CHALMERS
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Towards an Excellent Vehicle Damage Centre

Improving internal operations based on measures intended to increase customer satisfaction

Master's thesis in Quality and Operations Management

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Abstract

This project has been performed in collaboration with Bilia AB, which sells vehicles and offers aftermarket services. The topic for the thesis is within their damage centers that repairs vehicles damaged in collisions or due to vandalism. The dominating customer for authorized damage centers are insurance companies. The amount of labor that insurance companies pay for a repair is based on time studies from similar damages. This means that for a damage center to be profitable they must work efficiently. In essence, a damage center's processes and their performance are vital for profitability as they get compensated for a fixed amount of time. Insurance companies often have agreements with several competing damage centers. Meaning that a damage center also needs to satisfy the insurance companies needs in order to get an inflow of damaged vehicles.

Each damage center is operated by a manager who has a high autonomy when it comes to how the damage center is run. This relates to how the daily work is conducted and organized, what metrics that are used, and how the damage centers performance can improve. This can partly be explained by the different prerequisites in terms of shop floor layout and the investments that have been made in equipment and technology. This has resulted in a non-standardized process among the organizations' damage centers. Due to the differences, it is difficult to gain insight of what the key factors are that result in a high profitability. Currently, the company is monitoring the process symptoms (economic measures). Meaning that it is difficult to gain an understanding of what causes that have led to those economical results.

The purpose of the project is to expand the current knowledge about the damage center process and express what the driving factors are that result in a high-performing damage center. During the project, improvement opportunities and best practices are intended to be identified. To achieve the purpose the project consisted of a literature review, 21 semi-structured interviews with the organization, nine damage center visits, and one workshop. In addition, process data and current economic measures have been analyzed throughout the project.

Based on the results of this study, it is not currently possible to be certain that the main factors that result in a successful damage center have been identified. This can partly be explained by the result of the measurement system analysis that showed that it did not capture the process performance, and that the data is unreliable. It can also be explained by the lack of operational KPIs that exist today. However, based on theory and interviews a set of new operational KPIs is presented that are intended to explain the difference in performance between damage centers. An important finding is that the managers and employees of the damage centers are unaware of the importance of the customer needs (especially repair lead time). The developed operational KPIs are intended to help damage centers to decrease the repair lead time, while increasing their efficiency. Repair lead time is a customer need that insurance companies use to evaluate damage centers performance, meaning that it affects their hourly wage and presumably also the inflow of vehicles. The analysis showed that there are no clear trade-offs to achieve high resource efficiency and a high flow efficiency at the same time, rather the opposite. Meaning that decreasing the repair lead time will likely result in a higher resource efficiency. Lastly, best practices are proposed based on both the project's findings and theory. However, these have not been tested.

KEYWORDS: Damage Center, Lean Six Sigma, Efficiency Paradox, Customer needs

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1. Introduction

This chapter starts by describing a background about the case company and an introduction of the area that the thesis is written within. It follows by a description of the problem, the purpose of the study and research questions that will aid the project to achieve its purpose. Lastly, the chapter ends with a description of the delimitation of the project.

1.1 Background

Bilia AB describes itself as a one-stop-shop offering everything related to owning a vehicle (Bilia, 2020). They are one of Europe's largest car dealers with a leading position within service, sales of cars, transport vehicles and heavy trucks, and supplementary services such as financing and insurance (Bilia, 2020). The majority of their net turnover is generated by sales of vehicles, while the majority of generated earnings comes from the aftermarket activities. Meaning that the aftermarket activities are important in pure economical terms for Bilia (Bilia, n.d). However, the sales of new and used vehicles is strategically important to build a relationship with the customer, who will need maintenance and repairs after the purchase of a vehicle.

New passenger cars sold in Sweden include a "vagnskadegaranti" during the first three year (konsumenternas, 2019). Technically, "vagnskadegaranti" is a guarantee free of charge that only exists in Sweden. But from the customer's point of view, it is identical to an insurance that covers the repair cost in case of a collision or vandalism. The customer needs to pay the liability amount to the specific insurance company depending on vehicle brand if the vehicle is repaired. After the first three years, customers can buy an insurance for their vehicle to cover the repair cost (konkurrensverket, 2019). This means that there is a very large market for companies that repairs damaged vehicles, since all new vehicles are insured against damages. This means that for an authorized damage center, the dominating customer is the insurance companies. There are several competitors on the market which means that the insurance companies have the possibility to choose which authorized damage center they want to route vehicles to. The routing of vehicles to damage centers is explained by insurance companies to be based on geographical proximity (between the end-user's home address and damage center). But of course, damage centers that fulfill the needs of the insurance companies will get a greater inflow of vehicles.

To be able to repair a damaged vehicle for an insurance company in Sweden a computer software called CABAS must be used (konkurrensverket, 2019). The software is based on time studies and insurance companies pay for the time that is required according to the calculation. The insurance companies that dominate the market in Sweden own CAB Group, that are responsible for the time studies and CABAS (konkurrensverket, 2019). Since it is the customer (insurance companies) that are responsible for the time studies, they have an interest in a low (but fair) time. In essence, this means that a damage center cannot decide the price of their provided service. However, there are two ways for a damage center to increase their profitability. The first way is to continuously increase their efficiency to be able to work faster than the calculated time based on the time studies. The second way that a damage center can increase its profitability is to negotiate a higher hourly compensation with the insurance companies.

1.2 Problem description

Each damage center owned by Bilia AB is operated by a manager who is allowed to operate and design the damage center processes with a large degree of freedom. The damage centers manager reports to the regional operations manager that in turn reports to the central organization. The gained understanding indicates that if a damaged center performs well in terms of economic measures and customer satisfaction (both end customer and insurance company) no one will interfere with the damage centers process. Naturally, their damage centers must support the overall company strategy and vision. For Bilia, one aspect of the business that is deemed important is the front office operations. Thereby damage center managers do not have the autonomy to design them as freely as the back-office operations. Based on interviews, it seems like regional operational managers and the central organization does not systematically try to define and transfer processes and ways of working from good-performing damage centers to those that do not perform well. In fact, they rarely know how individual damage centers operate or their performance apart from economical results.

All damage centers have different prerequisites to perform well. Based on information gained through interviews and factory visits, factors such as car brand (which influence availability of spare parts, price, and repairability), and geographical area (customer base) are external reasons for a non-standardized process. However, there are also internal differences between the damage centers such as factory layout, size, if incentive wage is used (and what it is based on), and investments in machines and technology. These different prerequisites, some argue, are the reason that the process cannot be standardized.

The high autonomy and different prerequisites have contributed to a non-standardized process which makes it difficult to gain insight into what the key factors are that contribute to a repair shop that yields good results. The black box metaphor can be said to be applicable for a specific repair center. One key factor that has been mentioned and agreed upon in the organization is good leadership. Although two repair centers that seemingly have identical prerequisites, they can yield different economical results beyond random variation. In cases like these, there must be more explanations beyond leadership. Because of the differences in processes between repair centers, it is possible to identify best practice hypotheses from single damage centers and later implement and test the hypothesis at damage centers that currently work differently.

Today, damage centers are mainly monitored by efficiency and gross profit margin per function (sheet metal and paint), contribution margin for the whole damage center, and the cost items. Decisions are taken upon the result of these economical KPIs. According to employees in the organization, the financial statements can be used to get an understanding of the results and what actions are needed to improve the operations.

One can argue that the company is being reactive and tends to focus on and monitor the process symptoms (efficiency and gross profit margin per function, and contribution margin). The company does not have sufficient information or tools to be able to monitor and focus on the operational activities that lead to the economical results. This problem can also be based on an organizational culture that is short-term and economically focused.

This way of working has led to a lack of understanding regarding what the key factors are that result in a high performing damage center. Difference in performance between damage centers is currently mainly explained by “good leadership”. To understand the key factors that lead to good economical results, the company wants to focus on operational data. They have signed a deal with the service provider for the computer software CABAS and CabPlan (booking system). This means that Bilia possesses all relevant data from their operations, including data of sub steps in the process.

1.3 Purpose

The purpose of the project is to expand knowledge about the damage center process and express what the driving factors are that result in a high-performing damage center. During the project, improvement opportunities and best practices are intended to be identified. Further, the project group aims to validate the quality of the current dataset in order to develop operational KPIs.

1.4 Research question

The three following research questions have been developed with the aim to achieve the purpose:

RQ1: What is the current state of the organization regarding process improvements?

RQ2: What can be considered best practice for Bilia's damage centers?

RQ3: How can the organization work to reduce repair lead time without negatively affecting the efficiency?

1.5 Delimitations

Based on theory, qualitative and quantitative data analysis, operational KPIs and best practice are only proposed and not tested during the project. Meaning that it cannot be said that the study will increase the customers satisfaction (insurance companies and end users). The customer needs addressed in this project are those that are currently known by Bilia. The study has not involved customers to validate these, or to identify additional customer needs. Further, the study aims to bring up important factors and improvement proposals, but if or how these will be implemented will be left to the organization to decide. Lastly, the study was done together with 10 damage centers at the same company, the conclusions is thereby limited to the damage centers that have participated.

2. Methodology

This chapter describes the project's research strategy and approach followed by a description of the chosen research design (Six Sigma). Further, it describes how data was collected and ends with sampling and ethical considerations.

2.1 Research strategy and approach

The qualitative research strategy has an interpretive position of the epistemological scale which implies that the understanding of the social world is done through an examination of the interpretation of its participants (Bell et.al., 2019). The ontological position is leaned towards constructivism which means that social phenomena and their meanings are continually being accomplished by social actors. Meaning that social phenomena and categories are not only produced through social interaction, but they are also in a constant state of revision (Bell et.al., 2019).

Further, the study has an inductive approach where the study aims to combine theory and research. According to the authors, an inductive approach is suitable when having observations and findings which leads to theory. Bell et al. (2019) further describes that an inductive approach is useful when generating theories out of data and is linked to the qualitative research strategy.

The project will take on an action research approach, with the involvement of people from the organization. Action research is characterized by experiments on real problems within an organization, involving an iterative process of project phases. This project at Bilia AB is suitable for action research since the intended outcome of the research is a change in patterns, way of working and thinking (Bell et al., 2019). However, there is criticism of action research, the criticism is similar to that of qualitative methods in general. The lack of repeatability, lack of established trust in findings, and too much focus on the organizational actions are mentioned as criticism of action research (Bell et.al., 2019). This criticism is valid, but due to contextual information and organizational factors, the project group does not have the intent of a totally repeatable process, or that the results are generalizable beyond the sample. The involvement of people with a high expertise within the field of the problem increases the weight of the outcome in the study which could not be gained in other ways (Bell et.al., 2019).

2.2 Research design

The chosen research design is Six Sigma methodology which is a suitable method for well and semi-structured problems and from its underlying statistical modeling it is suitable for routine projects. The methodology helps to structure complex system problems and discover the real problem based on data (De Mast, J & Lokkerbol, J, 2012). The Six Sigma methodology provides a suitable way of working to find improvements of the current process and to decrease the variation to get a robust process that is efficient to handle variation. The project group has throughout the project been loyal to the problem which changed the focus from what was initially thought. It has been difficult to follow the Six Sigma methodology in this project. This can be explained by what turned out to be an ill-defined problem, without sufficient data or quality of data. But several six sigma tools were used throughout the project to structure the problem, analyze the measurement system, and propose KPIs. The five phases of the DMAIC cycle are described below.

2.2.1 Define

The main purpose in the define phase is to identify the goals, defining the scope and procedure of what to do. Further, getting an understanding of the voice of the customer (VOC) is also important during the define phase. Insights from customers will lead to understanding the customer needs and later defining what to improve (y) after finding the root causes of the problem (Carleton, 2018). In this phase, the project group uses several tools to identify the different functions in the process. A large part of the define phase is to conduct interviews and gain knowledge about the process and the interviewees' different perspectives over the process.

The Define phase further consists of several six sigma tools aim, effective scooping, pareto diagram, and process flow charter. These tools aim to identify problems connected to the process which helps to define the objective, problem, and select the right team to solve the project right (Roughton & Crutchfield, 2008).

2.2.2 Measure

During the measure phase, the project group wants to understand the current conditions with numerical data. The aim of the phase is to map the process and measure the process performance baseline related to its customer needs identified in the define phase (Carleton, 2018). One tool in the measure phase is the process map, which can be used to graphically identify each step in the process and sources of non-value-adding activities (Carleton, 2018). The process map helps to identify potential root causes, collect data, and identify non-value-adding activities.

Good conditions of the numerical data are essential to take the right decisions in DMAIC projects. It is important to classify and ensure the data quality, since it will be the basis for data-driven decisions. Furthermore, it is important to make statistical calculations between cause and effect which could be helpful to understand the variation (Carleton, 2018).

2.2.3 Analyze

The purpose of the analyze phase is to analyze gathered information from previous phases and prove the root causes identified in previous phases. It is important to analyze and consider potential root causes to find them (Carleton, 2018). Cause and effect (C&E) diagram are a valuable tool to use to collect knowledge and build support for the resulting solutions. Further C&E diagrams also enable the team to focus on the content of the problem and not what has happened historically (Carleton, 2018).

An effective type of analysis after doing statistical calculations is to do a graphical analysis to present data and generate clues. A graphical analysis can help to find trends, outliers, and cycles. The authors mention that it is important to formulate questions beforehand and try to solve them by looking at the graphs. The visual analysis supports to detect tendencies and identifying sources of variation in the process (Carleton, 2018).

2.2.4 Improve

The Improve phase helps to improve the process with solutions that address the root causes. It is important to identify solutions to the root causes with the help from previous phases (Carleton, 2018). The solutions can be confirmed by testing hypotheses or in smaller pilot projects. To generate solutions, several techniques can help to decide which to continue with. For example, a failure mode and effect analysis (FMEA) help to minimize the effects of potential risks and should be updated if anything is changed along the process (Roughton & Crutchfield, 2008).

Pilot studies also reduces the risk with the implementation and improve the success when implementing the improvement on a full scale. It is easier to control the implementation and easier to analyze before implementing it on a full scale (Carleton, 2018).

2.2.5 Control

The control phase aims to implement permanent tools and standardize the improvements developed and implemented in previous phases. To confirm that the improvements will be used, a control plan is essential to do. It is a set of documents including instructions, characteristics, operational activities to provide prevention against process drift or deviation. It also includes operating procedures and preventive maintenance (Carleton, 2018). The control phase further includes activities to validate customer satisfaction and the project's benefits. It is most often done through customer interviews and project benefits analysis.

2.3 Data Collection

In this thesis, the data has been collected through a literature review, interviews, organizational documents, and damage center visits. These will be explained in detail below. Figure 1 visualizes all conducted interviews, damage center visits, and a workshop. The duration and format are also stated in table 2.1. The damage center visits include several unstructured interviews and one semi-structured interview per damage center visit.

