have follow-up meetings are summarized in Table 8. The general view on how often was that it depends, and that it varies depending on what stage the project was in. Overall, the interviewees have awareness of what other needs were required from them but who needed the information was not that clear, see Table 8.

	How do they communicate	How often communication is needed	How often do they have following up meetings	Who do you collaborate with in following up meetings	Who needs information from you and what.
Logistic	Communication plan, meetings.	Depends on the stakeholder, every two weeks or weekly	Once a week	Mainly Purchasing and Technology	Logistic at the plant: how many new parts, when they will come, where to store. Production: when parts are available Quality: when parts are available and bring them to measure
Assembly/Fabrication	Email, Teams	Depends, but every day during the builds	Every day during the builds	Technology and Construction, Logistics and Assembly	Staffing situation
Quality	Meeting phone calls, a lot of mails.	Depends, not so often on regular basis more in cluster	Not so often	Product owners, Buyer and Supplier Development Engineer, Design Engineer and hopefully Assemblers and QA department.	Is the material any good, is it approved, is it not approved, why is it not approved

Table 8. Operations communication and collaboration

The summarized view of how they communicate and what differed a bit is presented in Table 8. One interviewee communicated mainly through project meetings that were between Technology and Operations, with Purchasing it was mainly following up about new parts. The interviewee had weekly meetings with the other departments and functions involved in the project. However, another interviewee only got information provided by the technicians. The third interviewee communicated with Technology and sometimes with Purchasing by phone. All three interviewees perceived that the communication and collaboration worked well between the departments. One of the interviewees thought it had improved during the last year since "… *it's been easier now to share information and also I think we at Operations are more mature now, to demand and require different things early in the project. And also, this with Teams and so on makes it easy to share, share the same information to many people at the same time."*

Some problems that were brought up were regarding not getting information and having different perspectives. One interviewee mentioned that they needed to chase the information in order to perform their tasks, as the interviewee said "... it can be frustrating that you have to reach out to people to get the information that you expect to be given to be able to perform your task," and "Sometimes information is missing and doesn't reach the end customer." The interviewees mentioned that people can have different perspectives or different views on how to solve the problem and this can sometimes cause discussions. Another common discussion was regarding time, as one interviewee mentioned "Time is often a substance for conflicts because from a product owner perspective and purchasing perspective you need to be finished on time. And time and quality do not always walk smoothly ... " Sometimes activities needed to be rushed through in order to meet the deadlines. Similar to the different perspective of time was that some interviewees perceived that both internal and external people have different expectations or that they were unclear, as one interviewee said "...sometimes there could be misunderstandings and so on, maybe unclear expectations..." Another interviewee agreed and thought it could be connected to seeing the bigger picture, the interviewee said, "I would say that it is connected to understanding and the knowledge, being able to see the bigger picture of something." It was only one interviewee that perceived that there exists bottlenecks and it was regarding emails and meetings with no obvious contact. If the one that sends the email or hosts the meeting expects something in return it needs according to the interviewee to be "... clear, it needs to be stated, it needs to be addressed to a person not a function," otherwise nothing will be done.

Information loss

Since it could be miscommunication sometimes, two of the interviewees perceived that it could be some information loss, as one interviewee mentioned "*I guess it happens that there is information that is not available and not shared, and normally we notice afterwards.*" Meanwhile one interviewee did not perceive that there was any communication or information loss. All the interviewees from Operations perceived that it exists in different cultures both location wise and department wise. However, it was not causing any problems.

All the interviewees from Operations mentioned that the communication was mainly through different platforms such as Teams, especially in these days with COVID-19. In normal circumstances they communicated more face-to-face but still had some digital meetings since Volvo CE is spread out location wise.

Push or Pull

The communication is perceived as both push and pull driven by the interviewees, one interviewee mentioned, "Sometimes it is push and sometimes pull, it varies a bit between them." They all agree that it should be more pull driven, as one interviewee mentioned "...actually it should be a pulling flow." However, one of the interviewees argues that somewhere it needs to be pushed in order to create a pull system, the interviewee says "...sometimes you need to push to start pulling."

The interviewees mentioned that there were different people that have the authority to take decisions on different levels. However, it is the steering committee that are the decision makers, they make decisions on moving on to the next gate, as one interviewee mentioned "when it comes to budget decisions or solutions overall level then it is the steering committee." Meanwhile, on a more detailed level one of the interviewees had the mandate to make decisions, as the interviewee mentioned "I can make decisions on: what task should we do and what order and so on." In regard to projects two of the interviewees did not have the mandate to make decisions, as one interviewee mentioned "I do not have it mandated then it is the project manager and construction," and the other interviewee said "But, there is different people for different decisions, I mean it could be buyer, it could be the SD, it could be the project leader, project manager." One of the interviewees brought up the importance of having a superior that could make the final decisions, since it was often that different functions have different opinions on which way to go, the interviewee said "So, for instance if a SDE or buyer or project buyer would like to have two different decisions then you need to have someone who can make the final decision should we go this way or that way. And I think that is important too, but otherwise you will end up in discussion in each topic and situations like my dad is stronger than your dad and stuff like that."

Culture

In regard to if there were differences in culture the interviewees agreed that there are differences depending on the people's background, location, and way of working. One of the interviewees said, "Not sure, I mean we are different plants. Yeah, there are some different cultures, try to handle this by having the same process and having this communication plan and so on. I think that's how we do it" while another interviewee stated, "We are different people and come from different cultures and so. We are different, we are a multicultural factory or company, so of course it could cause some confusion, but I have not seen many of those cases. I think it is something you need to deal with, then it is hard to see in general how to solve it." Lastly, another interviewee described the culture problem with an example: "So I mean if we take the QA as an example, I mean there is a QA department in Arvika and there is also one in Hallsberg, one in Eskilstuna, one in Braås. And they do not work in the same way and that can sometimes be a bit tricky to manage, because you are used to something and expect something and then you get another thing. And that could make the work situation heavier or easier, it depends." The interviewee meant that the culture seen as different ways of working can vary even in the same functions/departments depending on the physical location but the same interviewee also pointed out that the culture can also vary depending on if the people are introverted or extroverted, the way the communication flows changes, as this person said, "I would say that the base, the working base culture between departments are, I think they are aiming to be the same, to be best practice sharing and so on but there are different people working and different people sharing in different ways. I would say it is more people related then department related at least from my point of view it is."

Standardization

In regard to standardization, they all have a positive view. One of the interviewees felt that the standardization has improved because of the digitalization and the COVID-19 forcing them to work from home. This person stated that "We are sharing more information to more people now and more frequently." Two of the interviewees do not see any problems if the information were standardized, but one of them was concerned about what type of information that could be standardized and that would depend on the content. The general information was not seen as a problem by the interviewee that only saw benefits. The benefits the interviewee brought up were "it is recognizable no matter what project you are in or no matter who presents the project information." However, the detailed or pinpointed information and questions were seen as hard to standardized, since these often require a lot of discussions.

L-350 project

The interviewees from Operations had some different perceptions regarding the L-350 project. One of the interviewees was mostly involved in the B-build or prototype buildings and was therefore only able to describe that working procedure. In this part of the project, they work a lot with screening and the aim is to identify problems with the design, parts and so on. When the screening is done, they conduct a P-FMEA and lastly, they do the prototype build. When the build is done, they evaluate and write the Product Criticism on things that need to be improved. Another interviewee described it as *"There is a lot of mail going back and forward."* This person perceived that the L-350 was complicated since it was hard to know which person to contact and that there was a lack of information sharing to the support functions. The interviewee mentioned that *"it required some digging from my site to get the proper information on why it is, and do I need to change something to get the expected result in the project,"* and *"as a support function, if I have something to ask or pass along information that is directly related to the part there should be...I wouldn't need to search for the proper people to speak to."* So, the opinions are diverse depending on the role the interviewees have in the project and their own experiences, but it can also be concluded that the information shared in the project differs depending on the roles and functions.

5.2.1.2 Technology

In this section the answers from interviewees that work in Technology will be presented. The section is divided into first describing the working procedure, followed by the communication and collaboration between departments, what makes them proud, standardization and lastly, responses in regard to the L-350 project are analyzed. In Technology a total of nine interviews were done including people from different functions.

Working procedure

In this section the perception of the working procedure in Technology will be presented. In general, the Technology department follows a more complex model than the PSM flow used at Operations.

They follow the Volvo CE Project Model shown in Figure 46, which includes product development phases, gates, and project decision points. The model has four major elements or value streams: Knowledge Management, Product Development, Technology Development and Project Portfolio.



Figure 46. Volvo CE Project Model - Technology

Since Technology is such a huge department there were a lot of different opinions in regard to the working procedure and the information process. Those that were heavily involved in projects had a hard time explaining the process in a short and consistent way, meanwhile those that act as a support function for the project had difficulties explaining the process. In general, they perceived it as a cross-functional collaboration work, one interviewee mentioned that *"it is really important to support each other in different processes. Due to that, I know about my processes, the design engineer processes but I am not really skilled in operation processes or aftermarket processes and therefore it is important to have a dialog between each other."* The collaboration for most of the interviewees that was heavily involved in projects mentioned that *"if there are no project no real reason to have the contact, but we have a lot of projects so that is quite a natural way."* So, the working and information procedure occurs mainly through meetings in relation to projects otherwise, no collaboration or communication is needed.

One interviewee had the main task of gathering information from the rest of the organization in order to process the information and from that construct plans, road maps and give advice on what direction they should move towards. This function did not have many actual deliveries except as the interviewee stated that the role was *"to be some kind of glue in between all other functions and*

departments in the company for wheel loaders." Another interviewee's role was more to gather all the project managers and together share information regarding different projects. This person also has the responsibility to report to the steering committee when they need to pass gates in projects, the interviewee confirms that they have "gate-based Waterfall project, that's a collection of milestones we commit to perform during a specific time. Complete the gate before starting the next gate," and "We work according to the GDP global project model that we used within Volvo." When they communicate with the steering committee, they have a standardized way of working with information and communication in terms of standard reports, presentations etc. The interviewee stated that all project managers within Technology and wheel loaders had created a standardized form of presenting projects' related information to the steering committee.

In the wheel loader functions within Technology, they have a lot of specialists where the information/data they produce is crucial in the projects and their way of working differs from other departments and functions. One of the interviewees stated, "It's a little bit like we have small silos here that we work within, the way out is over to some other department but in the same project. We have less information sharing within the team."

As mentioned before, the support functions had a hard time explaining the working procedure since they are mainly involved in the end of the project. In the start they are just contacted in order to deliver for example the failure rate on parts numbers. The contact is mostly through the project leader. In general, it can be said that the working procedure varies depending on the function, role, and level of involvement in the projects. Some functions are involved in many phases or stages while others are included only in specific ones and/or are seen most as support functions, and therefore miss the holistic view of the working procedure.

The general answer on the timeliness of the projects was that it depends. It was depending both on the complexity of the question and in what stage of the project they were in. Another factor was which department or function that asked for the information. If it were for example Assembly or Fabrication, they get responses within hours or maximum 1 to 2 days, if it were from another function in Technology, it could be within 3-5 days depending on the question. It was also mentioned that Operations had higher demands on getting answered within a shorter time period due to not holding the production. One of the interviewees mentioned that it is important to sometimes prioritize the questions in order to answer the most important question, the interviewee said, *"it's the need to understand and prioritize the information."*

Most of the interviewees did not perceive that there was any unnecessary waiting time except for four of them. One interviewee perceived that they spend a lot of time just waiting for data, this person was heavily involved in projects and often had quite a few projects at the same time. Another interviewee mentioned that *"it could be that some people are not working with these project things full time, they have maybe more than one project, so if they are working with several projects they do not have time to work it though,"* and therefore there was some waiting time. One interviewee perceived that they from time to time needed to push in order to get the documentation

because they had a need to start working early in the process, but they did not get the needed information in time. Another interviewee pointed out that people's needs for socializing should also be taken into consideration and influence the waiting time "sometimes it is a need for that as well and to be maybe not always be fact driven to have more of a social interaction as well" the interviewee meant that some prefer emailing and interpreting the information by themselves while other people prefer meetings, groups discussions, etc. "So, it is important to understand that we all have different needs and to take on information and do something good about it."

In the following paragraphs, what is necessary to have and not is presented. In general, they agree that most of the data/information they request are necessary. One mentions that they do not use all the information they have when building prototypes, and this was seen as a waste and this person spent a lot of time transferring data from CAD to CAE. The interviewee thinks that everything is necessary but something that could be improved was to be able to delegate some of the simplest work tasks so that the interviewee could focus on more difficult tasks, "one way we can do this better is the other way that I distribute CAE data to the designer so he can run the simpler simulation at his own desk, that would be better than we do it now."

Three of the interviewees perceived that it was a lot of repetition in different contexts, one of them did repetitive analyses over and over again with a little bit of different numbers. Another mentioned that *"it is a lot of following up, do we keep the time plan, do we deliver as promised and so on and what are the expectations from different people delivered,"* he perceived it like *"baby sitting to over and over again explain why we have to deliver on time and why do we have to deliver to a certain quality to me that's a waste of time,"* this should be clear from the beginning. The other interviewee perceived repetition in explaining what information was needed for this function, the interviewee said, *"It is maybe that we need to bring up what we need in all projects, maybe that needs to be known beforehand exactly what should be supplied from the project side."* In general, the interviewees from Technology did not see anything that could be removed.

Some of the interviewees perceived that some meetings were time consuming, especially the more top level the meeting was. This was because often in those meetings there was only a small amount of information that concerned their role but at the meeting, they had to listen to all kinds of information which was seen as unnecessary. Meanwhile, there were some that perceived that all things they were involved in were necessary and there were no unnecessary steps.

There are a lot of things that could be improved like meetings, exchanging graphical or geometric data, creation of reports, the early warning team, and requirements. There were three interviewees that mentioned the need of improving the meetings in terms of preparation, focusing on what they could solve now, base the decision on facts and be less speculative. It should be stated beforehand what the meeting will be about and what question or goal that should be answered, so that everyone can prepare. In regard to exchanging graphical or geometric data there was one interviewee that perceived that this step could be much more efficient. The interviewee that reports to the steering committee felt like those reports were very time consuming and needed to be improved. In regard

to the early warning teams one interviewee mentioned that those are often finalized too early, the interviewee stated that "The early warning team steps could be improved, because it is finalized too early normal 3-6 months after start of production, but it takes longer time for the machine to reach the end customer, so when we run we could perhaps in the end have 10 machines at the customer and that doesn't give us much information it should be longer." The last improvement was regarding the requirements, the interviewee mentioned that "The requirement work, maybe is not the best company in handling it, so an easy, structured way of handling requirements and understanding the requirements could save time later on. For example, if you have misunderstood a requirement, you design it wrongly. It is time consuming at the end to fix it only because you have misunderstood a requirement."

There were different opinions about what was the most valuable for the interviewees. One interviewee said, "the most valuable or critical part is to make proper adequate conclusions, for example measurement or simulation to explain in a way that design engineers can understand and take action on it" and another stated "of course all project internal information sharing" which is similar to another that said, "I should say those more informed meetings in smaller groups, you solve a lot and get the project running smoothly." Three of the interviewees mention specific in the working process the technical readiness level, early warning team and pack meetings. The technical readiness level is a checkpoint to make sure that the parts should achieve a certain level of technical readiness, it is important to focus on this in order to smoothly move on and avoid problems later on. Pack meetings are cross-functional meetings where they meet and discuss different solutions, the interviewee argues that this is valuable since they get "a picture both from Operations, how they want to assemble the machines and also our needs that you need to service the machine as well later on." One interviewee expressed that the most valuable thing is to meet people face to face. Furthermore, one interviewee answered "I guess alignment on a lot of levels on a lot of information. As I mentioned before, what are the purposes of the project, what are the targets, when to deliver, so alignment on that is of course crucial." For another it was rewarding when the interviewee saw the result of everybody's hard work.

Communication and collaboration

In this section the perception of the communication and collaboration between departments from people working in Technology will be presented. Most of the respondents communicate with a lot of different departments and functions, see Table 9. In Table 9, the summarized view of how they communicate, with who and what information do others need from the interviewees are presented. The collaboration for most of the respondents was on a weekly basis, where demands to be solved are brought up. One of the interviewees that was heavily involved in projects mentioned that *"if there are no project no real reason to have the contact, but we have a lot of projects so that is quite a natural way."* So, the working and information procedure occurs mainly through meetings in relation to projects otherwise, no collaboration or communication is needed. The collaboration with other teams was mostly through project participation and that was the main work task for some of the interviewees. This means that some of them collaborate more with other teams than

with their own team, as one interviewee said, "I talk with the powertrain installation person on another team more than I talk with persons in my own team." The collaboration takes place mostly in digital forums such as Teams or Skype, see Table 9.

	How do they communicate	How often communication	How often do they have	Who do you collaborate with	Who needs information
		is needed	following up meetings	in following up meetings	from you and what
WLO Mechanical and Simulation	Nowadays it is 95% over virtual channels. Before COVID-19: walk around 7-9 km every day, communication was while walking or standing up (physical).	Not every day, a few times a week.	Once a week	Mostly with the Powertrain installation and Testing team department.	Simulation reports and insight on how to design the machine, provide information to make decisions.
WLO Product maintenance & NPD	Teams' meetings	All the time	Everyday	Everyone, project managers from all the departments	Align and make sure everyone have the same picture
Powertrain Installation R&D	Teams	It depends, mostly on a daily basis	Not involved in the projects, only if major problems occur	Not involved in the projects	Sharing information through Design Review
AH Engineering, VPD Calculation engineer	Teams or Skype meetings, emailing, reports	All the time	Weekly basis	All departments, mostly Product Platform, Powertrain installations, Exterior and Structure (engineering area)	Expertise information, calculate complicated things, second opinion, verify the design
AH Engineering Design Enginer	Digital	Pretty often	Once a week	All departments who are involved in the project. In NPD one guy is pinpointed for wheel loaders	How the frames look like, understanding of what we do and why
GPE platform	Worst case at the coffee machine, best case mail., meetings.	All the time, constant iteration	At least every week, during builds daily meetings	Everyone, mostly within the team (hydraulics, electronics, software, chassis and so on) project management meetings: market, aftermarket, operations, purchasing and technology.	Gather all the information and communicate how needs to do what in order to improve, do roadmaps, what needs to be improved. Everyone receives the information, but Technology is the main receiver.
UPP Uptime & Quality (Product Maintenance)	Digital meetings	Not so often	Once a month	Technology, Production and Regions. Main	Claim and statistic data. Mainly

Table 9. Technology communication and collaboration

				project leaders sometimes Design Engineer. Later on, the early warning team	Technology and Production
UPP-Diagnostic & service engineering	Digital meetings, before meeting up people that was located in the same area.	All the time, mostly in the early phase	Weekly	Not involved, it is the project manager for aftermarket	Operator's manual for production plant, different reports to project team e.g., maintainability report.

A majority (8) of the interviewees perceived that there was no clear work procedure, if they think they are moving in a direction that is not good they take actions but how to do it is flexible. One interviewee that was not heavily involved in the project perceived that they have a clear working procedure, the interviewee said, "We have processes in our Common, it is called, and there we have the design process, and you can, from there, go deeper into different areas in the project." However, they perceived that the communication and collaboration worked fine, and they trust each other's competences especially in the L-350 project, as one interviewee mentioned "I would say in this project we have a really good, good culture and good discussion. And a lot of solution focus and not really much prestige or protecting your own area, So, I would say it is working really good."

There were according to some interviewees a difference in the way of communicating with other departments since people have different responsibilities and perspectives. As one interviewee mentioned, "Operations are used to one kind of delivery culture and most other departments have other cultures." This view was not shared by all, some interviewees did not perceive that it differed at all. The interviewees had also different perspectives on who had the mandate to make decisions, some perceived that everyone had the mandate while some perceived that one had the mandate or that it was unclear. As one interviewee mentioned "Everyone, we make different decisions, and if you are uncertain you discuss with colleagues and sometimes, we escalate to our manager. We have an autonomy that is quite high. If you feel confident with the thing you have on your desk or the thing you want to say or do you can take the decision," while another interviewee said "That's a problem no one actually, no single person can make a critical decision is about to happen is that for example in my role I get the same question or similar question from 6 or 7 different persons then I know for sure that we are about to make a decision."

During the interviews there were some problems with communication and collaboration that were brought up such as getting in touch with people, misunderstandings, work overload and delivery precisions. One interviewee mentioned that some support functions could be hard to get in touch with since they were not bound to the projects. Similar to this was regarding the work overload that some functions had this caused problem with availability and prioritization, one interviewee mentioned that the bottleneck was "...peoples' or colleagues' availability, it doesn't matter if it's phone or chat or mail the availability of my colleagues is not as it should be, also my own availability, I am usually red on the status board, too many meetings." The high workload could also be due to the fact that some people are involved in several projects, the more projects the more communication you need to have, and it could affect the delivery precision.

Regarding the delivery precision one interviewee mentioned that it sometimes could be hard to prioritize between accuracy and good enough level. The more accurate the information needed to be the more time it would take; it was therefore important to have this in consideration when planning the projects. Another interviewee agreed and mentioned that "...delivery precision and delivery quality are the most common discussions or disagreement and lack of communication."

Another interviewee brought up that it sometimes could be misunderstandings in for example meetings, and the interviewee mentioned the importance of "...choose the right way to communicate. Some things are good to have documented for picking up later." This interviewee also perceived that sometimes there was a lack of communication and/or information sharing, this was according to the interviewee because of "...people are a bit scared to share information, it's many that don't think that someone else is interested in what I have been doing." A way to avoid misunderstanding or lack of communication is according to another interviewee to use the design reviews, the interviewee mentioned the risk of not sharing the information "...when we are the design department, and if designers are working by him or herself within one component with one system, within one area and do not spread the information about it and when the designer have finalized and thinks that this was a really good thing and then tells the other departments about it and we have lot of interference then of course we can get into problems." Another interviewee mentioned that they do not have the same information and therefore it could be hard to know which has the right one. To conclude, it is therefore important to share the same information between both internal and external departments and functions.

One interviewee perceived that they changed the processes so often that therefore the system will not reach maturity, the interviewee mentioned "*I think we tend to change processes so often, so we do not really develop a system for communication in a good way. So, problems identify so we change systems all the time but really, we do not let the system mature to be functional, so we rather change the system again and then we square one, again.*" This was causing some frustration and the interviewee perceived it as a problem.

Information loss

Overall, there seems to be low information loss in Technology, most of the interviewees perceived that the communication and collaboration gave them enough information. If they missed information, they were aware about the most common solution was to call or visit in order to fill in the gaps. One interviewee mentioned that it could be information loss in bigger meetings, as one interviewee said, *"in a meeting where we have more than five or 6 attendees, we lose info*

between the lines so we either have a new meeting to fill the gaps or individual talks on the side." The information loss was more on the project level than on the project manager level as one interviewee mentioned, "I don't think we lose so much in the project management team but in a project with 2-300 people there is of course not everybody reaching all the information." It is therefore important to work together and take time for the communication as another interviewee mentioned, "Take time for the communication and information, so repeat, sit together, talk with each other and so on. So, yes of course we have, we are missing something a lot of times and to work with that takes time."

Some interviewees mentioned that some information loss could be due to the fact that they are located in different cities, then they missed the face-to-face communication, as one interviewee mentioned, "If we could have R&D and the factory in the same building then I think we could improve a lot of things, due to the human face-to-face meeting is the most efficient information flow when you can have a dialogue instead of sort of monologue or something like that." However, the interviewees were aware that this was not a possible solution. One interviewee brought up that it could be hard to know if there was any information loss since Volvo is a huge company. Maybe someone in another area could have information that you are not aware exists but could be valuable for you to have. Similar to this another interviewee mentioned the importance of storing the information in the common Team places in order for everyone to have access to the documents. What is important is that demands are clearly stated, according to one interviewee "If our demands are really clear then it is easy to find an answer. But if our demands are unclear, then I do not know really what to do and then there will be even more loss of information or bad communication with other departments."

Push or Pull

The interviewees from Technology had different opinions regarding if the communication and collaboration was pushed or pulled. One interviewee perceived it as a pulling system and the interviewee preferred the pull system over the push. The interviewee also mentioned that "It is quite a pull they want our answers, but we could try to do that even more." Three of the interviewees perceived that it was more a push system and thought that in their positions they needed to push, as one interviewee mentioned, "I need to push so I have the answer before I go to project and tell them this is our solution. So, I need to push other departments to give the information to me." Some of the interviewee said, "Both, I think it is, it is both directions. I could feel that it's become more and more pull driven which I see is good, that we are asking for help, asking for collaboration, asking for solving things together, so."

Culture

To the question regarding if there were differences in cultures most of the interviewees (8 of 9) responded that these exist. Some of the interviewees referred to internal differences between the

different functions within Technology depending on different factors, for example one interviewee said, "most of the members in my team are very analytical mindset, they are very fact based, they think before they talk and that is a big difference compared to most other teams. Most people are highly educated, most are PhD or similar, so we have a special type of communication. That's different from other teams." Another one said, "we are working differently in Eskilstuna and my department compared with my neighborhood department. We have differences, we have things that are in the walls that are different and so on." But most of the interviewees referred to the differences in culture between different departments that we called external differences. The interviewees meant that there are cultural differences between Operations and Technology since their pace and way of working is different, these results quite naturally in different cultures as one of the interviewees said, "We are different. I think if you work for Product Development you think of things in larger cycles, longer lead times, but if you work in production, you are really problem solving oriented, if you have a production that has stopped you need to get it started today and if you ask me the question, I will think it for a few days before even start to calculate it." Another interviewee mentioned that cultural differences can emerge depending on the national location of the department which is not strange since different countries have different cultures and this fact is reflected in the company culture, as one of the interviewees said, "we have a lot of people helping us in Wroclaw from Poland. And they are involved in the project but in the project meetings...only the lead engineer is acting, and the lead engineer is translating the information to these guys and in that case, it could be information loss or communication loss. And of course, we have different mindset or culture in other countries of course we have." Finally, some people attributed the cultural differences to individual differences and not to departments or functions, as one interviewee said "some differences there are of course, but it is more down to people and maybe not departments, but of course some cultural differences there are more down to people." and another person stated, "I think when you work in a big company you will always have people that are not as open minded to new ideas and have the willingness to improve things. There are differences. We are trying to overcome them, but it comes back to people, depending on different people it could be different how open minded you are."

Proud

In regard to what makes them proud, there were three people that talked about feedback, both to give and to get feedback, internally and externally that made them proud. Some were talking about when they solve problems together, for example: early warning team, assembly test or how to service the machine. One interviewee said it was when "we can create a really clear decision, clear information towards each other, if we could have a communication package or if we could just have a call via phone that we are really clear towards each other. And what I say or show in my PowerPoint and so on will be taken exactly the same as what I say," so information is clearly understood and not interpreted in any way other than the correct way.

Standardization

In the Technology department there was a mixed feeling regarding the standardization, most of them thought it would be good to some extent as long as it did not hinder them to be creative. One interviewee mentioned that it could be hard to standardize since all cases are not the same and if the information does not fit in the standardized forms there is a risk that the information will be lost. Another had similar thoughts and pointed out the risk of not being able to step out of the box, the interviewee said that "*The problem might be that if you take the standardization too seriously that you cannot step outside the standard form. Because every day is different and every time there is a different need for information and information sharing. So, for me parts of it are the same often, but still there needs to be a freedom to go outside that and be able to prioritize."*

Some benefits with a standardized system that were brought up were that it could "simplify, you know what to answer, you know what to search," and "it is easily recognizable, it doesn't take that long time to understand the plan because it is familiar." When it is recognizable it will be more efficient and take a shorter time to understand the information since it is presented in a familiar way. One interviewee mentioned that standardization is especially beneficial to use when time plans are presented, quick information and reports are other examples where it is beneficial to standardize the information. One interviewee argued that standardization is a must in order to get people to work in the same way, the interviewee said, "I think there needs to be a system that forces people to do things in a certain way otherwise it will be done differently."

L-350 project

The involvement in the L-350 project differed a bit even in the Technology department and therefore the ability to describe the work procedure in the specific project differed as well. One interviewee from a support function was only able to describe it as collaboration "mainly through email, Skype or Teams calls from the one that needs my help, I think we have some delivery but deliver them on demand from other persons." One interviewee that did not felt a part of the project since the interviewee only reported to a project manager described it as "a typical project, running like old-school with different phases, different checkpoints, there is a project manager," this person supports the designer team with calculations and is more involved in the end of the project where they have discussions together with Arvika about manufacturing and assembling the product.

Most of the interviewees explain the work procedure as a lot of meetings and emails that in the end become reports or final product. Another interviewee had only attribute responsibilities which means that this person gives advice to the project team after having listened and read what is ongoing, mostly the Design Reviews. The meetings inside the project team are weekly, in the project managers' meetings they have a standard agenda where they share general information from all the project management teams. According to one interviewee there is a bit different information depending on if it is a project manager meeting or a steering committee, the interviewee said, "It's a different type of information when it comes to the steering committee, it is more of reporting and within the project management team is more to work together and coordinate and have all the different managers aligned regarding the objectives of the project." Another interviewee described it as they "inform about our needs quite early in the project and also supply requirements to the project and request which documents we shall have," in some cases they proofread the documentation they have requested with help from Design Engineers, this is done as early as possible before they are released in the different status. Furthermore, the interviewee explained that "mostly there is input given to the pack meetings verbally I would say."

5.2.1.3 Purchasing

In this section the answers from interviewees that work in Purchasing will be presented. The section is divided into first describing the working procedure, followed by the communication and collaboration between departments, what makes them proud, standardization and lastly, responses in regard to the L-350 project are analyzed. There were three interviews with employees that mainly worked with Purchasing and one that previously worked in another department that answered some questions regarding the interviewee's role in Purchasing.

Working procedure

In this section the perception of the working procedure in Purchasing will be presented. The working procedure regarding the information flow in the Purchasing department differs depending on which role they have. Some of the interviewees did not feel like they were a part of the NPD or the project, they were standing on their own relying on information from the purchasing project manager and the system itself. One interviewee said that "We have our own project managers to report to, so to say, not apart from the NPD itself," and, "So to a big extent we rely on the system for that part," and from another function in Purchasing, "I am not so involved in the project process, the buyer process is on its own." Meanwhile, another interviewee would describe the working procedure as "A lot of interaction and collaboration from the beginning of the project everyone is feeding in information, so communication and collaboration is the baseline for our work." This person experienced involvement in the project and that a big part of his work was to communicate with other people both intern with other departments, and extern with suppliers.

The working procedure also differed depending on the part itself, if it was a simple part, it was easily solved by using the system but if there were more complicated parts there was a need for collaboration and communication with other departments and the suppliers. In some cases, they involve the supplier even before the part is designed and in other cases, they involve them later on if problems occur. This was the same for all the four employees working in Purchasing. One of the interviewees mentioned that they were depending on the information they received from Technology in order to perform their work and that process could take up to three months. Another interviewee mentioned that *"We get information on a regular basis once a week from the specific*

project, that's the information I get," this employee was more dependent or received all the information from the Purchasing Project Manager.

The most time consuming for employees in Purchasing seems to be the work itself, with all those parts that need to be sourced, quality secured with the right cost and delivered on the right time. Also, the department is spread out throughout Europe and therefore it is time consuming for one of the interviews to reach out to all with more or less the same information and get a response in a decent time period, so the setup of Purchasing is complex. Another interviewee confirmed this, but also reflected upon if it is a key component or not, the interviewee mentioned that "our part in all of this is to run the APQP and PPAP. And I mean if it is a key component then that is time consuming definitely, if it is not a key component not as time consuming. So, it varies I would say depending on, yeah the type of parts you manage." From the Purchasing site there was nothing that could be removed from the process, they had a good system in place to support them. What could be frustrating for them was not getting the information needed or requested on time and therefore Purchasing needs to catch up with the delays. Furthermore, the most valuable steps were considered the face-to-face meetings for one interviewee and the APQP for another. The APQP is conducted together with the Quality function, and it is according to the interviewee "to make sure we quality assure the parts in a proper way."

One person experienced "some frustration, some information tends to take very very long time depending on workload," since they are usually involved in several projects at the same time which makes their workload very high, the interviewee also mentioned that currently there could be up to five or six projects at the same time. Another expressed that "Yes, you can say that I need to wait, it could go a very long time before I get any information at all and then all comes at once." This person experienced that sometimes the information comes late and that in general there is a lack of information about the project itself.

Communication and collaboration

In this section the interviewees from Purchasing's perspective on the communication and collaboration will be presented. The interviewees perceived that the communication and collaboration in general worked well, and they had been improved. In Purchasing it is common to communicate and collaborate cross-functionally and with different functions, see Table 10. As one interviewee said, *"We have a very very close collaboration between most of the departments, especially with Operations and Technology I would say."* Two of the interviewees communicated very often with other departments while one only did it when problems occurred, see Table 10. The most common to have them face to face, nowadays it was on Teams. Who they collaborate with, as well as who needs information from the interviewees can be found in Table 10. They all agreed that the working procedure was clear. The communication and collaboration did not differ according to the interviewees from Purchasing, one interviewee said it was because *"...my contacts are located in Arvika, and I am working there."*

In Purchasing everyone is entitled to make decisions if they have the information needed, but it also depends on what type of decision, as one interviewee mentioned, "I would say within our area and responsibility we have the full mandate to make the decisions in some cases with input of course from other functions as well." The buyers and supplier developers have the mandate to make decision needs to escalate to a higher level.

	How do they communicate	How often communication is needed	How often do they have following up meetings	Who do you collaborate with in following up meetings	Who needs information from you and what
PPD Project Haulers & Wheel loaders	Meetings, normally face to face, now by Teams.	Daily basis	At least two times per week	Cross functional, every one that is involved in the project (Operation, Technology, Purchasing, Aftermarket, Marketing and Lounge)	Operations: when they can expect deliveries of materials Aftermarket: contract situation what they are allowed to do with aftermarket, to parts, to what extent we can offer spare parts to customers. Technology: information about cost on specific parts.
Buyer	Mostly email or Skype/Teams meetings. Before covid some face to face meetings	When something does not work e.g., suppliers cannot reach requirements or when the tolerances are not possible to achieve from a drawing.	-	Suppliers, Design Engineer, Purchasing Project Leader, Manufacturing Engineer, Quality and SD.	If problems occur or cannot meet delivery time. Mostly construction and Purchasing project Manager.
Supplier Development	Email, teams, phone, physical meetings normally but not now.	Most of the time to some extent	Cannot estimate, not every meeting	Everyone	Purchasing Project Manager: Need to know when part is proved, Technology: To make sure the design engineers are aware of the supplier capabilities

Table 10. Purchasing communication and collaboration

One problem that was brought up was that people see things from different perspectives, the interviewee mentioned "You can see on the same task with different eyes, for one department it could be crucial, for one department it could be nicer to have, but we can do it a bit later so that
might be a conflict. "The fact that purchasers are spread out does not make this easier, since people can be occupied with other things, and you cannot just walk by their office to get an answer. If something was urgent, they sometimes struggled getting in hold with the proper person. Another problem that was brought up was the timing, some of the interviewees perceived that information was delivered too late, as one interviewee mentioned *"Historically one big thing has been that things are delivered to purchasing too late so to say, not within the planned timeline."* This has improved a lot during the last year since they are involved much earlier in the projects and also involve the supplier much earlier. One interviewee felt that they sometimes received too little information, they needed more information when they contacted the suppliers than they got, the interviewee mentioned that they have to *"So you might need to ask for complementary information and documentation."*

Two bottlenecks regarding communication and collaboration were brought up by the interviewees, dependency and finding information. One interviewee mentioned that a bottleneck could be built up if there was a lot of dependency for one issue that involved many people in many different functions. Finding information in the different systems was seen as a bottleneck since it could be tricky to know where to find the information.

Information loss

In Purchasing information loss did not become a problem. Some of the interviewees perceived that there did not exist any information loss at all. However, one interviewee perceived that it could be some information loss in for example *"if they found out something in Operations in Arvika for example, they have a really clear picture of the problem, but then they need to transfer the transcription to us at Purchasing in Eskilstuna or Technology. There you can lose a lot of detailed information."*

Push or Pull

The interviewees had different opinions regarding if the communication and collaboration was push or pull, one perceived that it was both. Meanwhile, one interviewee perceived it as push and another pull driven. One interviewee mentioned, *"You would always like to say pull and in some cases yes, we definitely have quite a lot of cases where it is pull."*

Culture

Three of four interviewees from The Purchasing department answered the question regarding their perception about differences in culture. They agreed that those existed but the reasons behind varied a bit. One of the interviewees believed that the differences in culture were more related to people and not departments, as the interviewee said "I would say it depends more …on the person than the department. So, I would not say it is not any difference between departments it is more on a difference between persons" while another person thought that the cultural differences were related to the department way of working, as the person said, "Yes there are, you work in different

ways. Purchasing has their way of working that differs from for example Production. It is more spontaneous and not so planned (Operations). It is easy to misunderstand each other, or it is information that does not get there in time." The third interviewee made a reflection about how the cultural differences can be overcome by adapting and being flexible "I guess that the main challenge for us is to adapt and adapt to the different cultures, so to say."