Table 2.1. *A list of all conducted interviews, damage center visits and the workshop.*

Position	Type	Duration [Minutes]	Format
Damage Center Manager	Semi-structured	60	Face-to-face
Damage Center Manager	Semi-structured	40	Online
Damage Center Manager	Semi-structured	60	Online
Damage Center Manager	Semi-structured	40	Online
Regional Operational Manager	Semi-structured	40	Online
Regional Operational Manager	Semi-structured	40	Online
Various	Damage center vistit	360	Face-to-face
Damage Center Manager	Semi-structured	40	Online
Regional Operational Manager	Semi-structured	60	Online
Damage Center Manager	Semi-structured	50	Online
Market manager	Unstructured	30	Online
Regional Operational Manager	Semi-structured	40	Online
Damage Center Manager	Semi-structured	30	Face-to-face
Damage Inspector	Unstructured	30	Face- to-face
Various	Damage center visit	180	Face- to-face
Damage Center Manager	Semi-structured	60	Online
Regional Operational Manager	Semi-structured	40	Online
Various	Damage center visit	360	Face-to-face
Various	Damage center visit	360	Face-to-face
Various	Damage center visit	160	Face-to-face
Various	Damage center vitsit	240	Face-to-face
Paintshop Coach	Unstructured	120	Face-to--face
Various	Damage center visit	240	Face-to-face
Paintshop Coach	Unstructured	60	Face-to-face
Various	Workshop	600	Face-to-face
	Sum	3340	

2.3.1 Literature review

An important part of research is to review the existing literature. It will help the researchers to determine what has already been known within the area. According to Bell et al. (2019), the literature review is directed to achieve an appropriate review of the literature in order to ensure credibility as someone who has knowledge within the research area. Bell et al. (2019) further mentions that it also will help to get knowledge about concepts and theories that may be interesting for the upcoming research. Further it will allow the project group to find gaps in research and identify potential needs for additional research.

In order to gain understanding within the research area, online databases were used. Online databases are the most valuable source of academic journal references and provide access to a huge number of reports in full text in a digital format (Bell et al., 2019). The project group used the online databases Chalmers Library and Google Scholar. To find information regarding the project's topic a combination of keywords was used. These were “Automotive/Auto/Vehicle/Car” in combination with “Repair”, “Damage”, “Damage center”. In addition, searches were also made including the above-described combination and the search words “Collision/Accident”, “Sheet metal”, “Body”, “Paint”, “Shop/Workshop”, “Improve/Improvement”, “Efficiency”, “Lean”, “Variation”.

The project group did not find any existing literature within automotive repair or damage centers that was deemed useful for the project's purpose. Therefore, broader search words were used to gain knowledge within the area of process improvements. The keywords that were used during this search was a combination of “Process improvements”, “Six Sigma, “Lean”, “KPI”, “Best practice”, “Efficiency”, “Variation”, “Lead time”, “Standardization”, “Low volume high variety”. This broader literature was the basis for the literature framework that was used during the project and are presented in the theoretical framework.

2.3.2 Interviews

Bell et al. (2019) explains that there are two types of interviews in qualitative research, unstructured- and semi-structured interviews. In a semi-structured interview, the researcher has a list of questions which are often referred to an interview guide that is used for several interviewees. The questions may not follow any specific order and follow up questions can be asked based on the interviewees answer of the question from the interview guide. The authors explain that unstructured interviews have similarities with a conversation because it often has a single prepared question covering a specific topic. The interview continues by asking additional questions that the interviewer sees worth asking (Bell et al., 2019). The authors state that it is important to be in a quiet and private space so the interview can be performed without interruptions and with a high focus.

Bell et al. (2019) further explains the importance of recording and transcribing interviews in order to capture as much data as possible during the interview. However, recording can cause the interviewee to feel inhibited. It can feel unnatural, and it is possible that it will negatively affect the interviewees' ability to speak freely. As described by Bell et al. (2019) one will generally receive more interesting information and honest answers if the interview is not recorded. This was the main reason why the project group decided to not record the interviews. Instead, the project group took notes during the interviews. Since it is not possible to write down everything that was said, the project group always had a debrief session after the interviews. During these, information from the interview was talked through and written down to make sure that as little as possible was missed. In addition, the project group at times contacted the interviewee afterwards to clarify or elaborate if needed.

Interview invitations were sent via email to all managers for damage centers (with sheet metal and an in-house paint process) and to regional operational managers. In the invitation, the project was briefly explained, and the topic and duration of the meeting was also stated. Of the 13 damage center managers that met the stated criteria, 10 participated. The Interviews were held either online or face-to-face (figure 2.1). Regarding the three managers that did not participate, two of them did not respond after several reminders, the third manager declined. Further, interviews with five regional operational managers were held online. The above-described interviews were semi-structured, and the duration was approximately 45-minutes.

The semi-structured interviews included two types of questions. It included a set of questions that was used to get an understanding of the damage centers within the sample, and how they differ. For example, questions about their painting box and the technology used, how they are organized with regards to functions and what their responsibilities are, how the production is scheduled, what the bonus salary is based on (if they use it), what metrics they use and why etc. But the project group also asked questions that required more thought from the interviewee, these questions were intended to gain a more in-depth understanding from their point of view. Questions such as, what the difficulties are to reach the economic targets, how they saw that their damage center process could improve, what the bottleneck in their system are, and if there is something that they viewed as interesting to look at but have not had time or managed to improve it.

To gain more information from operational employees, the project group conducted unstructured interviews during damage centers visits with employees working in the front office, spare part unit, sheet metal, paint, and the damage inspection. These were conducted to get more in-depth information about how the work is performed, employees' responsibilities, their view regarding current issues, and their improvement ideas.

2.3.2 Organizational documents

Organizational documents can provide researchers with valuable information and background about the company. Documents can offer insights about earlier managerial decisions to the project group findings that were made earlier. Bell et al. (2019) mention external consultant reports, firm's newsletter, and production plans as examples of internal documents. The organizational documents that have been used are mainly press releases, process improvement documents, and an external consultant report. These have given the project group understandings about the organization, damage center process, and improvement work that have been done either by either consultants or inhouse.

2.3.3 Damage center visits (Gemba walks)

Gemba is a Japanese word and means "the real place". In lean management, Gemba walk is referred to when management visits the place where the work is performed (Gessinger, 2016). The Gemba walk is an opportunity for management to visit the place with their own eyes and deeply understand the organization (Bremer, 2015). By dedicating time and putting effort to work side-by-side brings long lasting benefits such as respect and reliability from the employees. Gessinger (2016) further describes that it is more beneficial to keep the factory visits informal, without checklists and cameras because it minimizes the intimidation factor that easily can occur when management visits production. Bremer (2015) explains that management should actively listen, and respectfully ask questions such as what and why. The aim of these kinds of questions is to find the purpose and standard practices of the work task. Gemba walk can also encourage employees to think critically when questions are asked that require reflection from the employees (Bremer, 2015). This reflection can inspire employees to identify new and improved ways of working.

During the project, six damage centers were visited. The damage center visits included a damage center tour with the respective manager. During the tour, the manager explained and let the project group see their process. The tour could be described as an unstructured interview where questions were asked, and the manager could explain and show examples to clarify. It contributed with new understandings of the process and the work activities along the process. The visits contribute to seeing the differences between damage centers in the process and the separate functions' responsibilities. The project group were also allowed to walk around freely to and speak with all employees, without the manager present. This was deemed important in order to get more in-depth information and several points of view. The project group held several unstructured interviews with employees working at different hierarchical levels and functions.

2.4 Sampling

The chosen sampling method is convenience sampling. It is a non-probability sampling method that relies on the availability in a population. Meaning that the sample is simply a group of people that are available to the researcher (Bell et al., 2019). Given the project's purpose, all damage centers that are operated by Bilia and have sheet metal and in-house paint shop are of interest. Based on these criteria, there are 13 damage centers left. All managers for these 13 damage centers were invited to participate. The response rate was 77%, meaning that 10 of the 13 damage centers were included in the project. The main criticisms of the convenience sampling method is the low degree of generalizability (Bell et al., 2019). However, this project is not intended to yield results that can be generalizable beyond the chosen sample. Bell et al., (2019) mention that an appropriate sample provides a springboard for future research and allows links to be forged with existing findings in an area.

2.5 Ethics

Bell et al. (2019) mention four ethical principles that the researcher needs to consider when doing a qualitative study. The first principle is avoidance of harm, which means that both researchers and participants can be harmed in several ways. The authors mention physical harm, stress, harm to career, and harm to participants' development as examples of harm that could occur while doing qualitative research. To reduce the risk of harm, the project group introduced the project including the topic and intended outcome to participants. This allowed them to assess if it would be suitable for them to participate or not. The employees that have participated in the study have been anonymized in this study. In addition, the project group has not shared information that can harm a participant. This includes both in this written thesis, and during interactions with employees in the organization. It was deemed important to not tell what others have said if the information could be traced to its source and later result in harm for the participant. There is also a risk of harm for the company. The project group has gained access to internal documents, financial data and operational data for the year 2021. This information has been handled with caution, and financial information will not be published. Some operational data will be published, but no information that can be used to gain information of the participating damage centers.

The second principle is informed consent which entails giving sufficient information about the research and ensuring that there is no explicit or implicit coercion (Bell et al., 2019). Meaning that potential participants are informed and can make a free choice if they want to participate, without pressure from others. The project group has also informed and received consent from participants regarding what type of information that will be shared during the project and the written thesis. To avoid misinformed participants, the project group wrote a short description and purpose of the project in the participation invitation. Thereby, accepting the invitation can be seen as an informed consent to participate. When this thesis is finished, company representatives will be given time to read it. The project group will ask for permission, and it will not be published before an agreement is reached.

Thirdly, invasion of privacy is about protecting the privacy of the research participants. Naturally, some research topics can be judged sensitive to participants and their privacy, but the researcher cannot know in advance which topics that can be viewed as sensitive for participants. This is believed to be a low risk during interviews and interactions with people, mainly due to the project's topic. The main risk related to invasion of privacy and protecting the privacy is believed to be information sharing between participants regarding what others have said. Interviews can be seen as private information that is shared between the project group and the interviewee. Thereby, information regarding who and what others have said will not be shared during the interviews, regardless of if the information can be viewed as sensitive or not.

The last principle is prevention of deception. Bell et al. (2019) describe perception as presenting the project as something other than what it is. The project group has avoided it in two ways. Firstly, as mentioned earlier, the same honest description of the project has been sent to all participants before the interviews. The risk for participants to interpret the project differently is thereby reduced. Secondly, during damage center visits, some employees did not know about the project. During these interactions with employees the project group provided the same information about the project that managers have received.

3. Theoretical framework

This chapter includes theory based on existing literature that is used as a basis for this thesis. The chapter begins with providing information about processes and the importance of continuously improving. This is then followed by a description of efficiency and the efficiency paradox. Lastly, theory about standardization and key performance indicators is described.

3.1 Process Improvements

According to Bergman & Klefsjö (2014), a process is defined as a network of interrelated activities that are repeated in time, whose object is to create value for external and internal customers. The process transforms an input into an output and increases its customer value. External customer demand is continuously increasing and therefore, new technological solutions appear, and new types of business activities are created (Bergman & Klefjö, 2014). To satisfy the customer needs, the main process is complemented by management processes and supporting processes. The main process' task is to fulfill the external customer needs, which are changing over time. This implies that the process owner must continuously improve and understand its customer needs to be competitive. The management process' task is to make decisions about strategies and targets, but also to implement improvements in other organizational processes to stay competitive. The main process needs to be provided with resources and support, meaning that it must exist supporting processes (Bergman & Klefjö, 2014). Supporting processes have internal customers, examples of supporting processes are recruitment, maintenance, internal logistics and information (Bergman & Klefjö, 2014). A process generates data, which provides valuable information about the process. This data can indicate that a process improvement is needed, but it can also be used to confirm the result of a process improvement. Process improvement ideas can be applied at any level of the organization, but it is important to follow the three rules of process improvement proposed by Flanigan & Scott (1995). The first rule is to focus on the customer. Second, use the process view to deliver what the customer wants. Third, when you think you are done, begin the cycle again.

By continuously improving a process, increasing customer expectations could be met and customers will stay satisfied. According to Bergman & Klefjö (2014), improved quality affects productivity and reduces costs due to reduced rework, which implies improved profitability. Furthermore, it is important to improve all processes around the main process to gain higher quality by using fewer resources and lower cost. Creating satisfied customers means competing in the market, and by offering high-quality products with high levels of customer satisfaction, companies can keep and attract new customers (Tao, 2014). Furthermore, one of the definitions of a successful business is a satisfied customer.

Improvement work is often connected to the Plan, Do, Check, Act (PDCA) cycle which enables continuous improvements. The cycle helps to tackle assignable causes systematically and accurately. The aim is to start with the most important problem and move to the next problem when the previous is solved (Bergman & Klefjö, 2014). However, the Define, Measure, Analyze, Improve, and Control (DMAIC) cycle is a more complicated continuous improvement tool compared to the PDCA cycle (Sokovic, Pavletic & Kern Pipan, 2010). It is a data drive approach used for improving and stabilizing processes in five phases. The DMAIC cycle is most often used with the concept of Six Sigma while PDCA is predominantly used with Kaizen which is a Japanese term for continuous improvement (Sokovic et.al, 2010).

3.2 Customer value

It is difficult to imagine a successful business without a satisfied customer. Knowing what a customer wants can make the difference between success and failure. It is important to consider that there are two types of customers in a process, internal and external. An internal customer is a person or department within the company that you are in direct contact with. An external customer is a company who buys your product, or the end user (Flanigan & Scott, 1995). Customer feedback is important for both internal and external customers. Feedback is a measure of how the company performs, based on the customer's viewpoint. Customer feedback can be seen as advice on how to increase the customer value and is therefore a suitable input for process improvements.

Grönroos (2015) mentions that customer value within service management can be described as” a customer that, after having been supported by a service provider, is or feels better off than before”. Service management requires a customer outside-in perspective. It could be equated to the service provider's capability to support its customers' processes, that in turn enables the customers to create value (Grönroos, 2015). The author further describes that value co-creation between the customer and the service provider only occurs in direct interaction between the two parties. It is also important to consider that it is the customer that drives the value creation and increases the customer expectations which forces companies to increase customer value in their services or products.

3.3 Variation

In all situations in life, we experience variations, whose cause we are often unable to identify. Variatiation is often a source of inconvenience and a driver of cost when discussing quality issues (Bergman & Klefsjö, 2014). Variation exists in every process which often creates a lot of waste causing large losses. Bergman & Klefsjö (2014) mention that variation occurs by causes linked to vague routines, inconsistencies in material or disruptions in the process. However, to achieve effective production, it is necessary to predict the process ability to produce what is required (Bergman & Klefsjö, 2014).