Proud

The interviewees from Purchasing share a similar view of what makes them proud. They mentioned that they felt proud when they succeed in projects as one of the interviewees said, "I would say when you have launched the project successfully and you start getting some feedback afterwards from the project," and when they had close collaboration and communication when problems occur, it is in the smaller teams and with experienced people that the best information exchange occur, quoting some of the interviewees "The information and communication I have with construction, production technician and supplier where we work in a team, there we have the best information exchange, quality is involved as well as we have been working in the 350 project" and, "We have a tight communication, full transparency, if I have a problem I have no problem sharing with other Project Managers from the other functions. So, it's easy to reach out to the other project managers in the project." Furthermore, two of them were proud of being a part of the L-350 project due to that the involvement was higher from the start and that they have had consistency in terms of same experienced people working in the project, one of interviewees stated that "I am a bit proud of being a part of this project since it started. I think it is a very very good idea to have experienced people and be consistent in the project. You are not moving around people in the project, like this constant re-organization so we have been able to keep the same project team as the previous project, so we are familiar to each other."

Standardization

Regarding the standardization of the information and communication process, one of the interviewees stated that "we do have standardized communication as well within the milestones we have standardized templates to work with," while another one felt that "It feels like it is something we need that is missing today, we have no standards regards to information." Another one mentioned that "there is more to do in that front definitely." Therefore, it could be concluded that there are some diverse opinions about the standardization that exists today, this can be due to the fact that they are working in different functions and have different ways of working in these functions. However, they all share the same view about the importance of standardization, one interviewee said that "I believe it would be good if it is standardized because then you would be comfortable and recognize the information, it would be more easy and I would not have to search for it." and another stated that "So standardization is very very crucial, so you are not inventing your own kind of communication templates or different kinds of channels, so you are using the same in every project. So, standardization is important."

L-350 project

From the interviewees from Purchasing, it was only one that was heavily involved. As mentioned previously two of them are not heavily involved in projects and that was the case even in the L-350. They were involved earlier but not so involved that they could describe the working procedure in regard to L-350. One of the interviewees was working for another division during the L-350 so this response was not applicable in regard to Purchasing. However, there was one that was able to explain the working procedure in L-350 and the interviewee described it as "Start from left to right side, it starts with some kind of creation from Technology that wants to achieve something (customer feature, quality issue), technology creation, then Purchasing stepping in to find the right sourcing/find right supplier, negotiation to right cost then implementing this part through our production and operation channels". Further on, the interviewee described that Purchasing is working in between Technology and Operations in the NPD process. When they have come to industrialize and implement phases in the production, they have aftermarket customers together. Specific for this project has been according to one interviewee that "Everyone is involved in the project work in parallel rather than sequence with many functions at the same time."

5.2.1.4 Current information sharing system

This section aimed to find out the interviewees perception of the current information sharing system. Volvo CE uses SharePoint as their primary information system, but the researchers were interested in figuring out if there were other sources in use, key elements and how useful they were. The results will be presented per department in order to be able to compare those. Specific questions about the interviewees' perception of some SharePoint functions such as Product Criticism, Design Review and Verification Plan were asked.

Operations

Two of the interviewees mentioned that they have moved over to Teams and are doing it more and more. They perceived it as working well and the last year has helped them in the transition to Teams and they have become better at sharing information, one interviewee said that "we are using more and more Teams. We are sharing, we have groups in Teams and sharing information on that site." One interviewee mentioned the difficulties of storing information and making it useful for everyone. This requires that "people who should be able to read that information do have the proper skills to actually do it and I mean in a project you involve a lot of people. And yeah, different people have different skills."

Regarding the Product Criticism, one of the interviewees is the creator of it and therefore do not work with it after it is done. The other two had some different opinions, one mentioned that "*It is fairly easy when you know where to look and so on*" and the other interviewee said that "*It is very new for us, I have a little bit of difficulty*." This interviewee had some difficulties since the interviewee was not so involved in this and that it was new for them to work in.

Regarding the Design Review, two of the respondents perceived that it is working well and that the cooperation with other departments was valuable in these meetings they have in regard to the Design review. They also felt that it was easy to find it. Meanwhile, another interviewee felt that they were not involved in this, they were usually involved when it was too late to do changes, this person said that "So, yeah, basically you try to work some magic with no time-consuming actions so to say. Which sometimes could be really frustrating."

Regarding the Verification and Validation plan, the interviewees think it works well and that it is easier to handle than the other two. However, one interviewee mentioned that "but often it comes down to time, if you have proper time to verify something or validate it then of course, but if you are late in a project and you have a deadline, well those deadlines they sure will note move easily." Therefore, they sometimes take shortcuts to deliver on time. The interviewee highlighted that "from a verification and validation point of view, there is no successful shortcut, there is only luck." So, from the Operations perspective the Verification and Validation plan is of high importance and it is necessary to have the proper time to perform it.

Finally, the interviewees responded that there is redundancy in the system, meaning that the information could be stored in different places, or that they had to fill the same information more than once, as one of the interviewees said, *"We have for example the milestone we need to fill out or the time plan on at least two places."*

Technology

Three of the interviewees mentioned that they are working within SharePoint in order to store and share information. The perception is that it works well but it could be hard to find documents in there. Therefore, some of them are only uploading material that they can risk losing like PowerPoint or Word documents, but documentation that they need to prove they have fulfilled like ISO 9000 are stored in a place where they know where to find it. One interviewee mentioned that they use Teams more and more, which is connected to SharePoint, or what is uploaded in Teams can be found in SharePoint. The interviewee mentioned that *"it is different from department to department, so it is tricky to find documents in other projects or from other departments. So that could be a good thing that we have it more standard."* Some functions are using other systems like KEMS or Windchill where for example the full technical reports are stored.

Key elements for an information system seems to be searchability, that it is easy for people to find the right information, one interviewee mentioned that "It is to sort of pinpoint what's important right now and make it easy for people to find the information they need and maybe without knowing it but also when they look for something specific that it is easy to find. If they do not find it easy it creates frustration or even, they skip that step," another one mentioned the difficulties of finding information right now, the interviewee said, "Sometimes you have to search for it even if there is an impressive list of or catalogue to kind of search in and so. It seems to be structured but in reality, it is up to the person that uploads to put in the documents in the right file." One interviewee that is acting as a support function perceives that projects do not have one way to store information and think this is an issue, the interviewee mentioned, "I do not think it is one way to do it and one way to store so it is information all over the place on SharePoint perhaps on someone's computer perhaps, hard drives, hard to find and share information because you have to set up for every part of the process/protect it is a lot of email."

Regarding the Product Criticism, some perceived that it worked well and was crucial for their work, meanwhile some were not involved or were even aware of what it was. However, it sometimes becomes too detailed and as one interviewee mentioned *"It doesn't give me much guidance on the attributes I work with."* Another interviewee mentioned that *"It is a lot of points, we have around 300 or 400 points, and it is necessary, it is extremely good, it is like an action list where you know what you need to solve. So, it is a sort of reminder, so you do not forget anything," many of the interviewees think that the information stored in the Product Criticism is relevant. However, it was one that though it has become harder to work in. To conclude, most of the interviewees argued that it is a good standardized system and an easy and good way of sharing information.*

Regarding the Design Review, most of the interviewees are involved or have something to do with the Design Review. They argue that this is one of their key activities, one interviewee said, "when we have a full design that's one of the key activities, we should have more" and another one mentioned, "is one of the most important quality assurance systems." The Design Review is considered important since they meet cross-functionally to discuss and give feedback on the design, one interviewee mentioned "it is so important that we are sharing both within the department, with the cross department, cross areas to have it together with operations so they know, they can give feedback on how to assemble the parts, we need together with the aftermarket they know how to serve, how to exchange parts etcetera, etcetera."

Although it is important to mention that there were some that perceived that it was a bit unmatured and hard process, especially now when all communication is remotely. One interviewee mentioned that "I would say it's maybe a bit of an unmatured process, we do not have the same expectation of it and outcome of it, people have different views on it. People in the project might have one view and people outside the project have another view and so on," the interviewee could however see the benefits with the maturity as a freedom to use it different in different stages of the project, the interviewee said, "But on the other hand personally I feel that in the lack of maturity it also gives you a freedom to use it...different projects have different needs and different, I mean we have this several times in projects. So maybe the first time it could be maybe not that structured and so on. And the last one should be really structured and focused. It could also be a benefit that it is not that structured or matured process." The process was perceived as hard since the majority of topics brought up in the Design Review were about what is wrong with the design, not much focus was put on the good things. Regarding the Verification and Validation plan, there were three that have no knowledge about it. For two of the interviewees the Verification and Validation plan was a must in order to break down the requirements, but it is a huge work, one interviewee said, *"it is a tool that is needed within the NPD process."* The Verification and Validation plan is developed between the early pre-study and development phase when the requirements have been defined and approved. One interviewee perceived it as *"not standardized at all, just an Excel sheet where we share information."* Another one confirmed this by describing that they have a huge freedom to develop the plan for each project, the interviewee mentioned that this results in variation in quality level of the Verification and Validation plans. The variation of quality level is according to the interviewee because of *"different experiences and abilities to plan and to make good or less good plans so that affect this Verification and Validation plan."*

Lastly, all except one in the Technology department perceived that there exists redundancy in the system. The interviewee that did not argue with the others was only working with information coming from Windchill and that was almost the only place where the interviewee looked for information, sometimes SharePoint was used. Some interviewees did not see the redundancy as a problem rather as a quality assurance issue, one interviewee mentioned "sometimes it could be good also to see, just to secure, sometimes we look into the PDM system and sometimes we are looking into the aftermarket system, where we have the same information. But sometimes to see it from different views," another interviewee had a similar opinion that it was good to reuse information stored in one system to avoid starting from scratch every time, as the interviewee expressed "not try to invent the wheel every time." However, there were some that perceived the redundancy as frustration since they could not find information in an easy way. It is important to not adding to much new systems since adding a new system will mean more places to look for information which could increase the workload for some people, one of the interviewees mentioned that "to find the different reports we need to search in different systems, now we are adding a new system, that's maybe why we are a little bit conservative and do not want to add a system, adds workloads for us."

Purchasing

One of the interviewees that is not involved in projects felt that the current information system was "Very complicated and hard to find, a bit messy, maybe too many places to look for the information." and another interviewee shared the same feeling "I think that the main challenge today is that there is tons of information stored on 1000 of SharePoints - I would say one of the bigger challenges is to navigate between the SharePoints. To know where to find what, so to say." While another interviewee who was more involved in the projects mentioned that "We are using both SharePoint and Teams as communication channels. I would say that SharePoint is the location for master data, important documentation etc. and Teams maybe for easier communication, person to person communication", the interviewee did not share the same feeling that it was complicated. So, the opinions were divided depending on the interviewees' involvement in projects.

Regarding the Product Criticism there were divided perceptions, two of the interviewees were not involved in this at all and therefore had no perception of it. Meanwhile, two of the others were familiar with it, one that knows where it is stored and one that uses it and thinks it is an important part of that person's work. This interviewee mentioned that *"it shows what I need to strive and aim for towards my suppliers. And it also gives me a sort of a map of which people need to be involved to solve these issues."* Furthermore, the interviewee mentioned that *"you need a proper forum to review it in, and in that forum, it is absolutely crucial that people that have maturity to take a decision take a decision. Otherwise, there will be a lot of loose ends"*, therefore, it is important to let the right people look into the Product Criticism in the right forum so that the right decisions are taken.

Regarding the Design Review, three of the interviewees stated that Purchasing was not so involved in that, as one of the persons said "It is distributed from the Technology department/manager so when it comes to design review Purchasing is not heavily involved in those sessions I would say. Only get distributed documents from Technology leaders". On the contrary, one of the interviewees stated that the Design Review was a regular part of his work and very important "So I think the design review is a crucial part of the project and yeah you can only hope that you have the proper functions involved in a design review to take the best decision". From those statements it can be concluded that their participation depends on their roles, but it is perceived as important and that improvements have been made as one said, "I would say all of these reviews in the projects have improved significantly".

Regarding the Validation and Verification plan the interviewees answered similar to the previous questions about Design Review and Product Criticism, that they were not involved in this and therefore, had no perception about it. One of the interviews knew where to find it and sometimes used it for critical parts but it was not often.

Lastly, they were asked about if there was any redundancy in the system, since some of them did not work in other systems than SAP they did not feel that it was redundancy. However, one interviewee mentioned that they have some between SharePoint and Teams, this was mostly due to the fact that they have recently implemented Teams. Furthermore, this interviewee has the perception that Teams is easier to navigate than SharePoint and does not mind having the information stored in both places.

5.2.2 Capability

In this section capabilities regarding the information needed are going to be presented. The focus in this section is mostly on data collection in regard to L-350 but also what is interesting in the interviewees' work.

In general, the interviewees perceived that the goals for their function were in line with Volvo CE overall goal. The goals for the specific project had been clearly defined. Almost all of the

interviewees knew what the goals with the L-350 were, one interviewee that had a support function and was mainly participating in the end was not aware of the goals for the project.

5.2.2.1 Data/information collection process (in regard to L-350)

In this section the perception as well as the actual data and/or information collection process will be presented. The functions need different types of information in regard to the L-350 project and they are summarized in Table 11. Some of the interviewees were not able to answer what they needed, and they are therefore not included in the table, in total there were thirteen of the interviewees that responded. Some were able to specify exactly their needs and what and from what department while some had more difficulties, see Table 11. How often they need information, how many contacts are needed and what type of information they work with (unique or routine) are also presented in the same table.

What can be concluded is that three departments need information about the suppliers: Logistics, Quality and GPE Platform. Both Logistics and GPE Platform need the new part list, PPD Project Haulers & Wheel loaders and UPP Uptime & Quality also need information regarding the new parts.

	What information is needed	How often is information needed	How many contacts are needed	Uniqueness vs routine information
Logistics	From engineering department: the new part list or what new parts that it would be in the project. From Purchasing: what are the new suppliers or what new suppliers will be. From production: how they want the material presented, how should we supply the material	Continuously through the project.	The project group 5-6 people	Normally new and unique questions.
	to the operator .			
Assembly/Fabrication	It is hard to specify all the information needed to build this type of machine.	Daily meetings regarding B-build	Handful people sometime even more	Both
Quality	Knowledge about the suppliers and what they are capable of doing. In manufacturing and validation. Other departments' time limits. Some data or background on the design.		The SDE, the purchasing project manager and the supplier.	Information that already exists

Table 11. Data/information collection process (L-350)

WLO	From powertrain installation and the other one is from the product owner side,	2 times a week, every other day	The core between 5 or 10 persons, sometimes a dozen	Mostly new information over routine
WLO Product maintenance & NPD	The business opportunity document from marketing	All the time, every hour	As many as possible, in every project maybe 100 people involved	New information
AH Engineering, VPD Calculation engineer	Properties of the machine in all kinds: CAD data, data from Manufacturing, data from Product Platform, data from Hydraulics.	Weekly	One or two persons for L-350	Try to reuse
AH Engineering Design Engineer	A lot of information but it is a collaboration	Every day more or less.	About 20 contacts	A mix of both
GPE Platform	From Purchasing: find new suppliers and what kind of cost can we expect for the new component. From Technology: what kind of performance do we need from the new parts, in productivity and lifespan and many different things.	Product data not so often.	Contact around 50 within the project, but maybe 20 on a regular basis	New
UPP Uptime & Quality	Included part numbers, system set up something like that on a very high level, date of start of production and delivery date	No so often, usually get it from the project leader	One maybe two	Information that exists
UPP-Diagnostic & service engineering	A lot of information. E.g., Lubrication and service interval list where it shall be stated which services, assembly instruction both on different levels both on machine levels and on components levels, test instruction, drawings, hydraulic and electrical diagrams	Quite often	Maybe around 5 to 10 lead engineers or project members	Documentation that is not affected by any changes so to say.
PPD Project Haulers & Wheel loaders	A lot of specific information from Technology: what is the new technical content, how many new part numbers, what kind of parts numbers and technical documentation as drawing	Constantly		Routine information

Buyer	How they have calculated the target price and clear information about the time plan.	Do not collect or search, provided by the system. I ask for something when I have a problem. And that could differ.	The ones responsible for technical requisition, suppliers and contact with construction.	Information that already exists
Supplier development	From production: what issues did we have on the previous version, you need the input from the field: what issues did we have there, what are key components and not	Hard to answer, depends on if it is a key component	Complex parts maybe 3: Quality, Design Engineers and Suppliers	Information that already exists

The data/information collection according to the interviewees is mostly done by using documentations (7) in different forms. It could be for example measurement documents, PowerPoints, and new part lists. Some documentation is acquired from the system itself and some needs to be looked for. Email and meetings were also a common way to retrieve information. A lot of the interviewees use more than one communication channel, as one interviewee stated "*I use multiple channels. Phone calls, mails, chat, virtual Team meetings, I cannot say which one is more...I use many channels.*"

Most of the interviewees perceived that the collection of data or information works well or at least decent enough. One interviewee stated that "*it is very much up to yourself how to acquire the data.* Some people write long emails, other people make phone calls, get information orally. It is very individual; you have many information channels and all of them are good in some way." Similar to this two interviewees perceived that it depends on how valid the data are and that it differed in different systems, one of the interviewees mentioned "Depends what how valid the data are, is it a really important, you need to make some concept by your one and then ask several people and listen to them, do you think this could work is it okay for producing these parts, is it okay from purchasing, aftermarket, assembly line and when you have all things, most sometimes I'm using PowerPoint to just collect the data," and the other interviewee said "Very different from different systems, sometimes there are mature systems that can provide this data. Some systems need manipulate to really get out the information you want. So very different." The interviewees that were dependent on the system to deliver the data perceived that it worked well as long as the information was uploaded in the system.