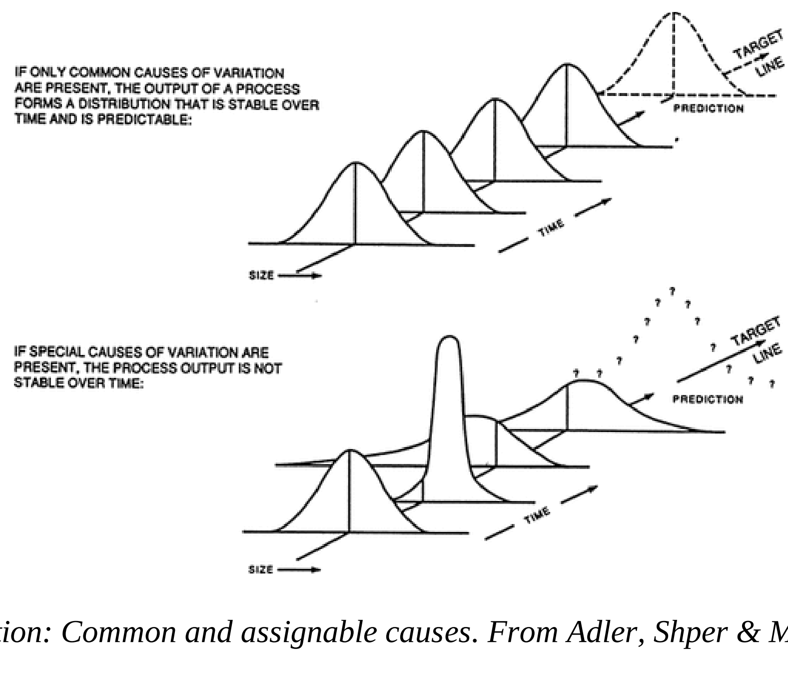

Figure 3.1. *Variation: Common and assignable causes. From Adler, Shper & Maksimova, (2011).*

There are two types of variation, common cause variation and assignable cause (special) variation. Common cause variation is inherent in any process, and the cause does not need to be identified (Deming, 1994). The process is performing as it is designed to do if there is only common cause variation. Common cause variation can be seen as random variation that cannot be eliminated. Assignable cause variation means, as its name suggests, that there is an assignable cause that can explain the variation (Deming, 1994). By eliminating assignable causes of variation, the process will yield predictable results (figure 3.1). A predictable process decreases the cost of defect products and increases the quality (Bergman & Klefsjö, 2014). Statistical process control and its primary tool, the control chart, provides information about the process and enables assignable causes to be detected (Benneyan, Lloyd & Plsek, 2003). When the assignable variation is eliminated, the process can be said to be under statistical control. Meaning that the process is predictable, and there are only common cause variations that affect the process (Adler et al., 2011).

3.4 Process efficiency

To be able to sustain long-term growth and profitability, companies must continuously improve their efficiency. The following section describes two types of efficiency, resource efficiency and flow efficiency.

3.4.1 Resource efficiency

Resource efficiency is the traditional form of efficiency and focuses on maximizing the utilization of the resources used in the process. Resource efficiency has been, and still is the most common way to look at efficiency. It dominates how we organize, control, and lead our organizations in different sectors and industries (Modig & Åhlström, 2015). Resource efficiency puts focus on the resources through a production process and is a measure of how much a resource is utilized relative to a specific period of time (Modig & Åhlström, 2015). From an economical point of view, it is wise to utilize resources as much as possible. The reason for this is that resources are often large investments, and thereby the alternative cost of not utilizing the resources is high. Therefore, it is important and the natural way for humans and organizations to maximize the resources as much as possible (Modig & Åhlström, 2015).

3.4.2 Flow efficiency

Flow efficiency is a modern way of looking at efficiency. Flow efficiency can be described as the amount of value adding time compared to the total amount of time. (Modig & Åhlström, 2015). The measure focuses on the unit flowing through the process. The objective of flow efficiency is to eliminate all non-value-adding activities and thereby maximize the unit's value adding time (Modig & Åhlström, 2015). This in turn increases the customer value due to a decreased lead time. However, the goal is not to increase the speed for the value adding activities, the focus is instead to find the right speed and eliminate all non-value adding activities. The authors mention that the right speed depends on the customer's expectation (often lead time). But the right speed depends on the process as well, it must be suitable for the process and its employees. It is important to find the right balance between the customer expectations and what is suitable for the process.

3.5 What allows a process to flow?

There are three laws that control processes from having efficient flows. It is Little's law, the law about bottlenecks, and the law about variations impact on the process. The laws are universal and can be used regardless of what type of unit that is flowing through the process.

3.5.1 Little's law

In terms of process flow, little's law addresses how process queues affect the process lead time. A process queue consists of several units. The units arrive to the system, and within the system, the units create a queue to later leave the queue and proceed to the next process step (Little & Graves, 2008). The queue is increasing if more units arrive than leave the queue.

Little's law says that the average number of units in the system is equal to the average waiting time in the queuing system multiplied by the average number of items arriving per time unit (Little & Graves, 2008). It is important to mention that the average waiting time is equal to the lead time within the specified system boundary. The time is dependent on where the system boundaries are defined, meaning where it is decided that the process starts and stops. The law can be applied regardless of how the system boundaries are set.

Little's law shows that the total lead time in a process is affected by the number of flow units and cycle time. Cycle time is the average time between two flow unit's completing the process and refers to the pace at which flow units move through the process. A longer cycle time occurs when a process activity cannot work faster or when there is a capacity shortage (Modig & Åhlström, 2015). In addition, little's law shows that the lead time increases if the number of units within the system increases. However, there is a paradox. To ensure high resource efficiency, resources must be utilized to a maximum, preferably 100 per cent. But to ensure this, there must be work to do, the work can never finish. Therefore, the process needs buffers in order to minimize the risk for a resource waiting for the next job. However, according to little's law, it is better if the resources are waiting for the flow unit instead of the other way around.

3.5.2 The law of bottlenecks

The law of bottlenecks contributes to understanding how processes work and what prevent companies from increasing flow efficiency. There are often stops along a process where queues arise. Those stops are bottlenecks and create variations along the process (Modig & Åhlström, 2015). Bottlenecks are very dangerous from an industrial organization point of view. The reason is, when bottlenecks arise, it limits the capacity of the production process (Wolniak et al, 2018). It implies that the lead time for a product increase and affects stakeholders negatively. A process where a bottleneck exists is mainly characterized by two main factors (Modig & Åhlström, 2015). Firstly, immediately prior to a bottleneck there is always a queue, regardless of whether it is information, people, or materials flowing through the process. Secondly, the process steps after the bottleneck have to wait to be activated and will therefore not be fully utilized. Because the bottleneck has the lowest throughput, the activities after will work at a slower pace (Modig & Åhlström, 2015). The authors mention that a bottleneck increases the lead time, and it is in most cases non-value-adding time that increases the lead time. Wolniak et al. (2018) describes that even if you eliminate a bottleneck, it will always appear a new bottleneck at another function, but you can minimize it by decreasing the variation.

There are many factors of a system that contribute to a bottleneck such as machine capacity and number of employees (Wang et al., 2005). The bottlenecks of a system may be different depending on different perspectives of view (Wang et al., 2005). Meaning that, one might view a specific process as the bottleneck in the system. Another might say that the bottleneck is a specific process step within that process. Both will be correct, but the different view based on their view of perspective will contribute to different results regarding the bottleneck. It is also important to mention that bottlenecks become more complex for larger systems and are therefore also harder to detect and solve (Wang et al., 2005). There will likely be many bottlenecks depending on the view, and once a bottleneck is eliminated, a new one will appear in the system.

3.5.3 Law of the effect of variation

The law of the effect of variation contributes to an increased understanding of a process and why it acts as it does. The law can be described as the connection between variation, resource efficiency, and lead time. Variation increases the difficulty for organizations to achieve both flow- and resource efficiency (Modig & Åhlström, 2015). However, variation will always exist in a process, therefore it is important to understand its consequences for the output. The cause of variation can be divided into three overall categories. The first is resource variation which can occur when employees work at different speeds or when machines break. The second is the variation of flow units which means that all units may not be the same. For example, cars through a production line have different sizes, characteristics, and color. The last category is external factors. Examples of external factors are variation in input, seasonal dependent trends and variation in demand that the process cannot foresee. These three kinds of variation in turn affect variations in operating time and the arrival time to the next process step (Modig & Åhlström, 2015).

The variation has a high impact on flow efficiency, this can be explained by the relationship between variation, resource efficiency (utilization) and lead time. This relationship is called *Kingman's Equation* (figure 3.2) and describes the relation between lead time (y) (cycle time) and degree of utilization (x) (resource efficiency).

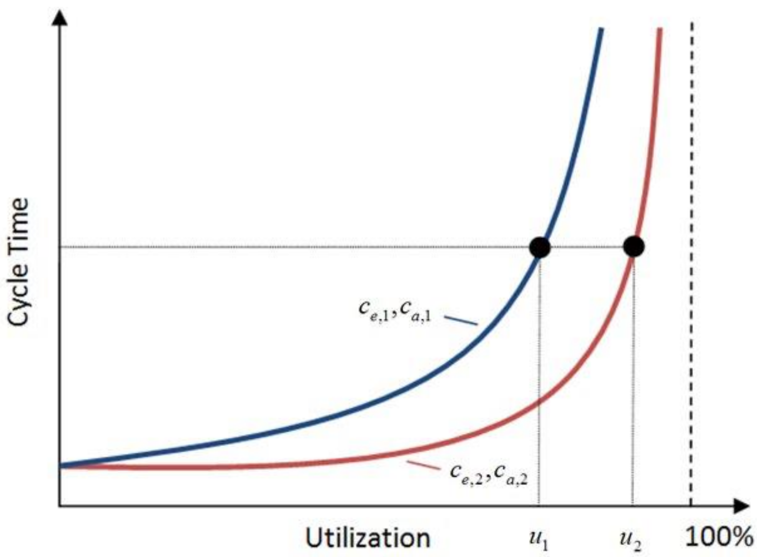

Figure 3.2. *Relationship between utilization and cycle time for two variability levels. From Ponsignon, T. Modeling and Solving Master Planning Problems in Semiconductor Manufacturing (2012).*

The relationship between lead time and utilization is shown in figure 3.2. The red curve represents low variation and the blue high variation. The form of the curves visualizes the first effect of variation. The closer the curves got to 100 percent utilization, the longer lead time. Meaning that the relationship is exponential rather than linear. The second effect of variation that can be seen can be described as, the greater the variation in the process is, the longer lead time. This since the blue curve, representing high variation is moved to the left, compared to the one representing low variation.

3.6 Efficiency paradox

Many organizations that are focusing on resource efficiency are also creating three sources of inefficiency which are explained below. In addition, focusing on resource efficiency creates negative effects. These negative effects create the need for a lot of additional resources, work, and efforts that would not be necessary if the organization were flow efficient (Modig & Åhlström, 2015).

3.6.1 Longer lead times

By focusing on resource efficiency, the process generates longer lead times. Longer lead times will also generate secondary needs among customers. The wait affects customers negatively through feeling worried and frustrated. In this situation with negatively affected customers, challenges and problems are created that the company is forced to handle. These effects in turn require additional resources and new work activities (Modig & Åhlström, 2015).

3.6.2 Many restarts on every flow unit

Starting over on the same task generates mental set-up time (Modig & Åhlström, 2015). Meaning that there is a risk that employees need to read instructions or categorize and structure the problem once again which creates delays. However, many restarts generate frustration among employees and customers who have to repeat or listen to the same information (Modig & Åhlström, 2015). In addition, many restarts generate secondary needs. Secondary need occurs as a consequence of a failure to satisfy the customer's primary need. The authors describe that secondary needs often can generate other secondary needs in a chain reaction. Therefore, secondary needs are very critical to have in an organization (Modig & Åhlström, 2015). Secondary needs consume resources and generate superfluous work (work devoted to take care of the secondary customer need). This can be seen as waste but is difficult to realize since employees think that they create value.

3.6.3 Many flow units

The third source of inefficiency is created in organizations that focus on resource efficiency and is related to people's ability to handle many things at the same time. As mentioned earlier, focusing on resource efficiency increases lead time. This in turn increases warehousing (in terms of spare parts and the unit). It creates three secondary needs for the organization (Modig & Åhlström, 2015). Firstly, inventory requires storage space which could generate overhead costs such as lighting, heating etc. Secondly, large volumes of inventory and work in process makes it difficult for employees to get an overview and handle. For example, it is difficult to find articles in a warehouse if the volume of inventory is large. Thirdly, high volumes of inventory and units in the production flow tend to hide problems. A company that works on many flow units at the same time has problems finding quality defects. Meaning that they must invest in more resources and develop structures and routines due to the large number of units to handle (Modig & Åhlström, 2015).

3.6.4 Efficiency paradox

As described above, by focusing on resource efficiency secondary needs occur which in turn implies unnecessary work. Those secondary needs would not occur if the primary need was fulfilled. But focusing on resource efficiency, organizations can feel that they are using their resources very efficiently but since secondary needs occur, superfluous work has to be done (Modig & Åhlström, 2015).

The efficiency paradox means that companies are wasting resources at different organizational levels. But the core of resolving the efficiency paradox is to focus on flow efficiency. By focusing on flow efficiency, an organization can eliminate secondary needs that arise as a consequence of low flow efficiency. Meaning that it is important to focus on lead time, work in process (WIP), and to minimize the amount of restarts. By focusing on these, the units will go through the organization faster and paradoxically, the organization will set free an amount of resources (Modig & Åhlström, 2015). However, the key for balancing between resource- and flow efficiency is to find the sweet spot between the two. The authors mention that the strategy for resolving the efficiency paradox is to implement lean. Lean involves focusing on flow, minimizing waste, and focusing on the real customer need.

3.7 Standardization and standardized work

Standardization is the practice of setting, communicating, following, and improving standards (Pereira, Abreu, Silva, C.Alves, Oliveria, Lopes & Figureido, 2016). According to Toyota, "One must standardize and thus stabilize the process, before continuous improvements can be made" (Liker, 2021). Mr. Taiichi Ohno, considered as the father of Toyota Production Systems states "Where there is no standard, there cannot be improvement" (Pereira et al. 2016). With standardized work, it is easier to understand and improve the process. It also enables one to measure an outcome from an improvement project, meaning that it is possible to determine whether the standard has been improved or not (Liker, 2021).

Standardized work is an essential part of the lean management system in efforts to eliminate waste, unevenness, and unreasonableness. It is used as a first step towards being a lean organization (Marksberry, Rammohan & Vu, 2011). Standardized work can be applied in both cellular manufacturing and pull production environments (Pereira et al. 2016). One of the objectives of standardized work is to be able to adjust the pace of the production line according to the customer demand. This flexibility, when it comes to pace, is achieved if operators can easily change position within the process (Marksberry et al., 2011). However, Williams (2001) argues that the reason for standardized work is beyond flexibility, it is an important factor in order to identify improvements and minimize inconsistencies (Williams, 2001). Standardized work allows for easier cross-training of operators, resulting in a flexible workforce producing low-cost, high-quality products. There are prerequisites related to standardized work, these are (Pereira et al., 2016):

- Takt time, the rate of production with respect to both customer demand and available resources during a period. The takt time can be calculated as the net available time during a specific period of time divided with the customer demand during the same period of time. Worth noticing is that the takt time has nothing to do with the operator's ability to produce at this rate. Calculating and monitoring the takt time means that abnormalities will be detected immediately, and it is possible to respond accordingly (Williams, 2001). As opposed to "daily quota", one does not need to wait until the end of the shift to know how successful the day where, it can be monitored in real time during the day.

- Standard work sequence is the order in which a set of tasks is done in a given process. It is both the safest and best way to do it (Pereira et al., 2016). The main focus is on consistency, not efficiency. However, increasing the stability and repeatability will also make the process more efficient and reveal additional improvement opportunities (Williams, 2001).