Although most interviewees perceived that the information collection worked well there were only five interviewees that did not have any obstacles when trying to retrieve the data and they also found some challenges, as one interviewee mentioned "*No, not really maybe it is not available yet or complete, that's the main obstacle I would say. Lack of data maybe.*" Some mentioned the difficulties to get in contact with the persons needed, due to the distance and the person's availability, one interviewee said "*Trying to retrieve data where you need, where the data needs another person to achieve then of course if you do not get in touch with that person*" and another

perceive it so regular that the interviewee call it a bottleneck, that interviewee said "The obstacle is usually the availability of the person I need to talk with. If I need to get in contact with someone, availability is the bottleneck." Another interviewee expressed the complexity in getting different answers when asking multiple colleagues and to know who that have the correct answer, the interviewee said, "You never, you are talking to five person and you get five different answers, if you think this is good some answer: no, yes or maybe or yea. I need to collect what is the, for me the best and in, is it really tricky thing…" Similar to this, another interviewee thought the most common problem was that the data was not relevant or valid enough, the interviewee said, "I would say, the most common problem is that you retrieve data but when you analyze you do not believe in it."

Another obstacle that was brought up was regarding timing, one interviewee said that the focus is mostly on releasing parts for different builds and therefore documentation comes in second place, the interviewee said, "struggle sometimes with the timing on released data but at the moment we are in a good position for the 350 I would say." For another interviewee, the struggle was regarding the complexity of the system which was not perceived as user friendly. One interviewee also mentioned that information needed was stored in different SharePoint and it was therefore hard to find. Similar to this another interviewee expressed that there is too much information and it could be hard to find the specific data you are looking for, the interviewee said, "It can be quite tricky to get specific information because you are drowning in information, so it is, if you are out for some specific information you want to see this information only but it is bundled together with an awful lot of data."

Some of the interviewees perceived that the data or information they get is relevant for their work. However, there were some that did not agree and mentioned that they get a lot of information they do not use. To most of the interviewee this was not seen as a problem, as one interviewee said, "*I got a lot of information that is relevant, but kind of easy to see what is relevant and not. Price and other purchasing issues I'm not interested in that, so but…easy to filter out.*" Another interviewee mentioned that although the data was not always relevant it could be good to get a more holistic view, the interviewee said, "*Electrical things, how electrical things works, it is not relevant for my delivery, but it is good for my own thing to have a better knowledge about the machine. So I understand our departments, if they have an issue with that, okay you know they are working with that or, I think it is good to get that data to understand other departments."*

Quality

In general, the interviewees perceived the quality of data as good or sufficient enough, one interviewee mentioned "*Most of the time it is clear and relevant, high quality*." In regard to this there were some that pointed out that the level could vary depending on where in the project they were, as one interviewee mentioned "*It gets better during the project. In the beginning they tend to start from an earlier machine or generation and then you have some carry over errors or data that is not valid for this new machine. But then we try to erase it so we clean data away, so it gets*

better during the project. "Sometimes, there could be a lack of data, or the data were not valid, this was however not causing any major problems according to the interviewees. According to one interviewee there were two major problems "There are two obstacles with getting data from other departments: one you need to understand them, two you need to be the recipient of the information so to say. If you get very detailed information about something you have never heard about then you do not know what to do with it. But I am pretty sure that the quality of the data is good even if you do not understand it, but part of the quality is to understand it." One interviewee mentioned that for this specific project they had good data into the project and that it worked very well.

Dependency

All interviewees except two expressed that they were dependent or even fully dependent on retrieving information from other departments in order to do their work, as one interviewee said "100% if they do not have the documentation, we cannot really do anything" and another said, "Totally dependent on all the data and information I receive from other people." One of the interviewees was not so dependent since that person could find the information needed. Another interviewee perceived that it depends on the situation, the interviewee said, "in some cases we cannot manage without input from other departments so it is crucial, and some cases we can manage by ourselves, so it varies."

The effects of being dependent on others were late delivery, reschedule activities and in some cases the interviewees were not able to perform their tasks, as one interviewee mentioned "Yes for sure we can be held back from performing our work" and another said, "as an example in the 350 we are missing some data from the external supplier so we need to replan activities to make them later in time when we have the data." It can in some cases lead to that the interviewee persons need to guess or make estimations in order to do their work, as one interviewee mentioned, "...then it affects us in that way that we have to guess, and we are not the experts." Similar to this another interviewee brought up that if they did not receive all information needed predictions will be less accurate and that will have an effect on the end result.

5.2.3 Improvement potential

In this section the answers regarding the improvement potentials will be analyzed. The section is divided by the interviewees' ideas and thoughts about future improvement areas followed by their perception of a visualization tool.

5.2.3.1 Future improvements

In this section the perception and ideas of future improvements will be presented. Overall, the interviewees were open to continuous improvements and thought that it always is something that could be improved, one interviewee said, "I would say I think there is, there will always be improvement potential. The day you say something is perfect then, yeah you are on the wrong

path. "However, it was a bit harder to know how the information process could be improved. The future improvements will be divided into three different areas: infrastructure/standardization, communication and Agile.

Infrastructure/standardization

Some interviewees talked about more standardization as a way to improve, in terms of; screening, when you should be informed, having the same baseline for communication, the same way of storing information and meetings. One improvement potential was regarding screening, the interviewee mentioned "I think we will be more efficient in terms of both screening and other things and to be able to see the problems we could face earlier and then we have above all this with the VR environment and be able to use it so we will find problems earlier in projects."

There is a necessity from the interviewees to know when they are needed in the project in order to plan their own work and to identify the needs from start to finish, one interviewee mentioned "I would say from the start of NPD process you should identify the needs from start to finish, where in the NPD process, do you need a certain function, if you can identify the proper people and identify the proper time to enter the project then I think it would be good." The problem today is that some functions do not get invited to the meetings. If they were, they could contribute with their knowledge as one interviewee said, "we could be much more involved than we are, we usually get noticed that things have happened after they have happened, some people do not know that we exist." Therefore, to have a baseline of communication is important, especially for interviewees that had a broad network and communicated the same information to different people. One interviewee was dependent on a good system to support him, the interviewee mentioned that "the better the system can support us the better it is." and "As long as we feed and use the system as intended. Because if we feed all information into the system, we would get more information out of it."

Mostly the support functions perceived that there was not a general way of storing information in regard to the project, or they had no access to that kind of storage. This was something that was brought up as an improvement potential, one interviewee mentioned that "product maintenance has a system called Chain (Volvo CE Case Handling) that is accessible for a lot of people and something similar would be beneficial for a project where you can find all the data and you do not need to go through SharePoints and like that." Meanwhile, another interviewee thought that Teams and digitalization could be the solution to that, the interviewee said, "I think it's this digitalization and teams that has made it a lot better than it used to be."

Good preparation and structure of meetings was another improvement potential that was brought up, there was a need also for having meeting minutes, one interviewee said, "A schedule on what the meeting will handle and of course meeting minutes that will be shared." If the employers would know what the meeting will be about, they would be able to prepare themselves and if the general information meetings were structured in the same way, then the meetings would be more effective. To have meeting minutes stored in one place would improve the information sharing, since everyone would use the same notes, now they are using their own notes which means that the information could be interpreted in different ways. It will also be beneficial for those who cannot participate in the meeting but need that information, one interviewee mentioned "*Maybe it is better to have it saved in one place, so it is possible for everyone to read and understand*." However, one interviewee mentioned the complexity with meeting minutes "*But that is not possible because in a meeting with 30 persons all are talking so much and if there was wrong information said and mentioned in these meeting minutes then it is not good,*" and "*it is not any clear answer often it is going to the right from the beginning and then ends up to the left, and what should the meeting minutes said*?"

Communication

For future improvements many of the interviewees brought up the importance of continuing with close communication and sharing information, one interviewee mentioned the importance of having a "*tight dialogue, talk often, and prepare. If all people know what is happening and they are involved, then the result will be much better. If they have knowledge then it is absolutely the best way,*" and another one said that "*communication is the trickiest part but also the most important thing we have in the project team.*"

Some of the respondents' ideal future was to have more personal communication in terms of faceto-face meetings and to work closer to each other, as one said "I want to go back to have more face-to-face meetings. That increases the quality of the communication," another argued "face-toface, have dialog and have a communication that everyone adapts to, everyone understands, that's the ideal future for me" and another said "I mentioned, to work closer to each other. As I mentioned now, we are a bit in silos working in our own departments, you should try to break that kind of isolation and mix people." One interviewee also wanted to avoid booked meetings, the interviewee mentioned "My ideal future is to be able to have project teams in an actual office environment sitting together and be able to communicate without booked meetings, I think the most effective and best ways of building teams and collaboration." In conclusion, some of the interviewees agreed that face-to-face communication and minimizing the distance between them is the best way to improve communication and it is what their ideal future looks like.

As mentioned before in general, the interviewees agreed that there is always improvement potential and one idea that came up was to take advantage of the already skilled people that work at the company by applying a button up approach and giving them all the necessary prerequisites to perform their work and share their expertise, quoting the interviewee "*There are always, we can always improve, yes. In which way, bottom up if the skilled person expert who is working in the project is missing communication, then we need to secure that we improve that as well. If the people who are working in the process feel they need better communication, then we should improve it."*

Agile

Three of the interviewees brought up the ongoing work with Agile or The Scaled Agile Framework® (SAFe®), where two are really positive about this change and one is a little more reserved. The intentions with implementing the Agile way of working are according to one interviewee, "to improve the communication between a responsible buyer for example to connect them with the right people in Marketing and Operations and Technology and. So, the answer is yes, there is potential and the way we are trying to deal with this is a new way of working in this agile, sustainable Agile framework it is called. It's getting people closer to each other." Another interviewee tries to implement agile tools in daily work when sharing ideas such as good enough drawings on a paper or a photo just to get an understanding inside the team. The interviewee also mentioned the benefits of using the whiteboard function in Teams and the purpose of using these tools are to make the information easy and understandable. As mentioned, there was one interviewee that was a bit more reserved when it came to Agile, this person could see the benefits with getting people to work closer to each other, however the interviewee pointed out that "If you set up teams as they were working before there will be no difference." Therefore, it is important to set up the methodology in a correct way, so it enables the right people to collaborate. Furthermore, this interviewee thought that colleagues including him could be better at following the process for documentation that actually exists and the ideal future was according to this interviewee, "to have the correct information at the right time, maybe it is not only the communication part, it is the documentation part. We need to be clear in our needs if they are not aware of it already and they need to supply information at the right time."

5.2.3.2 Visualization Tool

In this section the analysis of the interviewees' perception and ideas about a visualization tool is going to be presented. The section is divided in five sections: features, contexts, advantages and disadvantages, possible areas for visualization and lastly, the perception of Santoni (2019) solution will be presented.

Features

This section aimed to map out what features the interviewees would like to have in a visualization tool. Some preferred to be able to see changes and how the assembly process works in a Virtual Reality (VR) or 3D model as they expressed "*it is easier to see how the change is going to be if you could do it in a VR or 3D model.*" *and, "…mainly design on different things we assemble in and how we can do the assembly.*" If the VR tool is implemented, it is important to make it accessible to everyone as one of the interviewees stated, "*I see that's a real strength to have that kind of tool. Can we make it easier to access, can it be for everyone, can everyone have in real life all these things, of course it should be great.*" Another important issue that was pointed out was that this kind of tool needs to be fast as someone said, "*I would like it to be quick…we use power VR etc. for various dashboards but all of them when you start filtering etc. it takes ages.*" It was

also important to have an interface where it is possible to go from a picture to a 3D model as one interview said, *"if we could go from a picture to a model"* their understanding would be increased. Another suggestion was in regard to the whiteboard functionality that could improve their way to communicate *"…some better way to get into this whiteboard mode that could be good. Better whiteboard functionality, draw on the screen and very easy to communicate gestures…"*

Another important suggestion came from several of the interviewees that wanted to be able to have a holistic overview of the projects in an easy and clear way, a kind of planning tool, as they said, "an easy way to see what should be done and what has been done, and should be done" and, "a time plan, a good and clear time plan." Suggestions regarding specific areas also were touched such as implementing a real time updated key indicator for areas as cost which can also be considered as a part of a planning tool, the interviewee also added that "It should be easy to access this kind of information, are we on track or are we deviating, now it takes quite a long time until we realize that we are not on target." Furthermore, another suggestion was in regard to the possibility to see how the parts change over time where the current status is shown as a first picture and then its transition into a future status, a kind of predictive tool, as some of the interviewees expressed "the visualization could make it to add on dimensions, for instance you share something that shows the state of today, by visualization you could add on how it will change over time. Instead of showing two pics it shows how it moves from one to another."

It was also suggested to have a filter function that allows each function to selectively see what is of importance for them as one of the interviewees said, "What is important for me is that I can filter on tasks or actions allocated to me. If we have a visualization tool with all the different activities maybe, it is really hard to see what you really need to do."

But not all of the interviewees wanted to have a new visualization tool since it requires a lot of effort and as the interviewee said there are already tools that work "a lot of time the tool becomes more important than what it should deliver, and it becomes too complicated, and it is a big effort to know the tools and to learn the tools and really get something out of it. So, for me Excel, PowerPoint. Everybody knows them..."

Contexts

In this section the aim is to map out in what context the interviewees would make a good use of a visualization tool. Some interviewees would want a visualization of the work procedure in terms of planning and following up, one interviewee said "a visualization tool of the timeline of the project...that shows when, who does what is a good thing." and another expressed, "Of course when we follow up, I mean we have kind of balk jobs, need to realize 1000 drawings, and then it is really good to see in a visualized way okey we have done 30%, 30% on going and 30% is not started or something. So that would be used a lot and yeah, all the planning we do to describe activities and deliveries is really really useful." A visualization tool that could show what to do, when in a project, and who is responsible will be usable since according to one interviewee "it is

easier to see what needs to be done and when," so it will be easier for everyone to plan their own work. Similar to this, one interviewee would make good use of a visualization tool in "the planning part where we state our needs, and we can maybe visualize that the needs have been stated and when the needs have been fulfilled." This kind of visualization tool could also enable the company to make decisions to continue or not with a project quicker, as one interviewee mention "To be able to make a stop for the moment in a project quicker if we do not need to continue for a long time, money, money is consumed on a daily basis on a big project."

Furthermore, a visualization tool can be used in communication with others in different phases of the NPD process, brainstorming and troubleshooting were mentioned as possible contexts, and in cross-functional meetings. As one interviewee said, "Usually it's very handy when in a phase where we are brainstorming or troubleshooting." and another one said, "For example layout for a facility or a new product, new part and so on." It is important to point out that in some departments there are already visualization programs as FEM that are used to do mechanical calculations as stress, dynamic behavior, expected life of a structure, etc. One of the interviewees mentioned that "when we do FEM calculations, and you can plot whatever you want on that if it's life or if it's stress or if it's deformation we can visualize that. But you can also animate, that is the new level of it now with video sharing, share animations also for better understanding."

Advantages and Disadvantages

The advantages and the disadvantages that were brought up from the interviews are summarized in Table 12. The advantages have been touched upon in the previous sections, and some examples are that people are able to see the same thing, easy to imagine what is changing, when they need to be involved, gives an easy overview. However, there were some disadvantages or risks that are good to consider when constructing a visualization tool like the risk of focusing more on a tool instead of the communication itself or fooling the viewer. Therefore, according to one interviewee it is important to *"have good intentions with the information."* Another interviewee mention the importance of integrate the visualization in the tools that already exists, or when implementing a new tool be able to remove another existing tool, the interviewee says *"always when you are putting in a new tool then you need to ask yourself what tool do you take away, or how do you integrate that to the tools that you already have. If you only put a tool upon other tools that you already have then you put a burden on the employees..." More disadvantages and advantages can be found in Table 12.*

Advantages	Disadvantages
"Easy to imagine how the change is going to be, easier to see the change or what happened and so on."	"If I do not know that such a tool exists or do not know where to look if there is not a standardized way of presenting it, you do not know where to look and also it has to be so evolved that you could understand it. You should not have to be a highly educated person to be able to read it out because then it is the wrong tool."
"we are able to see the same thing"	"Some of the attendees, they do not take the needed space they need to be visible. They are silent or shy, that is a disadvantage with a whiteboard both physical or virtual. So, some people do not speak up"
"to what am I about to be involved and from when is it expected."	"I also see the risk of using tools instead of communication"
"If you have a process that never changes, that it is always the same then it is not a problem to create a tool that always shows the information in the same way."	"It takes effort to build up the models in the visualization tool and it takes time, and sometimes we do not have time to do this and so on. So, always when you are putting in a new tool then you need to ask yourself what tool do you take away or how do you integrate that to the tools that you already have. If you only put a tool upon other tools that you already have then you put a burden on the employees"
"The advantage is to get an easy overview."	"It is easy to just share my plot and you can more or less fool the viewer that you are in a good situation or a bad situation just by changing the color. It is important that you have good intentions with the information."
"it is maybe more clear than an email that says we need this, it is maybe easier if you have some kind of board or diagram that shows that a lot of information is missing."	"you lose some flexibility, maybe you need to tweak that presentation some way at a later stage, and then you are kind of hindered by that tool instead of helped."
"you have a common view, you can react quicker, you can take actions a lot quicker, you do not need to wait until a report is finalized, analyzed and channeled through the different layers for example."	"we are involved in a lot of projects and if it is done differently in different projects, it is hard to know where in the process we are"
	"you need to have the right ones, if you have too many, I have seen some dashboards earlier, if you populate an awful amount of data into different dashboards then you can easily get lost in the amount of information, so you need to be a bit careful what you want to visualize."
	<i>"it can be messy with pictures; it depends on the context. But I always prefer pictures."</i>
	"the more complex you make the presentation etcthe higher requirement you have to have on your equipment as well."

Table 12. Advantages and Disadvantages with a Visualization Tool

Possible areas for visualization

This section aims to map out possible areas for visualization, in other words which parts of their work the interviewees considered are reasonable to visualize and will contribute to the communication process. As mentioned above there was a need for some kind of planning tool. It could therefore be concluded that planning can be visualized. Planning could include things that concerns time plan, project description, staffing situation, status of approved parts and steps etc. There were two interviewees that mentioned that the visualization could be integrated in their daily work or systems they work with, one mentioned "It would be very helpful if we could have this visualization directly in the new part list in SAP" and the other interviewee mentioned, "be able to show different prices on a picture, yeah why not it could be an advantage that I am not aware of." All the suggestions from the interviewees are summarized in Table 13. These have been grouped in three headings: Parts, Planning, and Other.