- Standard work-in-process inventory is about making sure that a minimum amount of inventory is used to maintain the pace of production in a continuous flow and without idle times (Pereira et al., 2016). Kanban system is a tool to reduce the amount of inventory to a minimum, as both excess and too little inventory will result in decreased productivity (Pereira et al., 2016). Kanban system is an inventory control system for just-in-time manufacturing.

However, Williams (2001) argues that these three prerequisites do not need to be perfect, but major issues must be addressed before implementing standardized work (Williams, 2001). The author further stresses the importance of not waiting “until you are ready” because then the implementation of standardized work will never begin. Meaning that there are issues related to implementing standardized work, and these issues need to be addressed before. Once implemented, the idea is that the continuous process flow will bring problems to the surface. When this happens, there is a possibility to improve the process by solving the surfaced problem (Liker, 2021). However, standardized work can often be considered negative among employees. This is because the standardized work is decided by the management and implemented among employees, which makes the approval process delicate for the employees. Therefore, it is important to approve employees’ ideas for kaizen. It is a way for employees to increase the sense of being a part of decisions and increase autonomy (Marksberry et al., 2011).

Pereira et al. (2016) mention several advantages of standardized work. The authors mentions that it provides a basis for consistently high levels of productivity, quality, and safety. Further, it increases the process control which also enables an easier visualization of abnormalities (in for example a control chart). In addition, standardized work provides detailed, step-by-step guidelines for every job which contributes to control documents for employees which eliminates human errors in the process (Pereira et al., 2016). Marksberry et al. (2011) further describe standardized work as the “foundation for improvement”, which strengthens the value of implementing and using standardized work in production processes.

3.8 Key Performance Indicators

A Key performance indicator (KPI) represents a set of measures focusing on organizational performance. The measures are often the most critical for the current and future success of the organization. According to Parmenter (2010), KPIs have several characteristics. A KPI is a non-financial measure, it is a deeper measure than a financial measure. For example, daily sales are a result of a number of activities that have been done during the day. A KPI should be monitored frequently. A measure that is monitored less than monthly, cannot be key to the business. Further, a KPI is a current or future-oriented measure and not a measure of last month's events. In addition, KPIs should make a difference. Meaning that it should tell employees what action needs to take place if it deviates from normal. The author also mentions that a KPI is deep enough in the organization that it can be tied to a team and a responsible manager. Meaning that all employees in the team have knowledge of the KPI and could describe to senior management what has occurred if the KPI deviates. Lastly, before a performance measure becomes a KPI it must be tested to ensure that it creates value and has a vital outcome for employees and management (Parmenter, 2010).

The visualization is an important part of utilizing the KPIs' full potential. Data can be presented as text, in tabular form, or in graphical form (Junyong & Sangseok, 2017). When presenting data, the type of visualization must be chosen after carefully weighing the advantages and disadvantages based on which information that will be presented. The simplicity of presentation is one simple rule to bear in mind before making decisions about which method to use (Junyong & Sangseok, 2017). The authors mention that the use of colors makes the visualization clear and easy for the reader to interpret.

However, they also mention that some illustrations that are intended to compare results can deceive readers' eyes and lead to misunderstandings.

According to Ericson Öberg, Braunias, Hammersberg & Andersson, (2016), measurement systems reflect a bottom-up understanding of the process behaviors, which creates information for the joint strategic discussions between employees. Joint understanding of variation, created together as a team, has proven to be a necessary component for its success. Furthermore, KPIs it is important to find the most suitable visualization of the KPI that helps employees with guidance to make faster decisions if the process is out of the target (Ericson Öberg, et.al, 2016).

Success or failure of a KPI project can be determined by the presence or absence of the four foundation stones (Parmenter, 2010). The first foundation stone is the "partnership with employees, suppliers, and customers". Meaning that the organization must involve stakeholders and make joint developments to implement best practices and KPIs. The second stone "transfer of power to the Front Line" implies that a successful performance improvement requires empowerment of employees in the operational front line. By including the front line in the development of KPIs, it will also reflect the organization from a bottom-up perspective. The third pillar is "Measuring and Reporting Only What Matters". Meaning that an organization should only measure what is truly important for the business, no measure or report should exist because it historically has existed. Meaning that every measure should have a reason to exist. The frequency in which a KPI is reported and updated should reflect its importance for the business. The authors further mention that every report should link to a critical success factor. A critical success factor (CSF) is something that an organization has to do in order to achieve its goal (for example increased customer satisfaction, end-user involvement, or optimization). The fourth pillar is "Linking Performance Measures to Strategy through the CSF". Meaning that a performance measure must be linked to at least one CSF and follow the organization's strategic objectives to be called a KPI. In addition, the author mentions that organizations will be more successful if they have spent time defining and conveying its vision, mission, and values. They need to be defined in such a way that employees and management work with the KPIs on a daily basis. (Parmenter, 2010).

4. Current situation analysis

This chapter is a part of the results gained from interviews and damage center visits. It aims to provide a basic understanding of who the key stakeholders are, and their primary needs. It is then followed by information about all process steps in the damage center process. The intention is to provide a broad understanding of the primary tasks and the input and output from each process step.

4.1 Stakeholder Analysis

Improvement projects are often confronted with the task of balancing competing demands from different stakeholders (Arun Abraham, 2016). Thereby, it is important to understand the stakeholders and their needs. Donaldson & Preston (1995) mention that there is a correlation between stakeholder management and economic performance and thereby, it is important to conduct a stakeholder analysis. For this project, three primary stakeholders have been identified. These stakeholders are intended to be directly affected by this project. Because of this, it is important to understand what their needs are, related to the damage center process.

The first stakeholder is the end user of the vehicle, it can further be divided into regular and critical users. The regular user in this case means people that for example use their car for commuting to work or recreational activities. In brief, people that do not experience any major problem or inconvenience during the repair lead time as they can use a rental car during this period. The critical users are for example police and taxi drivers that need a specific vehicle to be able to perform their work. Therefore, the lead time is even more important for the critical users compared to regular users. What these stakeholders, regular and critical users, have in common is that they generally are not directly paying for the repair (konkurrensverket, 2019). The insurance company pays for the majority of the repair, and the price for the repair is not the most important factor for the end user, as they only pay the fixed deductible (excess) cost. The deductible amount is the part of the damage cost that the end user of the vehicle needs to pay if the repaired vehicle is insured. This amount is dependent on the type of damage, and not the price of the repair (Länsförsäkringar, n.d). Meaning that the total lead time (time the end user cannot access their vehicle), quality of the repair job, and availability lead time (time from damage is reported until it is handed over to the repair center) are the most important factors for end users.

As previously mentioned, insurance companies are an important stakeholder. Their needs are the same as their customers. In addition to the needs of the end user of the vehicle, the total cost of the repair is very important for insurance companies. But they have other goals for damage centers as well, for example usage of re-used spare parts and to repair plastic and sheet metal parts instead of replacing them. In line with the end users of the vehicle, insurance companies have an interest in a short repair lead time. Not only to satisfy their customers, but also since a longer repair lead time increases their total cost. This can be explained by the need for a longer car rental period. The absolute majority of cars that get repaired in the damage centers are insured. Meaning that it is crucial that the insurance companies are satisfied, which in turn is highly affected by the end user.

Individual repair centers are naturally another key stakeholder. They get paid by the insurance company or the end user of the vehicle. The invoice amount for labor is determined by the estimated time multiplied with the hourly negotiated cost, not the actual elapsed time. This estimated time is determined by how long a specific repair takes based on time studies. The time estimation is provided by the computer software CABAS from Cab Group and is calculated the same for all damage centers. Cab Group is majority owned by insurance companies. In order for a repair center to be able to repair a vehicle for an insurance company CABAS must be used (Eriksson, 2018). This makes efficiency very important for a damage center to be profitable. One can either make or lose money on a repair job depending on the difference between elapsed and calculated time. For a damage center to work efficiently, buffers are used before and between process steps. Meaning that one needs to balance the internal efficiency with lead time. Insurance companies can route their customers to damage centers that benefit their operations based on factors such as lead time.

Apart from the three primary stakeholders mentioned above, there are secondary stakeholders. These are CAB Group, spare part suppliers, and Bilia AB. However, these will not be the focus of this project. CAB Group and spare part suppliers are stakeholders that affect the process and are thereby included. However, knowing their needs and satisfying them will not lead to an improved damage center process for Bilia. Individual damage centers' needs should reflect Bilia AB’s overall strategy. Thereby the primary stakeholder focus will be on individual damage centers, and not Bilia as a company.

4.2 Damage Center Process

To get a better understanding of the damage center process the different process steps will be explained, including the input and output for each step. The information has been obtained primarily from damage center visits and interviews, but also from internal documents. Figure 4.1 visualizes the process from the damage center's point of view beginning with the damage inspection step and ends when the assembly step is completed. All process steps are the same for all damage centers among the sample. Although they are the same, how the working tasks are performed will differ between damage centers and the differences are explained below.

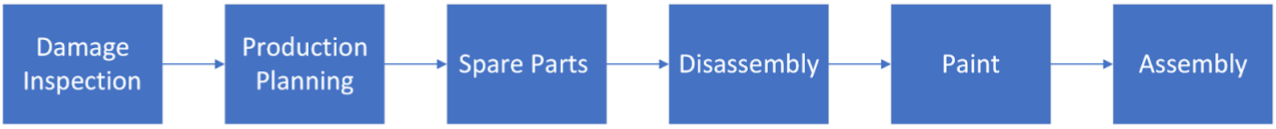

Figure 4.1. *A visualization of the damage center process and its different steps.*

Damage inspection

The first step in the repair process is the damage inspection. The aim of the inspection is to get information and photos of the damage. This is used as an input for the calculation of expenditure of time, cost for the repair, and a list of the needed spare parts. In addition, the end user will get a repair start data and preliminary finished date during the damage inspection. The inspection is normally performed on site with the end user present. In case the vehicle has been towed to the damage center, the end user is not present. The inspection can also be performed online based on photos taken by the end user. Naturally, it is more difficult to do a damage inspection based on the end user's photographs compared to seeing the vehicle in reality. If the end user's photos are not deemed sufficient by the damage inspector, the end user will be asked to visit the damage center for the inspection.

The first process step is that a damage inspector assesses the damages. They are knowledgeable regarding what parts that can be repaired based on the magnitude and position of a damage. The parts that generally are repaired are sheet metal and plastic parts, and these damages need to be measured. Damages that cannot be repaired will require spare parts that the inspector needs to identify during the inspection. In addition to this, the inspector needs to take photographs of all damages. These photos are useful for different actors during the entire repair process. But the main reason is that insurance companies require photos to justify the labor and purchase of spare parts.

When the inspection of the vehicle is completed, the inspector uses the computer software CABAS to calculate the required time of the repair job, repair cost and generate the spare part list. The inspector enters the license plate number for the damaged vehicle and gets a digital view of the vehicle model. From the digital view through CABAS, the inspector can mark the damaged area. Based on the previously chosen area, a more detailed view of options regarding damaged parts are provided. When a damaged part is chosen, the software automatically identifies all components that are needed to assemble the marked part. The parts are then automatically exported to the spare part list. For the damaged parts that can be repaired, the inspector needs to specify the damaged surface area, depth, and the geometrical design (number of creases and alignments) in CABAS.

Based on the damage inspector's description of damage in CABAS, an estimated time for each sub-task will be provided. The estimated time for each sub-task required in the repair job is calculated based on time studies made by CABAS. It is the estimated time for each sub-tasks that insurance companies pay for the repair job. CABAS provides job descriptions for both sheet metal and paint on all specific jobs. The calculation is then sent to the insurance company, who will determine if they approve the calculated repair or not.

The calculated expenditure of time in disassembly, painting, and assembly is then put into a booking schedule system, called CabPlan. Based on estimated time for the repair job and the availability, the customer will get a repair start date and a preliminary repair lead time. If the damage inspection has been done on-site, the end user of the vehicle will leave and the remaining steps for the damage inspection will be performed without the end user present. The next step is to search for re-used spare parts. It is a requirement from both Bilia and insurance companies' policies to use re-used spare parts instead of new due to environmental (and economic) goals. If re-used spare parts are not available, new spare parts will be ordered.

The output from this process step is a list of spare parts sent to the spare part unit, a scheduled time slot in CabPlan, and calculated repair time for sheet metal and paint which will be used in the production planning. Worth noticing is that the first sent cost calculation from the damage inspection can change along the repair process. If the required work deviates from the first approved damage calculation, the damage inspector must send information regarding the deviation to the insurance company for approval. Every time an existing damage calculation is updated it needs to be sent to the insurance company for approval, this procedure is called an "addition". The reason for these additions can be for example damages that were not first seen at the inspection. Identifying deviations from the damage calculation is important during every process step. Otherwise, there is a risk that damages are missed, or that additional labor is done without compensation.

Production planning

From the damage inspection, the customer will get a drop of day for the vehicle. This date is determined based on the production planning. Meaning that one part of the production planning is a step within the damage inspection, but damage centers also do a more detailed plan. It has been decided to view it as a separate process step. The production planning is done using CabPlan to see when there is free availability for both sheet metal and paint based on the calculated (estimated) repair time needed for the specific job. In CabPlan, the aggregated amount of available time is determined by the number of employees in sheet metal and paint respectively. Based on the estimated time for the booked jobs and the availability of time, it can show either excess or free availability (figure 4.2). In the same view in CabPlan, it is also possible to see how many jobs will go into and out of the function (sheet metal or paint) for each day.

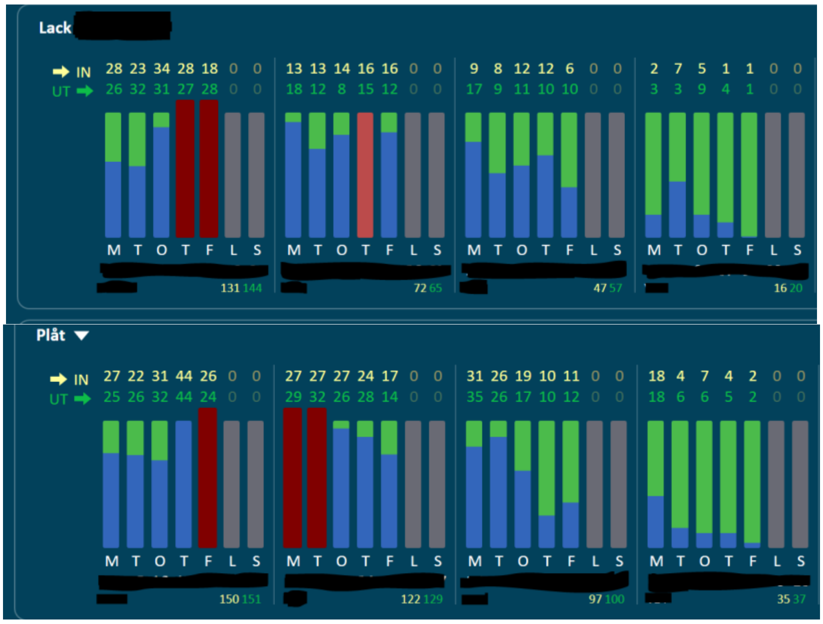

Figure 4.2. *Print screen from CabPlan. Daily booking schedule for sheet metal (right figure) and paint (left figure) respectively. Blue means time booked for scheduled jobs, green means available time, red means overbooked. The number above each bar is the number of jobs that are scheduled to begin and end for each process step (sheet metal or paint) for that day.*

The first planning step is done when the end user is present. The damage inspector will first check on an aggregated level (figure 4.2). If there is more available time than what is calculated for the job, damage centers have two different approaches for moving forward. Either, based on free capacity they schedule the disassembly step for the group. The individual that will perform the job will later be decided by a coach or dedicated production planner. For other damage centers, they look at all employees' schedules for the day where CabPlan shows available time. They then book the job for the individual that has time to perform the disassembly step. Meaning that a coach or dedicated planner only needs to make minor adjustments from the first production plan. When the disassembly step is booked, the planner needs to find a suitable day to schedule the paint step.

The same is done for the paint step, but this is not planned for individuals among the damage centers in the sample. Thereby the paint step is only planned based on the availability of the group. The paint job is often booked with some margin between the disassembly and paint step (this margin can be manually specified, or automatically in CabPlan). This is done for two primary reasons, firstly to ensure that there are some buffers between the steps to enable a more even flow. Secondly, the margin is intended to ensure that the given finish date that is communicated with the customer will not be postponed.

The assembly step is also planned with some margin between the process steps. Further, it could be planned for either an individual or the group at this planning stage. At all damage centers, it is the same employee in sheet metal who disassembles and assembles the vehicle. Therefore, if the damage center plans for an individual during the damage inspection, the planner schedules the disassembly and assembly step for the same person. For those who plan sheet metal work for the group only estimate when the vehicle is ready from paint and based on the required assembly time schedule it when there is available time for the group. Even if it is planned for the group, the same individual that gets the disassembly job will perform the assembly.

Meaning that, from the damage inspection, the end user gets a drop of date for the repair. The drop of day can be the same as the scheduled repair date, but the drop of date is often booked a few hours or a day before the scheduled repair starts. This is to ensure that the damage center always has a buffer with vehicles that can be repaired. From the process point of view, they have a scheduled repair start and end time for each process step (disassembly, paint and assembly). Meaning that spare parts can be ordered and sheet metal and paint can prepare for the job, and often plan the production in more details for both functions just before scheduled start. However, buffer time that is scheduled between each process step only affects the start and end time for each process step. In reality, these start and end times for process steps do not mean that much. However, as mentioned earlier, the end date is seen as a deadline. But if a process step needs jobs, they will start and end them before the planned time.

The production planning performed at the damage inspection is thereby done to give the end user a repair start and end date for the whole repair. But this planning is also needed in order to be able to order spare parts and as an input for the more detailed sheet metal and paint planning.

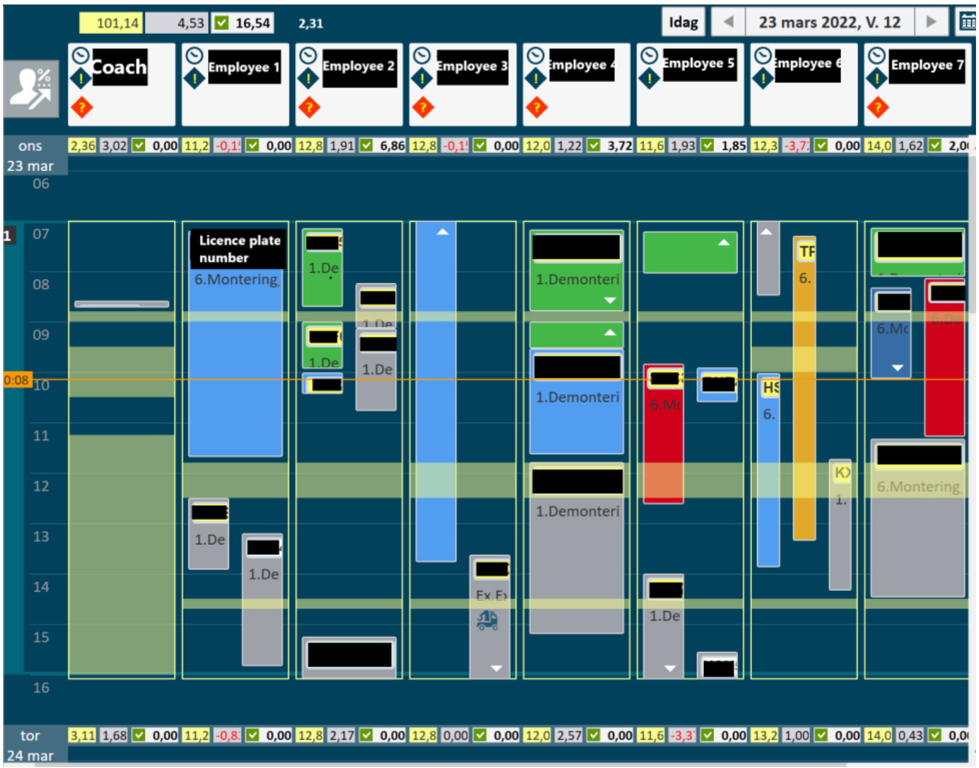

Figure 4.3. *Detailed production planning in a digital form, for sheet metal. Each employee will get an overview of what jobs are planned and the estimated duration of each task. The black boxes have been made to hide the license plate number.*

As mentioned, some plan the sheet metal tasks for individuals directly from the damage inspection. The scheduled jobs for individuals can then be seen in CabPlan (figure 4.3). Regarding those that break down the group plan from the damage inspection to an individual plan at a later stage, there are two main approaches that are used. The most popular approach is that a sheet metal coach or a dedicated planner assigns the jobs to individuals at a later stage, a bit before the start. The reason for why this is done in a later stage is that there might be a need to prioritize among the planned jobs, since more information is available at this later stage. This updated information can for example be the status of the spare parts for the jobs, who actually has time to do the job, and what jobs are most suitable to begin with. One or a few days before the production starts the individual in sheet metal will know what he/she will do. This can either be presented to the employee digitally using CabPlan (figure 4.3) or using an analog Kanban board (figure 4.4). A few damage centers that plan for the group from the damage inspection will instead prioritize the list of jobs according to what has been described above. But instead of planning for an individual, sheet metal employees will get jobs one by one from the coach as needed. Thereby the individuals cannot know what job he/she will perform next.

Figure 4.4. *Picture of detailed production planning from a visited damage center. At this damage center, sheet metal jobs are planned for individuals in advance. Each employee has 2 rows, one for disassembly, and one for assembly. The columns are current job, next job, and initiated job that lacks one or several spare parts. Color code scheme depending on the type of job.*

Regarding paint jobs, most of the damage centers among the sample schedules the job for the entire paint group. The painting process is divided into preparatory work and painting. The preparatory work in the paint shop is either done by a single person or by several people sequentially in a line. The final coloring painting in the process is done by a single person. However, paint jobs cannot be scheduled in advance to the same degree as sheet metal work. It is more reactive, based on what types of jobs that are started in the previous process step (sheet metal). It has been said that it is difficult to anticipate when the components, or vehicle is ready for paint. This means that some of the paint shops do not plan a job unless it is physically finished by sheet metal.

Spare parts
For the spare part step, the input is the damage calculation made by the damage inspector. From the damage inspection, the spare part employee can see what spare parts to order, and when the repair job is planned to begin. However, the spare part list created from the damage inspection does not specify the right variant to order. The repair part employee will use the Vehicle Identification Number (VIN) as an input to the car brand's computer software to determine the specific variant for all spare parts that needs to be ordered. Apart from ordering the right variants of the needed parts, they will also look at the pictures from the damaged vehicles to see if there are any parts, or damages that have been missed during the damage inspection. If the spare part employee identifies something that has been missed (either damages or spare parts) from the damage inspection, the spare part employee will contact the inspector to collaboratively solve the issue. In cases when for example plastic clips (or other low value items) have been missed, the spare part employee will order it without talking with the inspector.

When the parts have been ordered according to the planned repair start, the spare part employee will use CabPlan to communicate with other people involved in the process that the parts have been ordered. Different damage centers among our sample have different approaches regarding when the material is scheduled to arrive, some order the material to arrive at the morning of the planned repair start while others order it to arrive three days before the planned repair start. When the ordered spare parts have been physically received at the damage centers in-house warehouse, it will be marked to let everyone know that the repair job can begin (figure 4.5).

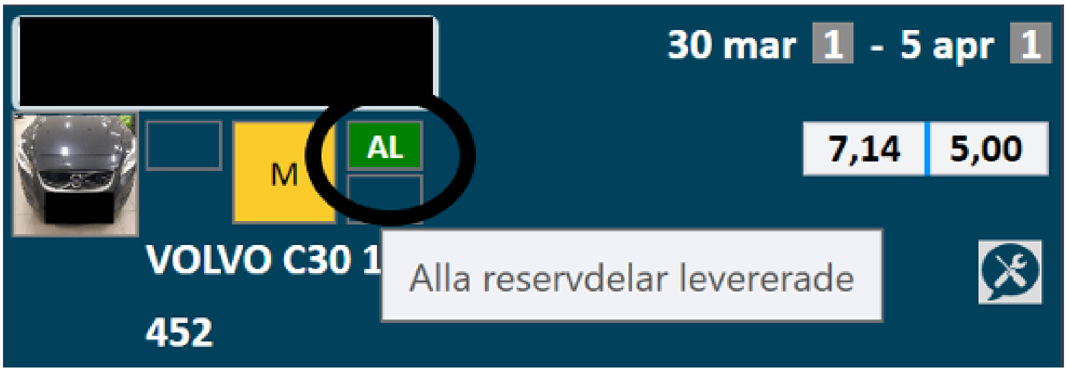

Figure 4.5: *Screenshot from CabPlan. This damage center has decided to use green color and "AL" to indicate that all the needed spare parts have arrived at the in-house warehouse. The two black boxes have been made to hide the license plate number.*

Figure 4.6: *Screenshot from CabPlan, for the same damage center. For them, red color and "B!!" indicates that the spare parts are late and will soon arrive at the in-house warehouse.*

Apart from verifying that the correct spare parts have arrived, the spare part employee's responsibility is also to pack all spare parts into a cart marked with the vehicle registration number (figure 4.7). This is to easily find all components at the repair start. For some of the damage centers, it is the responsibility of the spare part unit to transport the cart with material from the in-house warehouse to the sheet metal employee's workstation. This is done when the sheet metal employee has signaled, via a phone call, that the material is needed. The other alternative is that sheet metal employees themselves collect the cart from the in-house warehouse. If any parts are delayed, it is the spare part unit's responsibility to inform this using CabPlan (figure 4.6). This is done so that the planner or coach at sheet metal can make an informed decision whether to postpone the repair job or not, depending on what spare part it is and when it will arrive.

Lastly, there can be parts that are broken, but cannot be seen at the damage inspection, or that breaks during the repair job. It can also be that any spare part is missing, or that the wrong variant has arrived. When this occurs, the sheet metal employee will call the spare part unit and the needed parts will be ordered by a spare part employee during the repair.

Figure 4.7. *Example of spare parts that have been packed into carts. Depending on the size and amount of needed spare parts, they can in cases be fit into one cart or that the required spare parts needs to be stored at more than one location in the in-house warehouse.*

Disassembly and repair

The input to the disassembly and repair process step is the damage inspection that specifies what needs to be repaired, and the spare parts ordered by the spare part unit. The aim of the process step is to disassemble and repair damaged parts. During the disassembly and repair process, it is important to look for damaged parts that have not been identified at the damage inspection or spare part step. This is due to the fact that the vehicle is not disassembled at the damage inspection, meaning that there can be hidden parts that are broken, but not visible until the disassembly and repair step.

If the sheet metal employees identify deviations between the damage calculation and the actual needed work, a correction of the damage calculation needs to be done. This correction is done by either the coach, or the damage inspector. It is very important to notice these deviations and update the calculation, otherwise they will not be compensated for the additional work. In cases where additional spare parts are needed, the spare part unit or sheet metal coach will be contacted. The above mentioned deviations can for example be that needed spare parts are not included in the damage calculation, or that the surface area (for sheet metal) that needs to be aligned is larger than described from the damage calculation.

Damaged parts can be either repaired or replaced depending on which part and type of damage. All Bilia’s damage centers are authorized by the respective brand, this implies that they have to follow the auto manufacturers repair guidelines. Apart from this, each car brand has their own repair instructions that are used during the repair process. However, each employee has a high degree of freedom to decide how to conduct the work. The way of working differs both between individuals and damage centers.

Damaged sheet metal parts that will be repaired are aligned with tools such as hammers to their original shape. For those parts that will be painted, the sheet metal employee applies body filler on damaged surfaces, such as scratches or unevenness caused by aligning. The plastic and sheet metal parts that need to be painted will in some cases be detached from the vehicle. In cases where it is not feasible to paint detached parts, the whole car will go into the paint shop. Meaning that the process output from this step is either detached and aligned parts or a whole repaired vehicle.

Paint

The input for the paint step is either detached and aligned parts or a vehicle from the disassembly step. In cases where replacement parts are instead ordered, detached parts come directly from a spare part supplier to the paint shop. These can either be factory new parts (unpainted), or undamaged parts that previously have been used on another vehicle. The first step of the painting process is to collect the detached parts that are scheduled to be painted or pick up the vehicle from the parking lot (buffer between sheet metal and paint) in cases where it is required.

There are three preparatory steps that must be sequentially completed before a part or vehicle can be painted. The first step performed at the paint shop is to sand the surface that later will be painted. This is done to make the surface even and pervious for paint. The next step is to mask all surfaces that should not be painted. The last preparatory step is to apply a prime coat. Prime coat needs to be applied on surfaces (and adjacent surfaces) for most types of damages.

Before the color coat can be applied in the painting box, the color coat must be mixed using a variety of color compounds to achieve the specific paint code that is specified by the car brand. This is done by the painters, either manually (by weighing each compound) or automatically (by using an automatic mixing machine). This needs to be done before every painting session. However, many of those that mix the color coat manually do it in larger batches for high-runner colors.

The color painting is done in a painting box with a high degree of ventilation to ensure a high quality of the paint job. Some of the damage centers have an oven that is integrated in the painting box. Others have a dedicated oven next to the painting box. The oven is used to decrease the paint's drying time. The required time for the paint to dry differs widely among the visited paint shops based on what technology that is used. Lastly, the painters remove the masking and do a quality control of the painted surface.

The process steps are the same at all damage centers, but the distribution of work tasks among employees differs. Some of the visited damage centers are doing all preparatory work alone at the same place while others are doing it sequentially in a line. This can be partly explained by the paint shop layout and facilities. The output of the painting process is to deliver painted parts in the right nuance. This needs to be delivered to the assembly step according to the internal painting deadline.

Assembly

The input to the assembly step are spare parts, the painted vehicle or the vehicle and painted detached parts. The assembly step is the last step in the repair process. The aim is to assemble and prepare the car, before it can be delivered to the end user of the vehicle. The assembly step includes assembling the detached and painted parts as well as the ordered spare parts. When the parts are assembled, the visual outcome and functionality of the repair job will be assessed. Adjustments are often necessary for some parts at this final stage. Lastly, the vehicle is washed, and a thorough inspection is made to ensure the quality of the repair job.