Parts	Planning	Other
"new parts, working areas, layout, for example how parts should be kitted, packed."	"how the staffing situation looks that could be visualized"	"Everything it could be as boring as some administration, economical figure, resource."
"how many parts are to be measuredand the status of the part approved not approved, is there any feedback related to the feedback to the non-approval or approval."	"Time plans, project descriptions, etc."	"product cost, different kinds of performance data from the field certainly is possible, quality measures from assembly or production"
"what parts that have been checked from an aftermarket perspective, and in early warning team could be easy to pinpoint where we have the problems/issues where on the part we have the problem"	"if the requirements are fulfilled or not, if the requirements have been discussed and understanded, our needs"	"we are working in SAP and when we are in a sourcing phase, we need to monitor on a weekly basis on the sorting so we can realize our build in Arvika factory for example, and as it is now, I need to make this kind of visualization through material graph in excel. It would be very helpful if we could have this visualization directly in the new part list in SAP"
		"be able to show different prices on a picture, yeah why not it could be an advantage that I am not aware of. If you send information to suppliers, is that possible to visualize? It is CAD drawing. I use an Excel file where I put pictures in. then both me and the supplier know exactly what we are talking about. I am a picture person; some can talk about a part number and understand but I want to see what we are supposed to by not just a number."

Table 13. Possible areas for visualization

Santoni's solution

In this section the perception of the visualization tool that Santoni (2019) developed will be analyzed. The aim with the section is to see if this could be the solution to their problem or if there is a need for another visualization tool. Two pictures of the solution were shown to the interviewees during the interviews, Figure 47, and Figure 43 (see page 72), where they got the opportunity to express what they saw, and which one gave them the most information.



Figure 47. Measurement points organized by position on the frame and side (Santoni, 2019)

There was a mixed perception of the pictures, two liked the "first" one (Figure 47) and three "the second" one (Figure 43). The reason for the "first" was according to one interviewee "more minimalistic, more condensed," meanwhile the reason for "the second" was according to another interviewee "For me the colors are always very powerful. The second one is more powerful by the color." Some of the interviewees had a need of both or could see the benefits using both, as one interviewee mentioned "The control chart clearly shows what we have for trend and where we are in the draft. About the one with colors, it is not so much on how robust we are more about where the problems are in those cases. It shows the frames....we have benefits with using both, to see where on the frame we have problems, but also how we are if we are inside the control limits I think." Another interviewee mentioned that "the second" could be beneficial for discussions with people that are not into the details, meanwhile the "first" shows the actual data in a better way, the interviewee said, "I think the lower could be good for overview or for discussions with people that are not involved in the details, but they could get an overview of what is the problem and some kind of message. But maybe the top one is easier to use than actual data, detailed data and if you deep dive into certain issues, then this is more informative."

There was also some interviewees that did not perceived that this tool was beneficial for them or applicable in their work, as one interviewee mentioned, "I like to see colors...like a color layout where all new parts and processes were, to see where the change was going to be, where most changes were on a layout. But another presentation," and another interviewee said, "You want to

really see, I don't know what it is in here, but you will be able to see the number of dots, the average course, the colors to the scales, we do not want it compromised or aggregated in that way. "Furthermore, there was one interviewee that felt like these visualizations did not give this person enough information, the interviewee expressed "when you are digging into the problem you need to know a lot of more things to make a decision."

Another issue that was brought up was color blindness. Color blind persons would struggle with understanding this way of presenting information since they have difficulties in distinguishing colors. One interviewee that was color blind mentioned, "I am not a fan of that kind of graph really. It is a little bit too messy, so I think I prefer this kind of visualization with shape plot or what to call it, process change, it's a bit easier." If a visualization tool use colors it is also important to add symbols that represent the same as the colors for example plus and minus signs, as the interviewee expressed, "I am all up for presenting it with colors, but I also think that you should add symbols to that color so that people that have the disadvantage are able to be sure that they are reading it right, because otherwise there is a guessing game involved."

To conclude Santoni's (2019) solution is beneficial for some but not all departments, so the tool would benefit from some potential improvements. The solution could be good to use in general meetings to show where the problems are, one interviewee was able to see that this tool also could be used for showing deliveries, as the interviewee expressed, "I could use something similar to show delivery, the colors could represent time for delivery, green delivery in 3 weeks, red means slower delivery and so on. It would be easier for me to present to ones that are affected, and we could discuss which ones to prioritize." For a more detailed level there was a need for more information than the visualization showed during the interview.

6. DISCUSSION

In this chapter the results from the empirical findings and analysis will be discussed in relation to the literature as well as the Improve and Control phases in the DMAIC cycle. First, a general discussion about the current situation in relation to the literature will be discussed and some suggestions presented. The discussed topics are Infrastructure, Knowledge Sharing, Indicators and Visualization. This is followed by the Improve phase where improvement suggestions will be presented especially in regard to features and areas for visualization. Lastly, the Focus Group will be presented and discussed in the Control phase.

6.1 General discussion

In this section a general discussion about the current situation at Volvo CE and what the literature says will be presented. This section is divided into infrastructure, knowledge sharing, indicators, and visualization.

6.1.1 Infrastructure

In this section the current infrastructure will be discussed, and some suggestions will be pointed out. The section is divided by Waterfall vs. Agile, standardization and communication channels. Lastly, a bullet list with important factors that can influence and/or improve the infrastructure will be provided.

Waterfall vs Agile

From the interviews it can be concluded that Volvo CE is using the traditional Waterfall model in projects, although they have started to implement a more Agile way of working in terms of SAFe®. The literature suggests that the steps in a Waterfall model are planning, design, development, testing, and deployment and they are followed in that order (*Cocco, Mannaro, Concas, & Marchesi, 2011; Thesing, Feldmann, & Burchardt, 2021*). Volvo CE has two similar structures, one that is used in Operations, see Figure 45 and one that is more used in Technology and projects, see Figure 46.

The infrastructure of the information sharing and/or flow will be impacted by the structure of the organization since the different types mentioned in the theoretical framework will enable different types of structures as well as communication and collaboration ways. In a traditional structure like a Waterfall, it is common to work in silos which could make it harder to communicate compared to an Agile structure where you work in smaller teams and share information continuously throughout the work.

A traditional structure like a Waterfall requires that all activities are known in advance, therefore it is suitable when the outcome is clear (*Cocco, Mannaro, Concas, & Marchesi, 2011*). For the specific L-350 project the outcome and goal were clear for most of the interviewees, so the

Waterfall model suits these types of projects. However, when the task is to develop a new machine or improve the quality it is no longer clear what should be done, in these kinds of projects the Waterfall structure could hinder creativity and flexibility and thereby also hinder information and communication flow. In projects like this the literature suggests an Agile approach, for example Thesing et al. (2021) argued that the Agile approach is beneficial to use when the outcome of the project is unclear.

It is easy to believe that implementing an Agile way of working will improve collaboration and solve problems with the Waterfall structure. Some of the interviewees mentioned that the Agile structure could improve the communication and collaboration, as one interviewee mentioned, "to improve the communication between a responsible buyer for example to connect them with the right people in Marketing and Operations and Technology and. So, the answer is yes, there is potential and the way we are trying to deal with this is a new way of working in this Agile, sustainable Agile framework it is called. It's getting people closer to each other." What is important to have in mind is that an Agile structure would require a reorganization and restructure in order to actually manage the communication and collaboration, if the organization remains the same it will not improve the way of working or improve the collaboration, this was something that was also brought up by one interviewee, "If you set up teams as they were working before there will be no difference." There has been some reorganization in previous years in Volvo CE, but it might not be enough in order to handle the Agile or SAFe® way of working.

This issue can be solved by using a more hybrid model, as mentioned in the literature hybrid Agile-Waterfall models as the Agile-Stage-Gate model, combines the benefits of the two approaches without any major reorganization. The Waterfall model is used to plan the overall structure of projects and the micro planning and activities follow the Agile principles. According to Thesing et al. (2021) this structure will enable project teams to have richer communication and shorter feedback cycles, which was requested by several interviewees. It also will be more flexible and more adaptable to changes. As mentioned in the beginning, which structure the organization chooses will affect the infrastructure of information and communication flow. The researchers are not aiming to advise one or another structure, the purpose was only to point out what will be the outcome of each structure to give the company a deeper understanding of the impact they have on the infrastructure.

Standardization

The more people involved in each stage the more information will be needed to share and the more complicated it will be. Therefore, it is important to have a good infrastructure in place especially in phases where a lot of different functions are involved. It could also be beneficial to standardize the process as the information will be shared in one way, which could lead to a more recognizable and easier way of handling the information flow. How the current situation looks like as well as what information that can be standardized and not will be discussed in this section.

In the survey it was found that most of the respondents were included in the industrialization, detailed development, and final development phases, see Figure 19. Figure 19 was confirmed by the industrial supervisor during the visit to Arvika. From the interviewees it could not be drawn any specific conclusions about who was involved in which phase, although, there were some that were heavily included and some that acted as a support for the projects. Looking at it from the survey perspective it might be good to start building an infrastructure in the phases where most people are involved as the information sharing probably will be higher in those. However, there were more interviewees that had a support function that were in need of a good system of infrastructure. Since they were not involved in the project all the time, they were not aware of where the information was stored or what had been decided. Therefore, it is equally important to build a good infrastructure/system to store information for phases or functions that are not so involved.

The standardization of the current information flow was as mentioned in the analysis considered low both from respondents of the survey (see Figure 26) and from interviewees. One from Purchasing stated that they actually have standardized templates for communication during the milestones. For some interviewees standardization was something good or even crucial while for others it could be an issue if it hindered creativity. It is not possible to standardize everything, especially activities that differ from case to case. The standardization can hinder flexibility, and not being able to step out of the box as one interviewee stated. Therefore, from the interviewees it seems like detailed information that requires a lot of discussion is not able to be standardized. It can also be hard to standardize activities/information that are made in the project team since these differ from project to project.

Most of the interviewees thought that standardization could be good and beneficial since it will be recognizable, familiar and it will simplify the work, as one interviewee mentioned, "*it is recognizable no matter what project you are in or no matter who presents the project information.*" It will also be easier to search for information if an infrastructure and standardization of information flow is in place since it will be stored in the same way for each project. Another benefit is that it will push people to have a common way of working, as one interviewee mentioned, "*I think there needs to be a system that forces people to do things in a certain way otherwise it will be done differently.*" The interviewees mentioned that areas where it was beneficial to use standardization were in time plans and meetings. From the survey the respondents thought that project status and infrastructure could be standardized, see Table 4. To conclude the discussion, standardization is good when it comes to similar information such as project plans and the infrastructure where information is stored. An updated table that includes areas from the survey as well as the interviews is presented in Table 14. In the table the benefits are also summarized.

Project status/plan	Infrastructure	Benefits
When and what, I need to communicate to others.	Same setup of SharePoint (folders),	Recognizable
What work is ongoing	All documents placed in Windchill in the machine structure	Familiar
Scheduled de-briefing current status and needed status from a project demand point of view.	Data maintenance, Organizational accuracy, Data Sharing	Easy to search and find information
Rules/expectations concerning deliveries.	More standardization is needed.	Enable common way of working
Dashboard with all concerned new parts, followed during the project and its activities. Where are the critical parts and not	Same type of meetings and way of planning	
Time plans	Development contribution for become Technical Support Expert	

Table 14. Potential information that can be standardized and its benefits.

Communication channels

As found in both the survey and interviews the two most common communication channels were email and meetings, followed by SharePoint. In the survey the time spent on each communication channel was also presented, see Figure 22. The three most common communication channels were also the ones that respondents spent most time on. Many of the interviewees could prove this since they perceived that it often was spent too much time on meetings, sending and answering emails as well as searching for information in for example SharePoint. However, from Figure 22 and the three-point estimation it can be discussed if four hours should be considered as the most optimistic value since that was the most common response, the researchers made this assumption, but it was proved wrong. A better estimation could have been obtained using four hours as the most common time spent. Other insights from the interviews were that people were struggling to estimate how much time they spent and how much time each step in the process took.

One of the cornerstones mentioned in the theoretical framework was to base decisions on facts. It is important to use accurate data in order to make good decisions. As it was said before, when it comes to time and planning the interviewees struggled with estimating both how much time was spent and how long each activity took. This can be due to the complexity of the NPD process and that they do not measure each activity. For both the company and on an individual level it could be wise to try to map out how long each process takes, as well as how much time is spent on each activity and/or communication channel. This would lead to planning that is more based on facts rather than gut feelings, in other words more accurate plans. It would also lead to more awareness and understanding. By knowing or getting more familiar with what time each activity takes, the plans can be more accurate which can in turn lead to people knowing when they are needed. So, the planning on an individual level will also improve which will make an impact on many of the interviewees that perceived that they needed a better time plan, to visualize the product status and to know when they were needed. Measuring how long all activities take can be a huge and

complicated task. Therefore, to start with three-point estimations can be useful to map out that on an individual and organizational level.

Multiple different communication channels were used in Volvo CE, which the literature supports since different channels are beneficial for different types of information. According to Tkalac Verčič and Špoljarić (2020) what channels that are used in an organization will have an impact on the employees' satisfaction and effectiveness. Therefore, it is important to listen to the employees' perception of the different channels since a nonworking channel will lead to nonworking communication. SharePoint and meetings were two communication channels that many respondents wanted to improve or make more effective. This was shared by some interviewees, especially the meetings where many interviews spent a lot of time on. Suggestions to improve the meetings were to have a standard format, send out preparation before meeting and meeting minutes. By doing this people would come more prepared and were also able to go back and see what has been decided. This shows a need for both written and oral communication in regard to meetings. Therefore, it could be good for the company to investigate on which meetings it is possible to have an agenda sent out before and what meetings that could have meeting minutes. It is also important to decide who is responsible for doing those activities, if no one is assigned to the task it is easy that it falls between the chairs and is not done. Another important thing is to make sure that the employees have time to prepare. Some interviewees had a very high workload and putting more tasks could be a burden for those people even though it would make the meeting more efficient.

The interviewees confirmed both the benefits and disadvantages with the oral communication, many perceived that face-to-face communication was the most valuable where they exchanged a lot of information. Furthermore, they also expressed that the bigger meetings with more people involved complicated things, and these meetings were not so valuable or effective since there was a low amount of information that was useful for them. The literature suggests that oral communication works better for discussion, and written communication works better for information sharing. So, general information meetings might be better to send out by written communication channels. However, there is a risk that people misunderstand or misinterpret the information when it is only written down. Therefore, the researchers suggest that a combination of both written and oral communication channels are good to use in the meetings. This will reduce the interpretation, enable people to go back and see what has been decided and be able to get immediate feedback.

Factors that influence the infrastructure of the information flow

Based on the discussion above a bullet list of factors that can influence or improve the infrastructure of information flow are presented below.

• The kind of structure that is used.

- Hybrid models give more flexibility, are adaptable to changes and increase collaboration, communication, and feedback.
- It is equally important in each phase and for all involved, not depending on if you are heavily involved or a support function.
- Standardization is beneficial in an infrastructure when it comes to
 - Project planning
 - Project status
 - Documentation storage
 - Data sharing
 - Meetings
- Standardization is not beneficial in an infrastructure when it comes to
 - Detailed information that requires discussion
 - When it hinders from being creative or stepping out of the box
 - When it is different from case to case
- Preparation before a meeting
- Meeting minutes
- Map out the time of each activity.
- Use multiple communication channels.
 - Make sure that the communication channels supports the work tasks.
 - \circ $\;$ Listen to employee perception on the different communication channels.

6.1.2 Knowledge sharing

From a company point of view according to Nonaka (2007) when tacit and explicit knowledge interact is when the most powerful transfer occurs, this can be tricky since you need to find ways to express the inexpressible. Nonaka (2007) argues that the best way to do it is by using redundancy since it encourages communication and creates a common ground, and it is easier to see what colleagues are struggling with. The interviewees from Technology perceived that it exists redundancy and as the literature said they did not see that it was a problem rather a quality assurance one. However, too much redundancy can, as expressed by some, create frustration since it was hard to find the information in an easy way and know which information. In the other departments, redundancy was not perceived since they mostly worked in one or two systems.

As mentioned in the literature, formal structures are often connected with explicit knowledge, that means that the knowledge is easily accessible. The informal structures are more tacit knowledge as for example innovation projects (*Lee & Yang*, 2000). This means that there is a need for both

structures since people are working with different tasks, as it could be found in the interviewees and survey some who worked with old or data that already exists had a need for a formal structure. From the interviews it was also clear that some functions were dependent on the systems to feed them with information, these persons worked with more explicit knowledge. Meanwhile, interviewees that work with more untouchable tasks and more tacit knowledge will have a need for a more informal structure. Aligned with the literature these persons had a higher need for meetings or face-to-face communication, meanwhile, those who worked with more explicit knowledge e.g., Purchasing had more need for the system to feed them with information such as documents or reports. It is therefore important to consider both informal and formal structures to satisfy everyone. According to the literature it is crucial to have a good system for storing and reuse information and knowledge.

The knowledge transfer or information that was needed according to the interviewees was mostly explicit knowledge in terms of data in various forms and new part list, see Table 11. There was some tacit knowledge that needed to be transferred from different departments to others, such as how to supply the material to the operator, and information on how to build the machine. The tacit knowledge was overall hard to explain for the interviewees as the answer was often not more specific than a lot of information. What can be concluded from the interviews and survey is that people often share information cross-functionally over departments and they also collaborate to some extent cross-functionally. According to Argote and Ingram (2000), there are rising problems transferring knowledge to higher levels such as other departments or divisions. Since Volvo CE shares a lot of information between departments it can be good to measure the quality of the information that is shared. Referring back to the cornerstones, to base decisions on facts, what is not measured cannot be improved. To measure the information performance after the transfer is done can be good for self-evaluation and for the organization to understand and improve. Argote and Ingram (2000) brought up some factors that affect the knowledge transformation "...such as the reliability of the source, predicted difficulty of transfer during the early initiation stage, whereas factors that affected the execution of transfer, such as the recipient's ability to absorb knowledge, affected difficulty during the implementation phases" (p. 161). More about indicators and how to measure the quality of information will be discussed in the next section.

6.1.3 Indicators

Quality or performance indicators are used to measure and control efficiency of a process or system, and are usually used in healthcare and manufacturing, and these indicators are used as a basis for applying corrective measures and continuous improvements (*Vuk*, 2012). But quality indicators are not usually used for measuring the quality of the information flow, way of working or communication and collaboration.