5. Results and Discussion

The following chapter includes further information and discussion of certain parts of the process steps that interviewees or the project group have seen as especially interesting to focus on. It includes an analysis of the damage center process, including improvement potentials. It follows by a description and discussion of the different types of monetary compensation used in the sample, and how it can affect collaboration. The second half of this chapter consists of a description and analysis of the current dataset and the KPIs that Bilia currently uses. Then, data regarding lead time and resource- and flow efficiency is presented and analyzed. Lastly, the new operational KPIs are proposed.

5.1 Damage center process improvement potentials

Based on the process steps in chapter 4.2, there are key factors that managers and employees have identified as important for the process. These are based on several interviews and damage center visits and will be described below. The purpose of this subsection is to describe why it is important as a basis for improvements.

Damage Inspection

The majority of damage center managers view the damage inspection as one of the most important steps in the damage repair process. They emphasize the importance of identifying all damages at the inspection. If all damaged parts are identified and included in the calculation of damaged parts, it simplifies the remaining process steps. But it is also important to describe the damages correctly in the damage calculation. Otherwise, it is a risk that tasks are performed but not invoiced to the insurance company. However, a deviation from the initial damage inspection calculations will always be present due to the difficulties to identify all damaged parts that can be hidden behind other parts on initial damage inspection. Damaged parts that are not included in the calculation often emerge during the repair process of salvaged cars.

Some of the visited damage centers inform the end user to wash the car before the damage inspection. However, if the vehicle is dirty to the degree that it is difficult to see the damage, the inspector will wash the surface around the damage. Damage inspections have mentioned that a newly washed vehicle is important for a good damage calculation. For a newly washed vehicle, it is easy to see and measure the surface of damage. Damages can be hidden, and thereby missed if the vehicle is dirty. Photos are taken around the vehicle at the damage inspection to document the visual condition of the vehicle, which are used in case the end user claims that Bilia have caused additional damages during the repair.

Based on visits in the paint shop, the project group has seen vehicles with obvious visible damages that have been missed during the damage inspection. In those cases, visible damages have gone through the damage inspection, spare part unit and disassembly step without anyone noticing it. From visits to the paint shop, it has also been clear that the surface area of the damage specified at the damage inspection can at times be totally wrong. The reason for this is that the damaged surface that needs to be aligned and painted is only estimated (eyeballed) and not actually measured. Meaning that there is a risk that the performed job does not get adequately compensated. The need to measure the damage is important when it comes to the area that will be repaired. Meaning the surface area and depth of sheet metal that will be aligned, and surface area of the plastics that will be repaired. Because these are compensated based on the repair area (and depth for sheet metal) and the placement of the damage. When it comes to damages such as scratches (where filler needs to be applied, but body alignment is not needed), the surface area does not matter since the whole damaged parts needs to be painted. Meaning that the compensation for the repair job differs depending on the size of the damage, but that the compensation for the paint job will be the same regardless of the size (since the whole part needs to be painted).

It is important that all damages and spare parts that have been missed or are incorrect in the calculation are discovered as early as possible in the repair process. All visible damages must be included and calculated correctly in the calculation from the damage inspection. However, damages and spare parts that cannot be seen at the damage inspection must be identified at latest during the disassembly step.

The estimated repair time is a reliable input to the production planning, but only if all work and spare parts are included. If additions to the calculation are made, due to newly identified damages or needed spare parts, it creates non-value-adding activities such as contacting the coach, contacting spare part units, in cases contacting the end user, and occasionally even driving in and out cars more than necessary. Meaning that it results in disturbances for the production flow and can create a need to reschedule jobs in the production plan. The production plan will be unreliable compared to a calculation that is right from the beginning. In addition, a missed spare part that will not arrive until the scheduled assembly, affects end user and insurance company negatively in terms of increased lead time and increased cost for car rental. If the damage calculation is done correctly, it enables the spare part unit to order all needed spare parts at once. Which in turn means that the risk of a paused repair job and non-value adding activities is reduced.

The damage inspector also has the responsibility to determine a repair start date together with the end user. There is a clear pattern that most of the repair jobs will start at the beginning of the week and finish at the end of the same week. This is a pattern that repair centers are aware of, although some do not know to what degree. During the damage inspection, the end user will be given a repair start date (meaning a drop of day for the vehicle), and an estimated repair duration (3-5 or 5-7 days for example). As for now, the damage inspector should give the end user the first date with availability, regardless which day of the week it is. Damage inspectors have explained that end users that get a suggested drop of day at the end of the week often wish to drop the vehicle off at the beginning of next week instead. For the damage inspector, this is a difficult situation. Should the end user or Bilia be the one to satisfy? Accepting the end users demand could mean that the production at the end of the week and beginning of the week will not be fully utilized (the logic for this statement will be explained in paint, later in this chapter). On the other hand, not accepting the end user's demand could mean a dissatisfied customer, resulting in that this or upcoming repair might be lost to another actor that competes with Bilia. This conflict of interest is due to the fact that damage centers do not operate during the weekends. The end user is aware of this and in most cases wishes to minimize the time they cannot use their own vehicle. If a repair job is scheduled for Thursday or Friday, this would often mean that the vehicle will be at the damage center over the weekend when no one is working. Meaning that the repair lead time for the end user will automatically be longer if the scheduled drop of day is at the end of the week. Not only will the repair lead time be longer, the cost for the end user will also increase for those who use a rental car during the repair lead time. If the end user has insurance that includes rental car cost, the end user still needs to pay 25% of the rental cost. In cases where the end user needs to pay the whole cost for the rental car, it is even more understandable that they do not accept the drop off day to be Thursday or Friday if the repair is estimated to take 3-5 days for example.

Production Planning

Planning the production to the degree that it is reliable has been identified as an issue. The problem can be explained by three factors. Firstly, the time that is scheduled for a function (sheet metal or paint) is based on the described damage from the inspection. Meaning that it is not possible to achieve a reliable production schedule unless all damages are included from the damage inspection. Secondly, all required input must be available at the planned production start. Required input for sheet metal are the vehicle for the disassembly step, and the vehicle, spare parts, and painted components for the assembly step. For paint, it is detached components or the vehicle. If the input is late, the job naturally needs to be postponed and the plan cannot hold true. Lastly, even if all damages are included from the damage inspection, it is still difficult to estimate the required time. The estimated time is based on time studies from CABAS. In reality, most of the tasks are done faster than the estimated time. In the planning system, CabPlan, it is possible to adjust an employee's work pace. If the estimated time (from CABAS) is 100 minutes for a task and an employee's work pace is set to 120% the planned job duration for that employee will be approximately 83 minutes (100 minutes / 1.20 = 83 minutes). Meaning that adjusting the employees work pace in the system can be used to fine tune the production plan. On an aggregated level, the total amount of available time during a period is based on the following calculation:

$$Total\ avilable\ time\ [h] = Scheduled\ work\ for\ a\ specific\ employee\ [h] \\ * Work\ pace\ for\ the\ same\ employee\ [\%] * Number\ of\ employees[-]$$

It is the manager and employee at the damage center that adjust and set the pace of an employee based on historical data and the employee’s desired salary goal (for those that have individual variable salary). Based on information obtained from interviews with managers, they have explained that it is difficult to set a pace that reflects reality, although it is regularly adjusted. According to managers, it is beneficial to adjust the pace and set it above 100% for those employees that persistently performs well. For some employees, it is notoriously difficult to set a pace. Managers have said that it is pointless to adjust the pace (from 100%) for some. The reason for this is that the variability is simply too large. Both when it comes to job-to-job and month-to-month variability, they can perform well above or below 100%. What also has been mentioned is that managers for a damage center are reluctant to set the pace to under 100% for those who consistently underperform. The reason for this has been that it is demotivating for the employee, and that can signal that it is ok to consistently underperform.

As mentioned in chapter 4.2, some damage centers plan the production for the whole functional group and the sequence in which the jobs will be performed, but they do not decide by whom the job will be performed. This means that once an employee needs a new job, they take the first one planned for the group. Others plan the jobs for individuals directly from the damage inspection. Meaning that each employee can see the jobs that are planned for them in advance. A manager for a damage center that recently changed from having no planned jobs for an employee (only a plan for the functional group) said that the employee productivity increased. His explanation was that employees were more motivated to complete the tasks that were planned day-to-day, simply by having an individual goal to achieve. In addition, if jobs are planned for individuals, they can prepare and familiarize themselves with the upcoming jobs.

During an interview with a sheet metal employee, he explained that the daily planned job was useful for him to understand whether the productivity setting for him was correct. He mainly repaired salvage vehicles and large damages (the types of jobs that are most difficult to estimate required time for, but also difficult to achieve a good damage inspection). His productivity was previously set to 80%, but he noticed that he frequently managed to complete more than the daily jobs that were planned for him. Because of this, he contacted the manager, and they adjusted his productivity to

120%. After the recent change, the planned daily jobs better reflect what he managed to complete for a day. Ultimately, this adjustment means a more reliable production plan (for both the end customer and internal processes). It is also important to notice that this was achieved without much effort or analysis. However, that he could identify that his productivity setting was currently incorrect was due to the fact that jobs were planned for individuals. If jobs were planned for the group, he would most likely not identify this since there was not any clear set goal for what he needed to achieve per day based on the current productivity setting. On the other hand, one damage center that plans the work for individuals expressed that it can be a risk as well. There can be a tendency that individuals only complete the jobs that are booked for them each day. This even if they had time to complete more jobs that day, and subsequently would receive a higher variable salary.

Improving the reliability of the production planning will likely lead to several benefits. From the end user's point of view, it would mean that the risk of postponement will be reduced. For the damage center this means less time spent in phone calls with the customer informing, and in cases also explaining why the end users pick up date is postponed. Additionally, if the plan is reliable, proactive decisions can be taken. For example, that paint job employees do some of the tasks usually performed by sheet metal employees, or vice versa. To a degree, this is done today at some of the damage centers.

Although not solely dependent on the reliability of planning, it can contribute to a reduced repair lead time. The logic behind this statement is that damage centers might compensate for the production planning reliability issue with extra buffers that would not be necessary if it was reliable. This has not explicitly been said, but what has been said by most of the managers is that they strive to overbook the sheet metal (the first step in the repair process) in CabPlan by approximately 20 percent. The reason for the overbooking strategy has not yet been understood, but presumably the reason is due to the uncertainty of the production planning.

Production planning should be done with respect to both sheet metal and paint. This is due to the fact that the repair process is dependent on both sheet metal and paint. There are interdependencies between the two functions. The Sheet metal group must disassemble parts for the paint group to have something to do. Likewise, the paint group must transform these parts so that the vehicle can be completed by the sheet metal group. Looking at sheet metal and paint as a system can be seen as obvious. But in practice, it is often overlooked. Today, the planning of ingoing vehicles (done by the damage inspector) is primarily done with the capacity of sheet metal in mind. During interviews, it has been understood that damage center managers are stressed, and fear for the moment when the sheet metal is not fully utilized. However, they accept that the paint shop at times does not have anything to do. This is difficult to understand since both sheet metal and paint contribute to the economic result. To problematize it further, most of the managers claim that the paint shop is the bottleneck of the repair process. Given what they say is correct (that the paint shop is the bottleneck), it is difficult to understand why they do not plan based on the paint shop and try to utilize it as much as possible. This has been asked to the managers, and the answers have varied. Some do not see the problem with planning the production almost solely based on the sheet metal since "sheet metal hours feed the painting hours". They do not see any other possible way of planning. Others see this way of planning as an issue, but that planning based on the needs of the paint shop is difficult to achieve based on their view. Among the damage centers in the sample, there are a few that historically have not had an in-house paint shop. Meaning that it can be an old way of thinking and working, from the time when there was only sheet metal work to consider. One manager identifies this as a possible explanation for why the paint shop does not get the same attention that sheet metal does.

With regards to the balance between sheet metal and paint, several managers have addressed that the production mix is important to achieve a good process flow. The mix refers to what types of jobs that are planned (based on the balance between required hours for sheet metal and paint). As for now, the mix is not deliberately chosen based on any planning criteria. Due to the random variation in the sequence of the vehicles inflow, there will at times be a good production mix which increases the performance of the system. Where the performance refers to the lead time and efficiency. A manager that has experienced the effects of a good production mix explains that it is difficult to achieve deliberately. This is due to two main factors, firstly the manager said that some damage centers do not have the required inflow in terms of volume to achieve a plan for a good mix. Secondly, that it would imply that the user of the vehicle will not primarily be given the first available time.

For those damage centers that repairs salvaged cars, these types of jobs are often used to balance the total workload between both sheet metal and paint. The reason is that salvaged cars generally mean lots of hours for sheet metal, but comparably few hours in paint. In addition, these jobs (salvaged cars) are perceived as a good way to achieve a mix since the repair lead time acceptance is generally higher (both from the insurance company and the end customer) compared to cars that can be driven between damage inspection and repair start. Another reason is that salvaged vehicles are located at the repair center's parking lot and enables a quick solution to even out the current workload.

To achieve a good mix of jobs, planners need to look at each CABAS calculation planned for each day to understand what type of job it is (for example structural damage, damaged front bumper, scratched door etc.), and the estimated time for sheet metal and paint. Meaning that there are not sufficient prerequisites to achieve a deliberate mix, according to those that plans the production. Several managers have expressed a wish to get a visual representation, or count based on what types of repairs is planned for each day. As seen in figure 5.1, one can only see the number of hours booked as disassembly (demontering) and assembly (montering) for each day in sheet metal, but not what types of jobs it is. However, one can get an indication of whether there are small or large jobs scheduled for a function for a specific day. This is done by looking at the total booked estimated time for a function and dividing it by the number of jobs for the same day. This can provide valuable insight to achieve a good mix of jobs for the upcoming production.

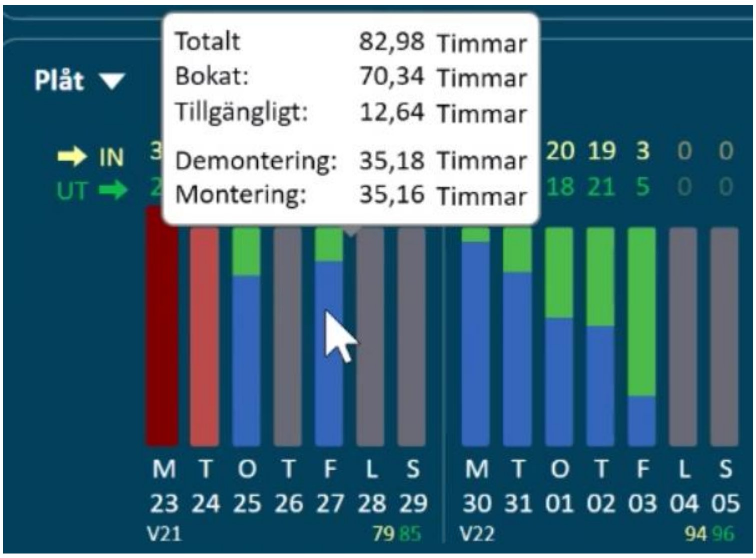

Figure 5.1. *Screenshot of the view in CabPlan that the planner uses when booking a job.*

Spare part unit

Ordering the needed spare part, and the right variant, to arrive at the right date is the most important task for the spare part unit according to interviews. As mentioned in the previous chapter, the right variant of the spare part for a specific vehicle is not specified from the damage calculation. For one of the visited damage centers, there was an ongoing issue that the right part, but wrong variant was sometimes ordered. Ordering the wrong variant of spare parts and forgetting to order some or all spare parts have been mentioned as problems. The explanation is said to be human error, but also new employees without sufficient experience.