During the Define phase of the DMAIC cycle, specifically when applying the Effective Scoping tool, the researchers identified that there were no indicators that could measure different aspects of the data/information flow. The researchers defined these needs as the small y's (see Appendix

C). In order to make an objective evaluation of these identified aspects it was decided to construct a survey focusing the targeted departments and functions, where the responses of the quantitative analysis would give the researchers the possibility of construct some indicators that measure some interesting components that can conform a quality indicator, and some other interesting aspects of the information, communication, and collaboration within and between departments and functions.

The quality indicator was built by taking the mean of four components as presented in chapter 5.1 which gave a quality indicator of 3.85 in a scale from 1 to 5, which shows that the quality of the information is quite good or approved in terms of how useful it is, how important is for the receiver in order to perform his/her work, how understandable and how reliable it is. As said before, the aim of constructing quality or performance indicators is to use them as a base for continuous improvements, and there is a big potential for improving the quality of the information flow as it was detected during the qualitative analysis.

Some other interesting indicators were how much new knowledge was gain from the received information (3.5), if they shared a common way of working (3.17), how well the collaboration between departments worked (3.1), if they shared a common language (3.5), how well did they understand the roles and responsibilities (3.78), and finally their degree of own understanding was measured (3.5). What can be noticed from these results is that all the indicators are normally distributed around the mean (3) slightly skewed to the positive side which shows that there is approval from the respondents but there is still a good potential for improvements.

There is not a standard way to measure the quality and some other components of the information flow, way of working or communication and collaboration. This was an attempt to prove that these important topics can and should be monitored and measured regularly to guarantee the good performance of the projects.

6.1.4 Visualization

The company already uses several types of visualization tools, physical ones located in different places at the Arvika factory, as whiteboards and monitors, and digital ones as Excel tables, graphs, 2D and 3D CAD models, video, etc. The pandemic situation has generalized the use of tools as Teams and Skype for virtual meetings that have made the use of different kind of visualization tools more common than before, and in some ways have made the information accessible to more people but have also raise the bar regarding the use of visualization tools since the presented information must be clear and of high quality to avoid misunderstandings, lose time and miss gates. Iliinsky and Steele (2010) explained the importance of having clearly defined the intended goal with the visualization, and when this has been decided to do not overload the visualization with too much information, it must be as clear and simple as possible. Alhadad (2018) also warns about the risk of overloading information when using visualization that can lead to visual clutter which is not only bad from an aesthetic perspective but can also create confusion (Rosenholtz, Li, Mansfield, & Jin , 2005).

Physical visualization tools are good to use when people are in place, but due to the current situation where most people are working from home, and since the departments are located in different cities, it is important to use digital visualization tools. It was also realized that different departments have different needs, and that one common visualization tool would not cover everybody's needs. Another important factor that was discovered is the need to consider disabilities as color blindness when presenting information in colors, as it was explained in chapter 3.7, as much as 10% of the male population and 1% of the female population are affected by this color vision deficiency (Ware, Chapter 4 Color, 2004). This can be tackled by putting symbols in connection to the colors so the risk of misunderstanding information can be avoided. Diversity and inclusion are crucial issues that must be considered.

6.2 Improve

The Improve phase in the DMAIC cycle aims to improve the performance of the process based on the findings made in the Analyze phase. Due to the complexity of the scope of the master thesis and the time limitations, a PFMEA was not performed, but it is strongly recommended to continue the work and to carry out such analysis based on the findings of the Analyze phase.

Nevertheless, it is possible to make recommendations in regard to the found performance indicators in order to improve them. The researchers' recommendation is to continue exploring the possibility of building an infrastructure that enables a high quality information flow that is standardized and common for all the departments and functions. It has been discussed that there is not a single way of working and that different cultures exist in the company, and these must be tackled by adapting to changes and being flexible. The topic is complicated and there is not a single solution for improving the situation. Reflection is a term that is used in lean management, Hansei in Japanese, and aims to self-reflect in order to improve. Reflection is also applied in the Design Thinking culture and is a process of questioning, evaluating, and learning from own experiences and even from mistakes. It requires self-awareness and openness to changes. Reflection is something that came along after performing the focus group at the Arvika factory and was highly appreciated by the participants which will be further explained in the next section 6.3. The pace of the work and workload is usually high and do not leave too much time for self-reflection and take a step back to move forward. Socializing and casual encounters at the coffee machine belong to the past which makes it even more difficult to immerse in another environment.

The quality of the information can be improved if the communication and collaboration between departments and functions are also improved. Cross-functionality is a key component to achieve these by involving all departments from the beginning of the projects and not only at the end or seeing them as support functions. These would most certainly increase the self-commitment and motivation of the employees, and in turn will improve the quality and accuracy of the information that is shared. It is also important to continue building a suitable infrastructure that allows it. Currently, the information can be found in different platforms such as Teams, Windchill,

SharePoint, Chain, etc. The same information can be stored in different places, and it is not crystal clear where to find it, a lot of time can be spent in just looking for information.

Features

According to Iliinsky and Steele (2010) visualization is one way to present information to enable common and better understanding that will enable knowledge transfer. The literature stated that there are multiple ways of visualizing data and tools, this was confirmed both in the survey and interviews. From the Analysis phase it was possible to identify some features that the respondents would like to have in a visualization tool. The most important identified features were:

- VR or 3D (on for example things that are assembled or how they are assembled)
- Whiteboard mode on (e.g., Teams, features in that e.g., draw on the screen, communicate gestures)
- Kind of planning tool (see the status today and how it could change, when to deliver, what should be done, what have been done, time plan)
- Realtime update of key performance indicators (are we on track or are we deviating)
- Go from picture to model with a good interface/transition.
- Kanban board

There were a variety of features and desires that were expressed both in the quantitative and qualitative data gathering process, such as having different layers that could be chosen in other to select what was of interest for each individual, some people preferred colors, other preferred Excel tables and specific data, while others simply did not want to have more visualization tools that the ones that already exist. These conclusions from the interviews and the survey are aligned with what Alhadad (2018) considers as a good tool as mentioned in chapter 3.7 Visualization.

Some of the above presented desired features (Kind of planning tool, Realtime update of key performance indicators and Kanban board) can be combined in a planning tool which can be designed as a Kanban Board that even shows real time updates of important KPIs. A Kanban board is usually used in lean management as a way to visualize the status of the work, using cards that can be moved when the work has been performed. Some of the advantages of a Kanban board is that it makes the different stages and what needs to be done visible and easy to understand. It also shows what needs to be prioritized, bottlenecks and milestones/gates (*Cocco, Mannaro, Concas, & Marchesi, 2011*). Also, it visualizes the process for those included in the project so they can focus on what needs to be developed in order to optimize the process. Therefore, the researchers strongly recommend Volvo CE to investigate if it is possible to implement a Kanban board planning tool even in the NPD process, as for today they are using similar tools in the production. The investigation should look into if it is possible to implement it, who should be responsible for

feeding the system with information, and if the time spent on feeding the system is worth the outcome.

Areas

Furthermore, it was also possible to identify different areas where a visualization tool could be successfully used. The most important ones are the following:

- New parts, working areas, layout, for example how parts should be kitted, packed.
- How the staffing situation looks that could be visualized
- Status of what job is done e.g., how many parts are to be measured, approved not approved.
- Time plan, project descriptions
- Product cost, different kinds of performance data from the field certainly is possible, quality measures from assembly or production.
- If requirements are fulfilled
- Visualization of material graph in SAP
- Price, why it differs if we do this or that.

There were several areas that were pointed out by the respondents, and these differed a lot in between. Even if different layers are implemented in a single visualization tool, having such a variety of features and areas of use is not practical, it would require a lot of time developing such a tool, it would cost a lot money and might not be as efficient as the existing ones. There is a necessity to make an assessment in order to prioritize what is more important to visualize and in which areas, as someone said, "*you cannot fulfill everybody's dream*". A new tool must be cost-efficient, simple to use and accepted by the potential users, otherwise there is no meaning in investing time and money in creating new visualization tools. Furthermore, one single tool would have a risk of having too much information and according to Alhadad (2018) to have an overload of information is one of the factors that could lead to visual clutter which will have a negative result in the visualization. An overload of information will according to Illinsky and Steele (2010) also lead to longer time for users to find and understand the message. Besides this, when talking about computer-based visualizations, there are several aspects that must be considered such as functionalities that allow the users to filter information, zoom in and out, nice interfaces, etc. (Ware, Chapter 10 Interacting with Visualizations, 2004).

Even though, one single visualization tool is not possible to develop in order to meet everybody's demands, the power of using visualization tools cannot be forgotten. The recommendation to the company is to use multiple visualization tools that fit the purpose of what data or information that is going to be presented. In order to make sure that the visualization fulfills the purpose, the

researchers recommend the company to follow the summarized recommendations mentioned in chapter 3.7 Visualization together with the guidelines, see Appendix I.

6.3 Control - Focus Group

The Control phase is the last one in the DMAIC cycle and aims to ensure that the improvements are achieved and make corrections if deviations are found. The project did not reach this phase since no improvement action has been applied yet. Nevertheless, as a way of validating some of the findings, a focus group was carried out during the visit to the Arvika factory. The way it was conducted was explained in chapter 4.2.4, and the results are going to be discussed below.

Focus Group

The focus group was planned to serve as a way to confirm and/or validate the researchers' findings in regard to a visualization tool. It also aimed to add new ideas that had not come through the previous data collection methods in order to give more complete guidelines to the company. An additional benefit was that the participants had the opportunity to reflect upon issues that are rarely discussed, as they expressed it, which was highly appreciated.

The following questions were discussed:

- 1. What features would you like to have in a visualization tool?
- 2. In which areas is it possible to use a visualization tool?

During the first round the two questions were openly discussed before presenting them the suggestions. The objective was that the participants would not be influenced by the suggestions and were encouraged to use their creativity. The two groups came up with different inputs to the two questions that were discussed, which was the aim of separating the original group in two. The first group of three participants made a distinction between features regarding what can be considered graphics, and the content of a visualization tool. The second group focused more on pointing out possible features. Table 15 shows the results to the first question.

	Group 1 (three members)	Group 2 (2 members)
Gra	phics:	Content:
•	In axels: units, time	Overall dashboard for all projects
•	absolute values	 Visualize how the organization/network interacts.
•	control limits	 Risk management (D-FMEA, P-FMEA)
•	"are" vs. "should" values	At the individual level, measure the
•	current situation and trend.	impact/contribution of one's own performance.
Con	tent:	
•	Simulation about optimal status	
•	"Drill-down" tree	
•	being able make comparisons between different	
	things (project, machines, parts, etc.)	
•	Color coding.	

Table 15. Question 1: Feature	Table 15.	Question	1: Features
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What was important when discussing the different areas where a visualization tool could be used was that the purpose must be clear. It is not just about developing a new tool without having a real objective/goal that would bring benefits to the company. The tool(s) should provide a base for decision making, contribute to less errors and to reacting in time. The results to the second question are shown in Table 16.

Table 16. Question 2: Areas

	Group 1 (three members)		Group 2 (2 members)
•	Colored product variant, fixtures – less errors	•	Everything
•	Caster planning	•	At different levels
•	Information		
•	Decisions		
•	Almost anything if the purpose is clear		

During the second round, the suggestions that came from the quantitative and qualitative analyses were discussed. In general, the participants agreed with the suggestions that were presented, but could build on those and discuss pros (+) and cons (-), and even more importantly they could reflect upon what is feasible to do in terms of cost and efficiency. The first group discussed the suggested features in general and came up with important things to be considered, while the second group discussed each suggestion separately and built upon them. The results are shown in Table 17.

Table 17. Discussion of suggested features

Group 1 (three members)	Group 2 (2 members)
 Simulation: effect of different changes Drill down, connected data to next level Impact in safety critical areas Material sourcing: geographic representation of where the material is right now. Bottleneck impact, pros, and cons Automatic data update 	 VR or 3D: + cheaper to fail than in reality Could be used to visualize increments, bottlenecks, ergonomic evaluation. Whiteboard mode + Planning tool: + good, areas as PI planning could be improved Decomposition and lead time for different activities Real time update on key indicator: + Very important to get feedback directly Build in controls in the process e. g. UT ultrasound, or the robot can signal. Kanban board: + Exist only physically (e.g., trial run), good to digitalize it

The suggested areas were also discussed by the two groups, the first group was a little bit more critical about the suggestions since some of them were very specific and would be beneficial only for some areas, it was discussed the necessity to evaluate how valuable it would be in terms of cost and efficiency, is it a real need or just a desire? Having a clear purpose was once again lifted up. Some new areas were also highlighted as it is shown in Table 18.

Table 18. Discussion of suggested areas

Group 1 (three members)	Group 2 (2 members)
 Process indicators Add simulation: effect if change something Suggested proposals only available for a few, increase accessibility, connect Target group? SAP: Performance, impact on Quality, delivery time Connect to purpose, show/explain purpose on/with visualization Connect delivering time with accessible resources, e. g., fewer → longer time 	 New parts, working areas: Visualize new articles and activities that must be finished Which ones need extra quality controls What is going to be control How many outcome tests are in progress Visualize the flow

During the third and final round, the participants presented their feedback to the researchers. The focus group lasted about 150 minutes. It can be concluded that the focus group was very beneficial for both the researchers and the participants, since it led to validating most of the suggestions as well as identifying new features and areas for visualization tools. It also led to reflecting upon the topic, which is emphasized by the lean management and the design thinking practitioners. Another reflection from the focus group is that it is possible to conduct it with a mix of in place and online participants.

It can be argued why the results of the focus group are presented in the discussion part of this report, and not in the analysis, but as mentioned before, the Six Sigma methodology is quite flexible and allows for iterations and moving back and forth in the different phases. The researchers agreed to use the focus group as a part of the Control phase for validating the findings.

7. CONCLUSIONS

In this last chapter conclusions of the research are presented. The chapter is divided in three parts: general conclusions, reflection about the chosen research methodology, and future research. In general conclusions the research questions presented in chapter 1.3 will be answered followed by an objective reflection about the applied methodology. In future research, suggestions on possible future work and research will be presented in regard to both academic and industrial contribution.

7.1 General conclusions

The aim of the report was to identify important factors and flaws in the communication and collaboration in the NPD process in order to investigate the possibility of building and implementing an infrastructure that supports the information sharing. It was also of importance to investigate if a general visualization tool can serve as an instrument to help in the information sharing and decision-making. In this section the research questions will be answered.

RQ 1: What important factors and flaws in communication and collaboration are important to consider when building an infrastructure that can support the data/information flow?

There are multiple factors that are crucial to consider when building an infrastructure such as what organizational model the company is working according to (Waterfall, Agile, Hybrid etc.), the importance of including all employers' needs, who should have access to the different systems, the amount of standardization, what communication channels to use, informal and formal structures, how to transfer tacit and explicit knowledge, what storage system for information is going to be used and how to measure performance in order to be able to improve continuously.

The organizational model will serve as a base of how employees are able to communicate and to what extent. Waterfall and Agile models have their pros and cons, therefore a combination of them will probably enable a better infrastructure since it gives the advantages of them both. From the interviews it was clear that not everything is possible to standardize. Therefore, when building an infrastructure for the information flow it is important to consider what and how much should be standardized. Possible main areas in regard to Volvo CE are storage of information, project status and plans.

It is important that the infrastructure enables both tacit and explicit knowledge transfer since people have different tasks that sometimes require tacit and other times explicit knowledge. Redundancy is a way to transfer tacit and explicit knowledge since it creates communication and a common ground, it can also act as a quality assurance of the information. A use of multiple communication channels is preferable since the different channels are beneficial in different ways and are used for different purposes. The best way to make sure that the employees are satisfied by the communication channels is to ask and listen to them. The higher satisfaction the people have on the channels the better the communication will be, the more effective and successful the
company will be. It is also important to consider what storage system should be used since it is crucial in order to enable information sharing, in the system information should be stored in the same way so it is easy for the user to find it.

RQ 2: Is it possible to facilitate the information exchange by using a visualization tool that is useful for all users?

The research showed that it is not possible to facilitate one visualization tool that will be useful for all users since the people are in need of different data, information, and knowledge both tacit and explicit. A tool that would have given all the necessary information would need to include a huge amount of data and information. Therefore, it would have a need of a huge filter, so that the searchability will be difficult which will result in time waste for finding the right information and it will cause frustrations and an unused tool. However, using multiple visualization tools for different purposes in different areas is strongly recommended. For Volvo CE it is especially beneficial to use in the areas:

- New parts, working areas, layout, how parts should be kitted, packed.
- How the staffing situation looks.
- Status of what job is done.
- Time plan, project descriptions
- Product cost, different kinds of performance data from the field, quality measures.
- If requirements are fulfilled.
- Visualization of material graph in SAP.
- Price, why it differs if we do this or that.

It is crucial that the visualization tool presents the right information as well as enables the user to transfer the information into knowledge. Therefore, when constructing a visualization or showing different graphs it is important to consider the purpose of using it. Another very important consideration is that whatever visualization tool is decided to be developed, it must be cost-efficient in order to be worth the effort, since both time and money are decisive elements that should bring benefits for the company.

RQ 3: What kind of features are important to include in a visualization tool?

In a visualization tool the features that should be included are the ones that fit the purpose of visualizing the data or information, it will therefore vary from situation to situation and the context in which it is intended to be used. Therefore, a general conclusion of what features that are important to include is not possible to make. However, a list with the different features that were important for the employees working at Volvo CE that were pointed out in the survey, interviews and focus group is going to be presented below:

- VR or 3D
- Whiteboard mode on digital communication platforms

- Kind of planning tool
- Realtime update on key performance indicators.
- Go from picture to model with a good interface/transition.
- Kanban board
- Using colors and symbols to highlight
- Filter function to zoom in and out in the data.

As it was stated before, some of the features can be combined since they can complement each other. The researchers have previously made recommendations regarding desirable features to include in visualization tools. It is also suggested to further investigate the topic in order to make sure that the tools serve a purpose and are user friendly.