The communicative part of the spare part employees' responsibilities is very important. Everyone involved, especially the production planner and the sheet metal employees need to be informed using CabPlan if any delays occur. In this way the production can be rescheduled accordingly. The end user can then be informed that the drop off day is postponed due to a missing spare part. Meaning that the end user can continue to use their vehicle in the meantime, and the repair lead time will not be affected.

As earlier mentioned, spare part employees will collect the spare parts and place them in a cart, marked with the vehicle identification number. For some damage centers, the spare part employees transport the spare parts to the sheet metal employees, but transportation can also be the sheet metal employee's responsibility. Damage centers that recently have extended the responsibilities for spare part employees to also include transporting the spare part to the sheet metal worker have mentioned that they have seen positive effects. One manager explained that the door to the in-house warehouse at his damage center was locked, and when the sheet metal employee needed the spare-parts they would need to knock on the door. At times, this meant that sheet metal employees had to wait a long time until someone opened. However, spare part warehouses are generally not locked for employees, so this issue is not applicable for all damage centers. But what is applicable for all damage centers is that it can be difficult for sheet metal employees to find what they need at the warehouse. Although most parts are already packed in a cart, there can be parts that cannot fit in the cart and thereby is placed somewhere else. The reason for why sheet metal employees still collect the cart from the in-house warehouse at one of the visited damage centers was that the spare part unit was understaffed. Unless this is the case, it is difficult to understand why it should be performed by a sheet metal worker.

Disassembly

It has been clear from interviews and damage center visits that managers and coaches stress the importance that the sheet metal employee works systematically during the disassembly step. Sheet metal coaches have even said that much of the difference in performance between a good and poor performing sheet metal employee can be explained by their way of working. From what has been understood, the systematic way of working means to assure that the previous process steps have been done correctly, but also to do the tasks in the right sequence.

Regarding the sequence that has been explained as best practice, there are a few preparatory steps before the actual disassembly and repair of a vehicle can begin. The first preparatory step is to briefly look into the job using CabPlan to make sure that the spare part unit has marked that all spare parts have arrived, and to familiarize with what type of job it is. This step is important to begin with, otherwise there can be a risk that the disassembly and repair step cannot be completed at once due to a vital missing spare part. Once this has been done, the sheet metal employee will call the spare part unit to receive necessary spare parts to their workstation (or go and pick them up from the in-house warehouse for some). It is important to do this at an early stage, to make sure that the spare parts arrive at the workstation as fast as possible. Next, the employee will pick the vehicle up from the parking lot and transport it to their workstation. When the vehicle and all the spare parts have arrived at the sheet metal employee’s workstation, the sheet metal employee should carefully look at the damage calculation and compare the described damages (what is included in the calculation) with what damages that he/she can see. This is for two main reasons, firstly to ensure that there are not any further damages that have happened between the damage inspection and drop-off day. Secondly, to ensure that the damage calculation has been done correctly. After all, the sheet metal employee that repairs vehicles for a living possesses lots of experience and knowledge based on similar repairs that he/she previously have done. There can for example be things such as clips that often break during disassembly and are not automatically included when the spare part is ordered. It can also be that the sheet metal employee knows from experience that an increased area needs to be aligned based on the specific damage. Damage inspectors and spare part employees will generally not have the same degree of knowledge as the one who performs the repair.

These control steps are important and are explained to be beneficial because it ensures that the sheet metal worker (and Bilia) get compensated for all the tasks that are performed. It has been said that there can be smaller subtasks that are performed during the repair that generate money, but that are not invoiced to the insurance company. This since these tasks can be done relatively fast, and no one bothers to specify that they are done, or that the sheet metal employee does not know that it is not included in the damage calculation. For the end user and the insurance company the extra control step is also of value. Because it ensures that no damages are missed. From damage center visits, the project group has seen obvious damages that were identified firstly at the paint step, but that should have been repaired at the disassembly and repair step. Ultimately these above-described control steps result in a decreased repair lead time and an increased resource efficiency.

However, there can still be labor and damaged spare parts that cannot have been included in the damage calculation or seen by the sheet metal employee regardless of the knowledge, especially for salvaged vehicles. As can be seen in Figure 5.2, some parts cannot be identified and included in the calculation until the vehicle has been disassembled. Meaning that, in those cases it is important to disassemble as much as possible in the disassembly step, and order all needed spare parts. In addition, it is also important to ensure that the right variant have arrived and is placed in the spare part cart.

Figure 5.2. *A salvaged vehicle that illustrates the difficulties achieving a good damage inspection in some cases.*

To do as much as possible during the disassembly step is something that all damage center managers and coaches have stressed. Regarding the difference between the disassembly and assembly step, it is quite flexible regarding which tasks are performed at which step. Thereby, a missing spare part that was intended to be used for the disassembly step can arrive at the assembly step without necessarily causing any disturbance or increased non-value adding time for the sheet metal employee. The repair lead time does not either must be affected.

If any spare part is missing, the sheet metal employee has to contact the sheet metal coach (or damage inspector) that has to do the addition. If the inspector is doing the additions, it increases their knowledge about damages and spare parts that often are missed. But from gaining understanding, it is often the coach who does this. Additional spare parts must be ordered during the disassembly step. Because it enables missed spare parts to arrive before the assembly step.

In some cases, the sheet metal employee or a coach must decide if he/she sees it suitable to begin. To clarify, in some cases it might not be wise to begin the repair job. The reason for this can be that a spare part has not yet arrived or that an ordered spare part will not arrive until several days or weeks (or even worse, that there is not any estimated arrival date). In cases like these, the vehicle can still be drivable, and it is wiser to not begin the disassembly and repair step until the spare parts have arrived. For some damages, there is a risk that the vehicle cannot be driven or be placed on the floor without assembling parts that later will be disassembled due to a missing spare part. To illustrate the issue, if there is a missing spare part in the wheelhouse of the vehicle seen in figure 5.3 it would mean that the wheels and related parts need to be assembled to be placed on the floor and/or driven to the parking lot. This “unnecessary” assembly needs to be performed in order to use the vehicle lift and workstation for another vehicle, until the spare part arrives.

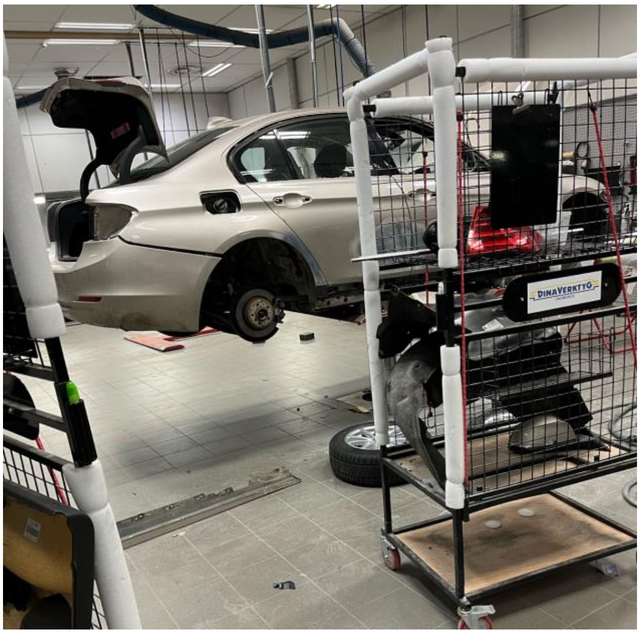

Figure 5.3. *Example of a sheet metal employees works station at the disassembly step. To the right, a cart for the disassembled and functional part can be seen*

The information and insight described above about the disassembly step have been obtained during interviews with managers, coaches, and employees at sheet metal. Regarding how to actually repair the vehicle, there is not much that has been said. What has been said is that the sequence is important, and to make sure that everything is correct before the actual disassembly and repair begin. To make sure that all discovered spare parts actually are ordered at the disassembly step, which means that they have a chance to arrive until the assembly step. If this is missed, it causes unnecessary long repair lead time for the end user, but also disturbance and non-value-adding activities (which leads to decreased efficiency) for the damage center. At some of the damage centers, the managers have said that every sheet metal employee agrees that this is the best way to work. But that employees are stressed, forgets, and directly begins with disassembly and repair of the vehicle. The individual variable salary can be a factor for this issue according to some coaches and managers. The reason is that some employees are eager and stressed to reach a high individual bonus and thereby forgets, or do not feel that they have the time to reflect before they begin. On the other hand, a manager for a damage center said that all his sheet metal employees do not agree that this is the best way of working. The same manager said that he knows that the best performing sheet metal workers for his damage center are working in the way described above in this subchapter.

Paint

Several managers and employees mention that the painting process step is the process bottleneck but at the same time, many damage centers have low efficiency on Monday mornings and Friday afternoons due to lack of incoming paint jobs from the sheet metal. This can be explained by the fact that the most popular drop of the day is Monday. For many sheet metal disassembly and repair jobs, it takes a few hours until the paint job can begin. This means that the paint shop does not have anything to do during Monday morning, given that there is not any buffers or paint backlog. In addition, most of the vehicles are assembled and handed over to the end user on Friday. Meaning that there are not many paint jobs going into the paint shop during Fridays (especially afternoon). As a consequence, some of the painters do smaller tasks that usually are performed by sheet metal employees during Monday mornings and Friday afternoons. This is done in order to decrease the waiting time for incoming paint jobs. In addition, they will get compensated for the sheet metal work that they perform.

If the production planning is more reliable and evenly distributed over the week, the buffer between disassembly and paint will be more stable over time and the variation in lead time will be reduced. Today, the paint shop is generally not fully utilized although some view it as a bottleneck. As explained, the paint buffer for many paint shops is built up from Monday afternoon and culminates (and leads to orders in backlog) at mid-week. On Friday afternoon the buffer is low (or zero) levels again until Monday afternoon.

The painting boxes and ovens have a fixed drying time. The paint box and ovens specification dictate the number of painting cycles per day. To increase productivity, it is important to maximize the physical space utilization of the painting boxes every painting cycle. However, the physical space utilization of the painting box is dependent on the ventilation. A good ventilation enables a higher degree of color difference for each painting cycle, but also allows placing the components and vehicle with a minimal distance between them.

The paint shop gets scheduled start time and deadline from the production planner. The paint shop receives many paint jobs each day. Often, it is the paint shop coach that plans in which sequence the jobs should be painted. This is primarily based on the deadline set by the production planning done by the damage inspector. To a degree, the paint shop coach or the painter in the paint box decides the sequence based on color and size to maximize the utilization of the paint box while meeting the scheduled deadline. An increased utilization of the painting box means that the sheet metal employees can assemble the painted parts earlier, ultimately reducing the repair lead time.

As previously mentioned in chapter 4.2, the mixing of color coats could be done either manually or automatic. When this is done manually, the painter weighs every ingoing color compound based on the color paint recipe (figure 5.4) Then the color coat has to be mixed. According to interviews, there are more sources of error when the color is mixed manually. When the mix is done manually, the barcode of incoming components is not scanned. Meaning that there is a risk that the wrong color compounds are used. In addition, manual mixing requires more active work during the mixing compared to automatic. However, paint that is mixed manually is done in larger batches (not only for the specific upcoming paint job). The remaining paint will be stored in ventilated cabinets. Meaning that the paint colors (except low runners) will be mixed in an excess amount and stored in plastic containers to cover the anticipated upcoming demand (figure 5.5). Popular colors are stored in large containers and mixed in batches as they run out (figure 5.5).

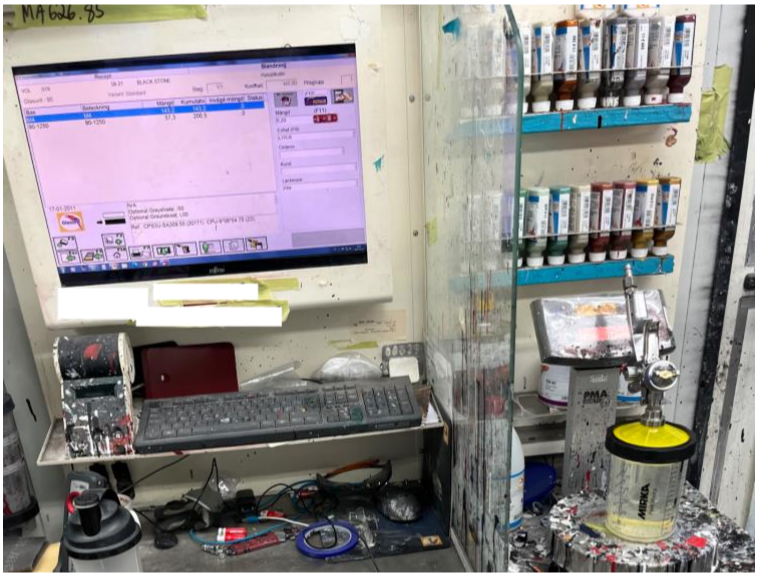

Figure 5.4. *The picture shows the scale and the computer that are used when the color is mixed manually.*

Figure 5.5. *The picture to the left shows ventilated cabinets where excess paint is stored in plastic containers. The picture on the right shows high-runner colors that are mixed in batches to fill the large containers.*

From the computer (figure 5.6), the operator chooses what specific color and parts of the vehicle that will be painted. Based on this input, the machine knows the exact recipe, and will specify what compounds that the employee needs to feed the machine. The barcode is scanned for each compound and the machine will automatically dispense the correct amount of each color compound and produce the right amount of finished color coat based on what part of the vehicle that will be painted. Since all barcodes of the ingoing color compounds are scanned, there is no source of error (except choosing the wrong recipe). Lastly, the automatic machine mixes the color during approximately 10 minutes. During this time, the painter could do other value adding tasks while waiting for the automatic machine to mix the color.

Figure 5.6. *An automatic setup for the mixing of color coats.*

One damage center manager mentioned that there are different methods used for masking whole vehicles. The first identified method means that the vehicle gets masked with plastic when it arrives at the paint shop. The surface that will be painted is cut out and its corners masked with tape (figure 5.7 to the right). Next step is to sand the whole part that will be painted. When this has been performed, the painter applies a supportive masking (figure 5.7 to the left). The aim of supportive masking is to cover the green plastic against the prime coat. It is only the surface around the filler that needs to be painted with primer. When the prime coat has dried, the painter has to sand the prime painted surface. The supportive masking contributes to a reduced surface area (see difference between right and left figure 5.7) that needs to be prime-painted and sanded a second time before applying the color coat. As a last preparatory step, the supportive mask is removed, but the plastic cover and the masking tape (that are applied when the vehicle arrives) are kept for the color painting step.

Figure 5.7. *The picture to the right shows how a masking is made. The beige paper, seen in the left picture, is the supportive masking used to not get prime coat on the green plastic.*

The second method is done in another sequence. The first masking is done with the aim to cover the car from the prime coat and dust particles from the sanding. The mask is applied to cover surfaces adjacent to the damaged part. After this first masking, the damaged surface is sanded and painted with a prime coat. Once the prime coat has dried, the surface is sanded a second time. Then the excess masking that is not needed for the color painting step is removed (figure 5.8).