7.2 Reflection about the chosen research methodology

The Six Sigma DMAIC cycle in combination with business research methods were the chosen methodology for this research problem. Since Six Sigma is based on multiple quantitative tools as well as some qualitative tools, a mixed methodology was considered as being the best option. The methodology was also considered appropriate since the first scope of the problem was very broad and needed to be understandable and measurable in order to be able to improve the situation. The aim of the interviews was to get an understanding and a perception of the information and communication flow. A general semi-structured interview guide was constructed in order to make sure that the necessary data were collected and to be able to compare the answers. This interview guide was sent to the industrial supervisor to make sure that the questions were understandable and clear to the intended persons. Some minor adjustments were done before the interviews, and the interviewees got the interview guide one week before the appointment in order to be able to be prepared. However, it was noticed that some support functions had difficulties answering questions regarding the project. So, it would have been beneficial to do two different interview guides, one with project questions and one without. This did not affect the outcome that much since the interviewees could answer the general questions regarding communication, work procedure and improvement potentials, and skip the ones in regard to the project.

In total fifteen interviews were conducted, which could be seen as sufficient for the time the master's thesis lasted, and the fact that a quantitative research was done in parallel. The interviewees were chosen by the industrial supervisor that had a better view of the people involved in the L-350 project. Almost all the different functions included in the L-350 project were interviewed. If the few functions that the researchers could not reach had been interviewed, it might have fulfilled the expectations. However, all the departments were represented in a good manner in regard to what size each department has and their involvement in NPD projects. Therefore, the researchers do not think the missed functions have affected the main findings. The interviews were recorded and transcribed in order to better analyze the responses. An Excel file was prepared where all the responses were collected, sorted out and compared.

The quantitative data were collected through an online survey constructed in Google Forms. This survey was sent to the industrial supervisor for feedback before making it official, even here some minor changes were done mostly to shorten the time to answer the survey. It was a quite extensive survey in order to capture all the aspects that were needed, and therefore it was estimated to take around 30 minutes to complete. The interview was sent out by the industrial supervisor to all the included functions managers that were supposed to send out the survey to their employees, since the researchers believed that more people would respond if the survey came from the manager rather than two unfamiliar students. How many people the survey was sent out to is unknown, and unfortunately there were some problems with firewalls at Volvo CE that resulted in some issues for some people to get access to the survey. This was eventually solved but it can be one reason for the low response rate. Another reason could be that the purpose of the survey might get lost when the responsibility of sending out the survey was put in another person's hands. On the other hand, the researchers did not have the network or access to all these people, and it might not have resulted in more respondents if it came from two unfamiliar students. Due to the low response rate, it was not possible to draw any general conclusions of how all employees perceive the information flow, as it was desired. However, since the researchers used a mixed approach, it did not result in any lack of data and conclusions could be drawn together with the qualitative data.

The literature review was collected through the Chalmers library and Google Scholar, the snowball sampling method was used, meaning when finding a good source, the references in that article or book were looked for in order to find more information. Some literature was also collected from relevant courses that the researchers had participated in. The researchers believe that a sufficient amount of literature has been collected. In some topics there was a lack of articles such as Six Sigma tools like Effective Scoping, in these situations previous master's thesis and PowerPoint slides have been used. It was noticed that there is a lack of data in some of the tools that will be further described in the next section.

The researchers followed the DMAIC cycle during this master's thesis and as mentioned before this is not a straightforward process, sometimes you need to go back and revisit for example the Define phase. Then, it often turns out that what was stated as the problem and/or the goal at the beginning turns out to be something else at the end. This was the case in this research, in Appendix D it was stated that the realistic goal was to find key factors affecting the information flow and develop a visualization tool. The key factors were defined in the general conclusion, see above. However, a visualization tool was not developed since the researchers found out during the process that one single tool will not fulfill everyone's demands, and that the need for different types of visualization differs from situation to situation. Another reason was that there were no tools that could be removed and just adding one more without removing something else will put extra workload on the employees, which in the end does not solve the underlying problem. Therefore, it was decided to do not construct a visualization tool. Instead, guidelines of what to consider when constructing visualizations were created in order to guide the employees to improve the quality of the visualization that is used today. To conclude, the problem you have at the beginning might not

be the same at the end of a research therefore, it is important to be flexible, reframe the problem, and adjust it to the findings.

7.3 Future research

This last section will cover the researchers' recommendations for future research both for academic and industrial contributions. During the research there have been brought up some subjects and areas that are in need of further investigation. These will be presented in this section. As mentioned in chapter 1.4 Limitations, it is important to know how well the information process works in order to be able to evaluate and improve things based on facts. The current evaluation process was excluded from this study but is recommended to do future research on how the evaluation looks like today, and also how it could be measured in order to make improvements.

In this research some indicators were presented and discussed regarding how to measure the quality of the information flow. This also needs to be further investigated, both for the industry and the academic world. There exists a lot of research on how to measure quality in the healthcare sector but not to a large extent in the industry, and especially not in regard to the information flow. This is something the researchers found important to bring up since it could be good to see if the quality indicators proposed for healthcare are applicable in other areas as well.

Another area the researchers perceived as a gap in the literature was the Six Sigma tools that have been used. In the literature there are a lot of articles about the Six Sigma methodology, but the tools that are suggested to be used are not supported by scientific studies. More investigation in terms of scientific inquiries are needed. These would include seeking conceptual understanding based on existing theory, posing empirically testable hypotheses, and using methods that allow replication to verify their accuracy, and that enable generalization.

The researchers wanted to contribute to the academia by providing some ways to measure different indicators in the information flow, but these cannot be generalized since they are only based on a case study. More research is imperative to do in order to make generalizations. Nevertheless, the researchers successfully combined the Six Sigma methodology with Business Research Methods using a mix of quantitative and qualitative approaches, which is quite innovative and can be used for designing future research studies.

The purpose of this study was to investigate what flaws and factors that can affect the possibility to build an infrastructure that enables the information flow and to see if there was a tool that could be used in any case at Volvo CE. It has been concluded above that such a tool is not feasible to achieve since it is not possible to fulfill everyone's needs in one tool, and this would not be cost-efficient either. But possible areas, and some suggestions have been mentioned such as Kanban Board and VR. Therefore, possible future work for Volvo CE to further investigate are presented below:

What features and areas should be prioritized when designing one or more visualization tools? What is the purpose of this/these? Are they cost-efficient?

Is it possible to implement a digital Kanban Board in the NPD process?

Is it possible to implement VR even more than it is used today?

In what areas can VR be useful to implement?

Finally, there is a huge potential for further investigation of the topics, both from the academic and the industrial side, and the researchers hope that their small contribution can serve as a base for future studies.

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APPENDIX Appendix A: AIM AIM EXPECTATIONS

Optimal cooperation and communication as well as the necessary conditions on site are crucial to accomplish the desired outcome.



Appendix B: Is-Is Not Matrix

	IS - IS NOT ANALYSIS							
Problem definition:								
	IS	IS NOT	CHARACTERISTICS: In IS compared to IS NOT	CHANGES: In characteristics				
WHAT	Which are the specific objects?	What other similar objects could also have been defect, but is not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?				
	Information flow between different departments (External problems)	Internal/local information flow in the departments (our assumptions from meetings)	Location of the problem: External against internal problems in the information flow	Yes, location, culture, work load, attitude, pride				
	Technology							
	Operation							
	Purchasing							
	Which ones are involved?							
WHAT	Which is the specific defect?	Which other defects could also have been observed, but has not?	CHARACTERISTICS: In IS compared to IS NOT	CHANGES: In characteristic				
	Insufficient and unclear communication/collaboration	Lack of knowledge	The knowlegde exists in the company but how to use it and share it is missing	Yes, location, culture, workload, attitude, pride, awareness				
	Problems in cross-functional work	Knowing your own responsibility and role	Who to deliver/ask for the knowledge is unclear					

	Rework in terms of new meetings/emails etc			
	Unclear who to contact			
	Lack of common way of working/routines			
	Lack of common language			
	Knowledge about other departments' responsibility and role			
	Lack of visualization			
	IS		CHARACTERISTICS: In IS compared to IS NOT	CHANGES: In characteristics
WHERE	Where geografically can the object with the defect be observed?	In which other places could the defect also have been observed, but has not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?
	Bottleneck in Sweden? Operations - Purchasing - Technology (which one? all? in between?)	International communication/collaboration (we will not investigate this)	Located in Sweden in contrast to abroad collaboration	Yes, location, culture
	Physical and/or remote collaboration			
WHERE	Where on the object is the position of the defect? (Where is the spider in the net?/ the department with most information/communication flaws (bottleneck))	In which other positions on the object could the defect have been observed, but has not?	CHARACTERISTICS: In IS compared to IS NOT	CHANGES: In characteristics
	Spider in the net?			
	Specific department/s?			

	IS	IS NOT	CHARACTERISTICS: In IS compared to IS NOT	CHANGES: In characteristics
WHEN	When was the defect first observed?	At which other point of time could it have been detected, but was not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?
	Varilight (2010)? Lack of common concepts and definitions - made it difficult to elevate the question and zoom out to get the overall perspective. The issues were owned and driven by a sub- section of the organisation only.	Earlier	When a sub-section identified the issues for the first time	Yes, awareness on identifying the problem
WHEN	When since it was first detected has it been observed again? Is there a pattern?	At which other points of time since it was first detected could it also have been observed, but has not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?
	The problem remains or is recurrent (all the time or sometimes?)	Every time they have succeeded in a project (own assumption)	In the first case the project team is concious about the problem, in the second case only the successful final result counts	Yes, different evaluation patterns (more reflection about projects with problems that successful ones)
	3 dissertations, 2018 and 2019	Above needs to dubbelcheck with Volvo CE		
WHEN	When in the objects' lifecycle was the defect first observed?	At which other points of time in the objects lifecycle could the defect have been observed for the first time, but has not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?

	At the beginning? During the process (several loops?), at the end when the delivery is not in time?) When defined. It was a part of the variation in leadtime, quality etc. when control charts started being used on wheelers.	?	?	?
	Need to check with Volvo CE			
	15		compared to IS NOT	characteristics
EXTENT	How many objects (projects) have the defect?	How many objects (projects) could have had the defect, but has not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?
	It is a recurring problem (quantity)	Every time they have succeed in a project	A possible difference could be in the final evaluation of the result of the projects. Often a successful project does not attract the attention on detecting problems. The learning potential is bigger in project with failures.	Not necessarily, maybe the working process is the same but there may be other factors that could be affecting the outcome of the projects.
EXTENT	Which size has each defect?	What other sizes could the defect have had, but has not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?
	It varies from project to project	Bigger or smaller	Different size of the defect (our assumption)	?
	How to measure the size?			
	N/A? is there a KPI?			

EXTENT	How many defects are there on each object (project)?	How many defects could it have been on each object (project), but is not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?
	Unknown	Unknown	?	?
EXTENT	What is the tendency?	Which other tendencies could it have been, but is not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?
	Use the same patterns, habits/way of working	Laziness	There is not bad intentions behind the tendencies in the first case, maybe the right motivation is not in place. The departments/people do not have the same goals.	Not really, the non-observed tendencies are more related to personal characteristics and the observed ones can arise due to lack of common ways of working/tools, etc.
	Unwillingness to change	Untidiness		
	It is not a priority	Negligence		
	Not included in your duties			

	IS - IS NOT ANALYSIS							
Problem definition								
	IS	IS NOT	CHARACTERISTICS: In IS compared to IS NOT	CHANGES: In characteristics		ACTIONS TO COLLECT FACTS		
WHAT	Which are the specific objects?	What other similar objects could also have been defect, but is not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?		What data do we need to collect in order to confirm the assumptions		

	Information flow between different departments (External problems)	Internal/local information flow in the departments (our assumptions from meetings)	Location of the problem: External against internal problems in the information flow	Yes, location, culture, workload, attitude, pride	Qualitative data: Interviews, observations (Gemba walks), AIM workshops, Surveys
	Technology				Volvo: Is it more departments involved e.g., design? or how are the three departments divided?
	Operations				
	Purchasing				
	Which ones are involved?				
WHAT	Which is the specific defect?	Which other defects could also have been observed, but has not?	CHARACTERISTICS: In IS compared to IS NOT	CHANGES: In characteristics	What data do we need to collect in order to confirm the assumptions
	Insufficient and unclear communication/collaborati on	Lack of knowledge	The knowledge exists in the company but how to use it and share it is missing	Yes, location, culture, workload, attitude, pride, awareness	Qualitative data: Interviews, observations (Gemba walks), AIM workshops, Surveys
	Problems in cross- functional work	Knowing your own responsibility and role	Who to deliver/ask for the knowledge is unclear		
	Rework in terms of new meetings/emails etc.				
	Unclear who to contact				
	Lack of common way of working/routines				
	Lack of common language				
	Knowledge about other departments' responsibility and role				
	Lack of visualization				
	IS		CHARACTERISTICS: In IS compared to IS NOT	CHANGES: In characteristics	ACTIONS TO COLLECT FACTS
WHERE	Where geographically can the object with the defect be observed?	In which other places could the defect also have been observed, but has not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?	What data do we need to collect in order to confirm the assumptions
	Bottleneck in Sweden? Operations - Purchasing - Technology (which one? all? in between?)	International communication/collaborati on (we will not investigate this)	Located in Sweden in contrast to abroad collaboration	Yes, location, culture	 Qualitative data: Interviews, surveys, AIM workshops

	Physical and/or remote collaboration				
WHERE	Where on the object is the position of the defect? (Where is the spider in the net?/ the department with most information/communication flaws (bottleneck))	In which other positions on the object could the defect have been observed, but has not?	CHARACTERISTICS: In IS compared to IS NOT	CHANGES: In characteristics	What data do we need to collect in order to confirm the assumptions
	Spider in the net?				Qualitative data (interviews, surveys, AIM) in order to build a model/map
	Specific department/s?				
	IS	IS NOT	CHARACTERISTICS: In IS compared to IS NOT	CHANGES: In characteristics	ACTIONS TO COLLECT FACTS
WHEN	When was the defect first observed?	At which other point of time could it have been detected, but was not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?	What data do we need to collect in order to confirm the assumptions
	Varilight (2010)? Lack of common concepts and definitions - made it difficult to elevate the question and zoom out to get the overall perspective. The issues were owned and driven by a sub-section of the organization only.	Earlier	When a sub-section identified the issues for the first time	Yes, awareness on identifying the problem	Qualitative data: Interview with Anna and/or other stakeholders
WHEN	When since it was first detected has it been observed again? Is there a pattern?	At which other points of time since it was first detected could it also have been observed, but has not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?	What data do we need to collect in order to confirm the assumptions

	The problem remains or is recurrent (all the time or sometimes?)	Every time they have succeeded in a project (own assumption)	In the first case the project team is conscious about the problem, in the second case only the successful final result counts	Yes, different evaluation patterns (more reflection about projects with problems that successful ones)	Qualitative data: Volvo CE: Question about how the evaluation process works, what worked well?
	3 dissertations, 2018 and 2019	Above needs to double check with Volvo CE			
WHEN	When in the objects' lifecycle was the defect first observed?	At which other points of time in the object's lifecycle could the defect have been observed for the first time, but has not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?	What data do we need to collect in order to confirm the assumptions
	At the beginning? During the process (several loops?), at the end when the delivery is not in time?) When defined. It was a part of the variation in lead time, quality etc. when control charts started being used on wheelers.	?	?	?	Qualitative data: Volvo CE: Need more information about WHEN the problems with communication/informatio n flows arise in the process
	Need to check with Volvo CE				
	IS	IS NOT	CHARACTERISTICS: In IS compared to IS NOT	CHANGES: In characteristics	ACTIONS TO COLLECT FACTS
EXTENT	How many objects (projects) have the defect?	How many objects (projects) could have had the defect, but has not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?	What data do we need to collect in order to confirm the assumptions
	It is a recurring problem (quantity)	Every time they have succeed in a project	A possible difference could be in the final evaluation of the result of the projects. Often a successful project does not attract the attention on detecting problems. The learning potential is bigger in project with failures.	Not necessarily, maybe the working process is the same but there may be other factors that could be affecting the outcome of the projects.	Quantitative data: VOLVO CE: Need more information about HOW MANY projects that have the "defect", does it exist data on this?

EXTENT	Which size has each defect?	What other sizes could the defect have had, but has not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?	What data do we need to collect in order to confirm the assumptions
	It varies from project to project	Bigger or smaller	Different size of the defect (our assumption)	?	Qualitative/quantitative data: VOLVO CE: Need more information about effects of bad communication/informatio n flow in projects, HOW/IF is it measured today, HOW/IF they have any KPIs in regard to this
	How to measure the size?				
	N/A? is there a KPI?				
EXTENT	How many defects are there on each object (project)?	How many defects could it have been on each object (project), but is not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?	What data do we need to collect in order to confirm the assumptions
	Unknown	Unknown	?	?	Quantitative data: VOLVO CE: Need more information about HOW MANY projects that are struggling with collaboration/communicati on, is it every project, small projects, big projects etc.

EXTENT	What is the tendency?	Which other tendencies could it have been, but is not?	What is the difference in characteristics between IS and IS NOT?	Does this indicate that a change has taken place?	What data do we need to collect in order to confirm the assumptions
	Use the same patterns, habits/way of working	Laziness	There is not bad intentions behind the tendencies in the first case, maybe the right motivation is not in place. The departments/people do not have the same goals.	Not really, the non- observed tendencies are more related to personal characteristics and the observed ones can arise due to lack of common ways of working/tools, etc.	Qualitative data: Interviews with key persons from the involved departments at Volvo CE, observations at the workplace if possible
	Unwillingness to change	Untidiness			
	It is not a priority	Negligence			
	Not included in your duties				

Appendix C: Effective Scoping

Process owner (org):	VOLVO CE	Project sponsor:	CHALMERS	Six Sigma champion, MBB:	PETER HAMMERSBERG	
Effective Sco	ping of continu	uous improven	nent projects elow, is key to facilitate const	ensus in the shift of an organ	isation's mindsets from push to pull, in accordance w	ith the principles of
Supplier	Ing	out	Process Output		Output	
8b. Who supplies the inputs?	8b. Who supplies the inputs? Q8a. What are the inputs Q9. What does the system? inputs? Q9. What does the system require of the inputs?		Q7a. Team/project jurisdiction of changes	Q1. What comes out (of the physical flow) - OUTPUT?	Q3. What is required of the output from this particular user (List of big Y's and improvement proposals)	Q2. Who uses the output?
End user Buyer Suppliers (material, machinery, etc.) /olvo CE engineers Previous master thesis workers	x1: Customer requirements x2: Information/knowledge from suppliers x3: Information/knowledge from involved denatmente	Product specification Customer's willingness to pay Suppliers' part specification Suppliers' delivery time and ocet	Unknown	Information/Knowledge in terms of a CAD drawing and a report. Infrastructure to facilitate information and knowledge exchange.	Y1: Productivity in industrialization phase Y2: Delivery precision of information Y3: Quality of information Y4: Improve common way of working (routines) Y5: Improve common language/collaboration Y6: Clear visualization	Final customer: Manufacturing manager. Involved departments Technology, Operation and Purchasing
Government Top Management International committees	A4: Knowledge from previous projects x5: Knowledge from previous master thesis x8: Governmental regulations x7: Company regulations x8: International	Accurate and precise information In-time information Contact with right/key person Stored previous knowledge Laws, policies	Q7b. What competences are needed in the team (WHO)?		L44. What ONE MEASURE (Y) should be understood and improved? The y that scope the project and drive further exploration. Each small y has its own underlying system of influencing parameters, sometime overlapping. Use one template per y to reduce complexity Scope on y (not x - upstream) and don't proceed until Q1-Q4 is thoroughly understood!	
	standards x8: Company standards x10: New technologies	Upcoming changes in laws Company's manuals, guidelines, security issues Technical standards Information about company standards	General Manager Operations Arvika: Mikael Liljestrand VP Wheel Loader Product Platform: Emma Verner Director Purchasing Operations Europe: Ove Kempe		y1: Lead time between milestones/meetings' hours y2: Response time y3: Quality index (usability, clarity, etc.) y4: Degree of consciousness of common way of working y5: Degree of collaboration y6: Degree of own understanding	4.
		Updated knowledge of new technologies	Name of the underlying system that build up the y to be improved:		Q5. What is the baseline of the y and can that precis y be measured today (and can old data be trusted)? In other words: What is the facts behind the problem that form the base for our improvement promise? Show the data/proof of a problem!	
			Information flow		y1: data can be found and trusted y2: no data available, data can be estimated using a survey/interview. y3: no data available, data can be estimated using a survey y4: no data available, data can be estimated using a survey y5: no data available, data can be estimated using a survey/interviews y6: no data available, data can be estimated using a survey/interviews	
			From where is the physical output shipped?		Q6. What other Y can not be lost in the process (constraints)?	5
			New Product Development Process Top Management (mentioned above) must approve the new infractment into		Improve productivity in industrialization phase but do not loose the quality of information. Improve clear visualization but do not loose the common way of working.	

Appendix D: Project Charter

Project charter

Project title: Volvo Construction Equipment (TBD)

Unit Department: Quality and Safety

Executive		Senior Deployment Champion	
Deployment Champion	Volvo Group: Volvo CE	Project Champion	Anna Ericson Öberg
Master Black Belt	Peter Hammersberg	Finance Champion	N/A
IT Champion	N/A	HR Champion	N/A
Responsible Black Belts	Lovisa Arnoldsson Karen Carbonell	Telephone/e-mail	
Sponsor & process owner	Marcus Nävehed Henrik Gustavsson	Site or location	VCE
Project Start Date	January 2021	Project completion Date	June 2021
Expected impact level		Expected financial impact (savings/revenues)	TBD

Element	Description	Charter
1. Delivery affected	A short description of what is affected	Mismatch in the information flow and cross- functional work, insufficient/complex communication, and collaboration between departments

2. Benefit to customers	Define internal and external customers (most critical) and their requirements	 Internal customers: Invo Technology, Purchasing Benefits to the process of Shorter lead time validation monito Shorter lead time visualization, and Higher quality or decision support Reduced cost on and info-prop Better decisions industrialization External customers: Use (wheel loaders) Benefits: Better quality, 	olved Departme and Operations owner: e setting-up pro oring e data processin a analyses n information an communication faster (in the phase) ers of Volvo CE' shorter deliver	ents- 5. oject ng, nd stronger n, meetings, s products y time
3. Benefit to the business	Describe the expected improvement in business performance	Less complaints, improved quality experience and lower quality related costs.		
4. Measure to improve Define the baselines, your realistic goals for the project and the best-case targets for improvement.	Define the baselines, your realistic goals for the project	Actual value (baseline)	Realistic goal by project end date	Best case goal
	Vague standardization of Interaction channels and infrastructure between involved departments in the feedback loops	Find key factors affecting the information flow and develop a visualization tool	Test and implement a standardized information flow method and a visualization tool	
5. Impacted process	The specific processes involved in the project where changes can be implemented	Communication and information flow between different departments. Design, Product Development, Manufacturing, Quality, Purchasing, Operations, etc.		
6. Team members	Names of the participants in the project (area of competence)	Karen Carbonell, Lovisa	Arnoldsson	

7. Other people involved	List technical experts and other people who will be part of the team (area of competence)	Peter Hammersberg Anna Ericson Öberg Marcus Nävehed Henrik Gustavsson
8. Project delimitations	What will be excluded from the project	TBD
9. Required support	Support in terms of resources (human and financial) required for implementing changes	Support for data collection in terms of Gemba walks in the factory (Arvika), interviews, observations, workshops, etc. Access to human resources in form of contacts with key persons (see 5. Departments involved) and eventual mentoring. Access to appropriate software via Volvo CE for developing a visualization tool.
10. Project summary	A short description of the project	Identify important factors and flaws in communication in order to standardize the information flow. Develop and test a general and concrete visualization tool that can be applied to any case.

DEFINE phase completion date	TBD	MEASURE phase completion date	TBD
ANALYZE phase completion date	TBD	IMPROVE phase completion date	TBD
CONTROL phase completion date	TBD	PROJECT results presentation date	TBD

Appendix E: Data Collection Plan

1) What data will be collected?

- Quantitative data to get a general view of the communication and collaboration in regard to the information flow.
 - What needs to be improved?
 - The perception of a visualization tool.
- Qualitative data to get a deeper understanding of why the communication and collaboration in regard to the information flow work the way they do.
 - To compare the perceptions and to find out what improvements can be made.
 - Their perception of a visualization tool.

2) Where can this data be found?

• At Volvo CE, in the departments Operations, Technology and Purchasing.

3) When should it be collected?

- Quantitative data in terms of a survey at the end of March to May 2021.
- Qualitative during April 2021.

4) Who should collect the data?

• The researchers with help from the industrial supervisor regarding the survey

5) How should the data be collected?

- Quantitative through survey
- Qualitative through in-depth interviews, observations, and a focus group
- Due to the circumstances mostly online, through Google Forms and Teams

Appendix F: Semi-Structured Interview Guide

OPENING QUESTIONS

1. Could you present yourself

- Which department do you work in?
- What are your responsibilities at Volvo CE?

2. How many times have you visited the Arvika plant?

- If never why?
- (If many times) why?

BODY

Working procedure and Information process

1. Could you describe the working procedure and collaboration your department has with other departments and functions in regard to the information that is shared?

2. Can you describe the steps in the information sharing/exchange in the NPD process in detail (in regard to L350)?

- Which step(s) do you perceive as most time consuming and/or unnecessary?
 - What steps in the process could be removed?
 - What steps in the process could be more effective/improved?
- Which step(s) do you perceive as most valuable/creates most value?
- Are there any natural or unnecessary waiting periods (or interruptions) in the information transaction?
- Value Stream Mapping (VSM):
 - Which contacts add value to the information sharing/exchange process?
 - Which is the normal lead time for information sharing/exchange process?
 - Is there any waiting time? If so, how long does it take? And from which departments?
- 3. Describe the timeliness of the information when you work in a project
 - what is necessary (not to halt production or prolong industrialisation)?
 - what is good to have but not entirely necessary?

4. Describe what makes you most proud/stimulated and is interesting with the information exchange you do today?

5. How do you feel about the standardization of information and information sharing system?

6. Would it be any issue/problems if the information you share is standardized?

7. What are the key elements of the current information sharing system (SharePoint, method, structure where the information is stored)?

- How do you perceive Product Criticism in SharePoint?
- How do you perceive Design Review?

- How do you perceive the Verification and Validation plan?
- Are there any redundance in the different systems? (You need to fill the same information in different places)

Communication and collaboration between the departments (Technology, Operations and Purchasing)

1. Describe how your department collaborates with other departments and functions in NPD (intern and extern)?

- Who do you collaborate with?
- Does it differ between departments/functions?
 - If so, why? In which way (what differs)?
- When do you need to collaborate with other departments/functions?
- How do you perceive the collaboration with other departments/functions?
 - Why do you perceive this?
 - Where does this collaboration take place?
- 2. Do you have any clear work procedure or documented material of it?
 - Is it push or pull-driven?
 - Who has the mandate to make decisions?
 - Can you describe the work procedure in NPD in the L350 project?
- 3. If there is no clear work procedure, can you describe the connection in detail?
- 4. About the current process, how do you and the other departments communicate?
- 5. How often do you exchange information/communicate with other departments?
- 6. How often do you have follow-up meetings with other departments in regard to projects?
- 7. Where do you usually have meetings with other departments? (Physical or digital location)
- 8. Which departments are usually involved in these meetings?
 - What are the most common conflicts or problems in these discussions? How do you solve them?

9. Is there any collaboration between your department and Arvika plant? Do you have any problem in this process?

10. What information do you think the other departments need from you? (Specify departments)

11. Is there any communication problem even in the internal sub-departments in your department?

- (If yes) What kind of problems?
- 12. What kind of communication problems with other departments can occur?
 - How do you deal with these problems?
- 13. What is the major bottleneck in the communication system today?
- 14. Is there commonly any information loss in collaboration with other departments?
 - If so, how do you solve it?
- 15. Is there any information loss in the communication with the Arvika factory?
 - If so, what do you think could help to improve it?

16. Are there any differences in culture between departments in collaboration and communication issues?

- If so, how do you handle these?

Capability

1. What goals does your department strive for when you start a new project (think L-350)? Are they in line with Volvo CE main goals?

- Have the goals in L-350 been clearly defined?
- 2. What data/information in the L-350 project do/did you need from other departments?

3. How often do/did you collect data/ information from other departments in the L-350 project?

- How many contacts do/did you have to reach to get what you need?
- 4. How do you collect the data/information?
- 5. How do you perceive the process of data collection?
- 6. Do you encounter any obstacles when you try to retrieve the data you need?
- 7. Is all the data you get from other departments relevant for your work?
 - If no, what data is not relevant?
- 8. How do you perceive the quality of the data/information you get from other departments?

9. How dependent on other departments' data/information do you feel you are in order to perform your work?

10. Is your work being affected by missing data?

- If yes, in which way?
- 11. What would free up most time for you?

12. How does the time schedule go from your department to others? Is it always on time or is there any problem in this aspect?

- If it is not always on time, what could be the main reasons?

13. What kind of information do you mostly work with?

- New/unique questions or reuse routine information (information that already exist) 14. What is interesting/important for you (your role) in the communication with other departments?

15. What is interesting/important for the whole organization in your communication with other departments?

Improvement potential

1. Do you think there is a future improvement potential in this communication/information sharing process in NPD?

- If yes, in which way?

2. Do you have any own ideas of how to improve communication/information flow in NPD between departments?

3. Describe the ideal future of your communication with others?

4. Do you think a visualization tool will be beneficial for your work?

- If so in which way?

Visualization tool: a figure that helps you to see the process development. Visualization tools that could be used for visualizing the information in for example product criticism, verification and validation plan, Design review or from measure protocols.

5. If you had the possibility to choose, what kind of features would you like to have/see in a visualization tool?

6. In which contexts do you think you will make a good use of a visualization tool?

7. Do you think this kind of tool can contribute to improving the performance in your department?

- If yes, in which way?

8. Do you think this kind of tool can improve the collaboration between departments?

If yes, in which way?

9. Which kind of advantages or disadvantages can you see when using this kind of visualization tool?

- Why do you think so and in which area?

10. What kind of information that you handle do you think is possible to visualize?

11. What do you see in these pictures? From which picture do you get the most information from? Would you have some use of this way of presenting information?

From Excel table:





To this way of presenting information:



Shaped Plot with Variation represented with dimension and color

CLOSING QUESTION

Do you have something else you would like to add?

Appendix G: Interview Schedule

Date	Time	Department/role
14/4	10:00 - 12:00	PPD Project Haulers & Wheel loaders (PURCHASING)
14/4	14:00 - 16:00	Product maintenance & NPD (TECHNOLOGY)
15/4	10:00 - 12:00	UPP Uptime & Quality (Product Maintenance) (TECHNOLOGY)
15/4	14:00 - 16:00	WLO Mechanical and Simulation Engineering, Senior Specialist Sound & Vibration (TECHNOLOGY)
16/4	14:00 - 16:00	GPE Platform (TECHNOLOGY)
19/4	14:00 - 16:00	Purchasing Arvika, Buyer (PURCHASING)
20/4	10:00 - 12:00	Logistic (OPERATIONS)
20/4	14:00 - 16:00	Regional Commodity Supplier Development Manager EE, Cab, SMP & P - Europe (PURCHASING)
22/4	10:00 - 12:00	Quality, Purchasing, Supplier Development Engineer (OPERATIONS & PURCHASING)
22/4	13:00 - 15:00	Fabrication/Assembly (OPERATIONS)
23/4	10:00 - 12:00	AH Engineering, VPD (Virtual Product Development) Calculation engineer (TECHNOLOGY)
26/4	14:00 - 16:00	WLO Engineering - Powertrain installation, Development Engineer (TECHNOLOGY)
27/4	10:00 - 12:00	UPP Diagnostic & Service Engineering Eskilstuna, Method Technician (TECHNOLOGY)
28/4	08:30 - 10:30	WLO Powertrain Installation, Manager R&D/Construction (TECHNOLOGY)
28/4	14:00 - 16:00	AH Engineering Structure, Design Engineer (TECHNOLOGY)

Appendix H: Participants' background Focus Group May 27

Department	Role	
Operations Arvika - Quality	Head of Core Values ARV	
Operations Arvika - Quality	Head of Quality Engineering ARV	
Operations Arvika - Production Engineering -	Production Engineer	
Fabrication Engineering		
Operations Arvika - Production Engineering -	Head of Assembly Engineering ABV	
Assembly Engineering	Head of Assembly Engineering AKV	
Operations Arvika - Quality	Project Quality Manager Operations	

Appendix I: Guidelines

This guideline aims to serve as a short handbook about how to tailor-make information in a more standardized way in terms of visualization and quality indicators.

VISUALIZATION

This guideline is for everyone that uses and/or constructs visualizations in their work to show for others. It aims to guide and help construct accurate and good visualization.

1. What is the purpose with the visualization?

What do you want to show:

Comparison, Distribution, Composition, Relationships, Process, Create discussion etc.

Depending on what you want to show, and the purpose different tools fit for different situations. In the figure below you can see when to use some of the suggestions above.



Chart Suggestions—A Thought-Starter

www.ExtremePresentation.com © 2009 A. Abela — a.v.abela@gmail.com https://extremepresentation.typepad.com/files/choosing-a-good-chart-09.pdf?fbclid=IwAR0ODbCtOUpvIMBYXIXyPys1c4rGyQlKIGNKJvGGZiW7JkxjXF mXOOKuNEY

2. Who is the receiver of the visualization?

What knowledge does the receiver have of the subject? Depending on the knowledge of the receiver you might need to add explanations to the figure or visualization.

3. Check list

After deciding the purpose and who the visualization is for, it is important to consider the structure of the visualization. Here are some important things to consider when using visualization for data. It is based on Iliinsky and Steele (2010), Alhadad (2018) and Evergreen and Emery (2021).

Text:

- □ Have important information bigger, bolder, brighter, or more detailed.
- □ Have less important information presented with less intense colors or lighter lines.
- \Box Have a descriptive title with 6-12 word
- \Box Use a subtitle when need of providing additional information
- □ Hierarchical text size is preferable (title bigger than subtitle)
- □ Labels should be close to the data
- □ Do not use too many labels, it can take away the focus from what you really want to show.

Arrangement:

- □ If the information can be used independently, slide along relevant divisions, divide larger datasets into multiple similar or related visualizations.
- □ Use accurate proportions so it is possible to measure the length or area in the visualization
- \Box Use an order to present the data that is logical to the viewer.
- \Box Use the same unit/space between axes.
- □ Avoid using clipart or other illustrations in graphs. Colors:
- \Box Use colors AND symbols that support/explain the color.
- $\hfill\square$ Use standardized colors from your organization.
- □ Action colors should guide the viewer to key parts of the display
- □ Avoid using colors that are hard to separate if you are color blind, such as yellowblue or green and red in the same chart. If it is unavoidable add symbols that explain the same thing.

Lines:

- □ Use axes in both qualitative and quantitative data.
 - Qualitative axes can be defined as unranked or unordered areas or groupings.
 - Quantitative axes provide information and support search for relevant values.
- \Box Use one x- and one y axis for best interpretation.

Overall:

- □ Use organization standard symbols for showing for example directions.
- □ Adopt the precision to the receivers. Make it understandable.

4. Check the quality of the visualization

The above mentioned things to consider can be checked and evaluated in the link: <u>https://stephanieevergreen.com/wp-</u> <u>content/uploads/2020/12/EvergreenDataVizChecklist.pdf?fbclid=IwAR0Bcubk93FA5JT</u> <u>FLGDiMUzOufcyhOgIkL9nFdf5WD2X4qvxX7Wb2acsqZg</u>

5. After a use of a visualization tool

Ask the receiver for feedback!

QUALITY INDICATORS

This guideline aims to give recommendations when constructing a survey to measure the quality of information in the organization. The guidelines are built on the master's thesis written by Arnoldsson and Carbonell (2021).

- 1. To measure the quality of the information, the use of survey data is recommended.
- 2. Periodical surveys could be conducted targeting the departments and functions that are decided to be included.
- 3. The frequency of the survey is decided by the stakeholder.
- 4. Different variables that can compose a common quality index must be considered.
- 5. Some suggested variables:
 - a. Usefulness
 - b. Importance
 - c. Understandability
 - d. Reliability
- 6. Formulate questions based on the chosen variables.
- 7. Some examples of questions:
 - a. How useful is the information from (department/function)?
- b. How important is the information you receive from (department/function) for completing your work?
- c. How understandable is the information from (department/function)?
- d. How reliable is the information from (department/function)?
- 8. Use rating scale questions. The question displays a scale of answer options from any range. The suggested range is 1 to 5, where the different criteria are rated in ascending order. The respondent selects the number that most accurately represents his/her response.
- 9. With numerical rating scale questions, it is important to give the respondent context. Formulate clear questions and explain the value of the numbers on your scale.
- 10. Quality indicators are constructed based on the results of the survey.

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