Figure 5.8. *The picture shows the second method of masking. The supportive masking that has been applied for the preparatory work is kept. Only excess masking that is not needed for the color painting has been removed. The vehicle is ready to be covered with plastic.*

Once parked in front of the box, a second masking needs to be done (figure 5.8). This masking includes covering the whole vehicle with a plastic cover, cutting a hole in the plastic and applying masking tape around the surface that will be painted. The masking tape applied at this stage does not require any precision (since the first masking tape is applied carefully). Meaning that the masking tape is applied on top of the first layer with the sole purpose to fasten the plastic cover.

Figure 5.9. *The picture shows an employee covering the vehicle with plastic cover. It is the same vehicle that is seen in figure 5.8. The employee has been anonymized.*

Assembly

During interviews and damage center visits, there has not been much said about the last step in the process, the assembly step. Naturally, it is important that the assembly step is performed as soon as it arrives to minimize the lead time. For those damage centers included in the sample, the sheet metal employee that disassembles the vehicle will always be the one who assembles it. The fact that it is not clearly defined what should be done in each sheet metal step (disassembly or assembly) has been understood to hinder two different sheet metal employees to be involved in the repair of a vehicle. Based on the damage, if all necessary spare parts have arrived, and personal preferences, tasks that should be performed in the disassembly step calculation can be performed in the assemble step (naturally, parts that need to be painted must be repaired and/or detached in the disassembly step). Likewise, some of the tasks that should be performed in the assembly can instead be performed in the disassembly step. However, the sheet metal employee does not see which tasks are included (and calculated) in the disassembly and assembly step respectively. The sheet metal employee only sees what tasks should be performed, but not necessarily at which step. This flexibility when it comes to what should be done in each step has been explained as the reason for why the same sheet metal employee performs both the disassembly and assembly step for a vehicle.

Despite this ambiguity, the computer software CabPlan provides the estimated time in the disassembly and assembly task respectively. How this has been calculated is difficult to understand since there is not a clear boundary between disassembly and assembly in practice, and one cannot see what sub-tasks that build up the disassembly and assembly time for the time estimation. The project group found a manager that explains that there is a setting where one can specify a percentage of the amount of time that shall be in each process step (disassembly and assembly) in CabPlan.

As previously mentioned, employees can perform many of the tasks in any of the two steps (disassembly or assembly). Meaning that it is very difficult for the front office employees to anticipate and communicate a finish time to the end user of the vehicle. Those employees at damage centers that have an individual bonus based on performance are naturally reluctant to change so that one can perform the disassembly, and another employee the assembly. Because changing this would mean that if any necessary deviation from what is calculated to do in each step is made, the two employees repairing the vehicle would not be compensated correctly. This unfair compensation can occur if one person does more or less than what is classified (and calculated) as assembly or disassembly tasks. Reasons such as a missing spare part or personal preference can be the explanation for why tasks are not performed during the “correct” step.

However, even those damage centers that have a bonus based on the group's performance are hesitant that two different employees from sheet metal work on the same vehicle. The reason for this is said to be the risk of misunderstandings since most of the employees work differently. Another explanation for why both sheet metal steps are performed by the same employee is that it creates a sense of “ownership” and responsibility. Some have even explained that it is like craftsmanship, and that “one gets to know the vehicle during the disassembly step, which makes it easier to later be the one to complete the assembly step”. Practical issues related to finding the spare part cart (that is used for both disassembly and assembly), where the screws and tools etc. are placed have also been mentioned as issues if more than one sheet metal employee are involved.

This flexibility regarding what to do at which step can be seen as a potential risk contributing to poor performance. Mainly since, if some of the actual repair tasks are performed at the assembly step, any missing spare part or a previously unidentified damaged part will almost always create wasteful activities. The vehicle needs to be taken to the parking lot, and then back to the workstation when the spare parts have arrived. This increases the lead time for the end user as well. Standardizing the sequence of repair tasks and determining what always should be done in each step (disassembly and assembly) will reduce the mistakes.

5.2 Types of monetary compensation

Data about the different types of monetary compensation used in the sample was gathered in interviews in the beginning of the project. Meaning that the data only represent 10 out of 13 damage centers with an in-house paint shop.

Table 5.1. *A summary of the type of monetary compensation used for the damage centers in the sample.*

Function	*Fixed salary*	*Individual bonus*	*Group bonus*
Sheet metal	***2***	***6***	***2***
Paint	***2***	***0***	***8***
Other functions	***10***	***0***	***0***

Sheet metal
Currently there are three types of compensation that are used in sheet metal (as can be seen in table 5.1). The three types are fixed individual salary, individual bonus (fixed salary, plus individual variable salary), group bonus (fixed salary, plus group variable salary). In this section the primary focus will be on individual bonus and group bonus. Fixed individual salary will just be briefly mentioned. The reason is that it is only used by 2 damage centers and the gained knowledge of what it means and how it works in practice is limited.

Individual bonus is the most common compensation type in the sample. Several damage center managers argue that it is the best type of monetary compensation to use for sheet metal employees. This since it creates an external motivation for the individuals to perform well and achieve good economical results (both for the individual and the damage center). There is not much of a need to motivate and coach the individuals to meet the performance goals. Because if an individual works above the set performance target, both the individuals and the damage center will directly benefit from it economically. But it will naturally not encourage collaboration between sheet metal employees, everyone will do their best to achieve their own goals. But from a managerial point of view, it has been said that dividing the jobs equally can be a sensitive task. This is because some types of jobs will be easier to earn money on compared to others. Since individual bonus is so important for many, there is not a need to motivate the individuals to work hard. Instead, it becomes a need to ensure that everyone perceives it as fair when it comes to the jobs they get.

For those damage centers that have group bonus or fixed individual salary, it is not such a sensitive topic regarding who gets what job. But it can be difficult to motivate the individuals to perform. Especially for those damage centers that have fixed individual salary, it is important to set a clear target and make sure that employees perform. But it becomes difficult for managers to motivate the individuals to overachieve, since there is no direct economic gain for them. For those that have group bonus, there is an inherent goal to achieve above the set goal to get the bonus. The team spirit and collaboration will increase compared to those that have individual bonus or fixed individual salary. During the damage center visits, it has been seen that those employees that have group bonus have helped each other and collaborated. This has been seen to a limited degree, but still more than for the other two salary types.

A sheet metal employee explained that there is a risk that group bonus can create tension and conflicts. The main reason for this was that individuals might not have the same goals, and that some individuals do not want to work as hard as others. Managers for damage centers that use group bonus have explained that it is often the same employees that always are absent, and that some employees always contribute more than others. This will create dissatisfaction among the highest performing sheet metal employees due to the fact that the group variable bonus is divided equally among the employees. Managers at some of the damage centers that today have individual bonus have expressed a fear of losing the highest performing employees to competitors if group bonus is implemented. If they do not leave the company, it is still likely that they will not perform to the degree that they previously have. Their worries are based on the assumption that all employees will not perform equally. Meaning that although an employee works hard to the degree that it would result in a substantial monetary amount if individual bonus was used, it does not necessarily mean that any bonus would be achieved if group bonus was used. Although one's own performance becomes less important compared to individual bonus, the group must be satisfied with one's performance if group bonus is used.

Group bonus will, as earlier mentioned, encourage employees to collaborate. Employees can help each other on certain parts of the jobs, and everyone can do an assembly job for a vehicle, even if they have not previously disassembled the vehicle. But apart from these practical aspects of collaboration it can also mean that employees will see and understand how others work. It creates an environment that, if fostered correctly, will encourage employees to share tips, tricks and the best way of working. Employees will likely see how others work, and it becomes an interest for all that the best way of working is followed since it affects the group's bonus. But as expressed earlier, group bonus will likely cause an increased need to manage the group and ensure that the environment actually can lead to the mentioned benefits.

An aspect that frequently has been mentioned is the stress that individual bonus can create for employees. Managers and coaches for damage centers that today use individual bonus express that they believe that it creates an environment where people's wellbeing can be negatively affected. As a result of this, one sheet metal coach believes that people's desire to work will increase and the amount of sick leave will decrease if the individual bonus is changed to group bonus. On the other hand, two of the managers for damage centers that today have group bonus expressed that it often is the same employees that are absent. From their point of view, individual bonus would reduce this, since they would be more directly affected by it instead of the group.

In addition, a few damage center managers claim that the stress that an individual bonus can induce means that the mistakes and amount of rework increases. They further claim that tasks such as ensuring that all components have arrived, that all damages are included, and ordering missing spare parts at the disassembly step are frequently missed. The reason for this is said to be that employees do not perceive that they have time for it. Employees “know” that taking a few minutes to do the above described will benefit them economically, but they feel that they do not have time and instead just begin with the repair job. The managers that use group bonus claims that this is the case, and that unnecessary work caused by mistakes are reduced. They further explain that the amount of rework and lead time is negatively affected, and subsequently also that the customer satisfaction is decreased by the stress induced by individual bonus. Once a rework appears, anyone in the group can perform the rework regardless of who has caused it. For those that have an individual bonus, people are unwilling to do a rework job as it will negatively affect their individual salary.

According to interviews, the two managers who have group bonus both want to change it to individual bonus since it creates extra motivation among employees to perform. On the other hand, some of the managers and coaches who today have individual bonus instead want to change to group bonus. This in order to increase collaboration and team spirit among employees (as described above). Meaning that it is difficult to understand what salary type is most appropriate. There seems to be a tendency that managers want to implement the salary type that they currently are not using (regardless if they use individual- or group bonus). However, there are managers within the sample that currently use individual bonus and are certain that it is the best salary type for their damage center. The managers for those damage centers that have fixed individual salary did not want to change either. For the two damage centers that currently have group bonus, it is the sheet metal employees that have chosen the group bonus and are unwilling to change. The majority of the group seems to prefer the collaboration and team spirit over the possible extra individual monetary compensation.

Paint shop

In the sample, there are two types of salary identified used in the paint shop. Group bonus is used by eight out of ten damage centers. The remaining two use fixed individual salary. The mentioned reason for using group bonus is that the employees in the paint shop are dependent on each other as they work sequentially. Several employees are working on the same vehicle. Managers also mention that the group bonus in the paint shop increases collaboration and the team spirit. In addition, it is said that group bonus spurs employees to perform in the paint shop. But as mentioned above, it is often the same individuals that always are absent.

Spare part unit and production planning

Among other functions involved in the damage center process, there are generally no bonuses based on performance. Based on the project group's understanding, there is only one region that has a bonus for damage inspectors (front office employees) based on performance. But this is a minimal amount compared to the bonus that sheet metal and paint employees receive. In addition, the bonus is based on “customer (end user) satisfaction”, meaning that it is not solely based on their performance, factors such as repair quality and lead time will influence it. A damage inspector (front office employee) mentioned that from her point of view, variable salary based on performance would motivate them further. Especially since their tasks, such as communication with the customer, damage inspection and production planning are vital for the performance of the whole damage center. Further, some damage centers have a dedicated production planner that uses the first production planning done by the inspector as an input to create a more detailed production plan just before the production starts. These dedicated production planners do not either have any monetary incentive to perform well. The same can be said for the spare part unit. However, the spare part unit is not only working for the damage center. They also support the service center with spare parts that are needed during service. Meaning that it could be difficult to include them in a damage center bonus since they work for two different departments.

5.2.1 Collaboration

Based on damage center visits, it was possible to see some collaboration between sheet metal workers for those that had a group bonus. However, this was not seen during visits to damage centers that had individual bonus. One damage center manager argued that he prefers a group bonus since it increases the collaboration and decreases the lead time. The logic for the decreased lead time is that anyone in the sheet metal can complete the assembly once a vehicle is ready from paint. He further argues that this could not be done if the individual bonus was used, since sheet metal workers want to assemble the car that they previously have disassembled. The main reason for this is that employees generally earn more during the assembly compared to disassembly.

However, another damage center manager suggested having a group bonus based on the performance of the whole damage center. Based on the interviews and damage center visits, the project group has not got the impression that it is one damage center with different functions striving for the same goal. Instead, each function focuses almost solely to achieve their goals, even though this is done at the expense of other functions' performance. For example, almost none of the damage centers have regular meetings where both sheet metal and paint are present. If the bonus was based on the whole damage center's performance, this would encourage communication and employees to work together with other functions to achieve a good performance. As mentioned earlier, for some damage centers, the paint shop does not have anything to do at times. The reason for this is the production planning and the sheet metal unit that feeds the paint shop with jobs. It is difficult to believe that employees in sheet metal and production planning would allow this to happen if their bonus salary would be negatively affected. Meaning that, the interest to find solutions that benefit the whole damage center (all functions) will increase, thereby reducing the risks of sub-optimization.

The manager that suggested a bonus based on the damage center's performance mentioned that at his damage center both sheet metal and paint are present at the daily held meetings. The aim of having these meetings together is to promote communication and understand the current needs of other functions. Due to the current situation in sheet metal and paint, there could be a need to temporarily relocate staff, complete some of the tasks usually performed by the other function, or other changes that result in an increased performance for the whole damage center.

As an example of the collaboration to increase the performance for the whole damage center is the balance of work tasks for sheet metal and paint. As mentioned earlier, the input to the paint shop could be either a whole vehicle or just the detached damaged parts. If the sheet metal employees detach parts that will be painted, it generates extra labor for them. The extra labor is allowed to be included in the damage calculation, and thereby also invoiced to the insurance company. For the paint shop, receiving detached parts will increase the space utilization and thereby also increase the productivity compared to receiving a whole vehicle. In addition, the preparatory work for the paint shop will decrease in terms of masking if they receive detached parts. Lastly, detached parts can be directly transported from the sheet metal to the paint shop. Meaning that the paint shop employee does not need to pick up the vehicle from the parking lot. With an increased collaboration between sheet metal and paint, detached parts could be a production planning tool. If the current demand in sheet metal is low and the current demand in paint is high, sheet metal employees can detach parts to even out the current workload between the two functions. Likewise, painters can paint detached parts themselves or paint whole cars if the current demand for sheet metal is high and low for paint.

Many of the damage center managers have explained that detaching parts that will be painted is beneficial for the performance of the whole damage center. However, during a visit to a damage center it could be seen that parts that "should" have been detached instead were received as whole vehicles at the paint shop. The reason for this is that sheet metal employees were reluctant to detach parts since it would negatively affect their individual bonus salary. Especially, sheet metal employees claim that they tend to "lose money" if they detach parts that need to be adjusted during assembly. Due to this, they had come to an agreement that parts that do not require adjustments should be detached by sheet metal employees. Generally, the bonus system (either individual- or group) means that decisions are made to maximize one's own gain even if this means a loss for the company as a whole. If the sheet metal employee detaches all parts, it can benefit the company as a whole, even though not beneficial for the sheet metal.

Several damage center managers mention the importance of having continuous feedback between sheet metal employees and damage inspectors. The aim of this is to increase the damage inspector's knowledge about the repair process. At some damage centers, coaches or any of the damage inspectors make the additions if the calculation is incorrect. This means that the employees that have made the first calculation are not aware of the mistakes and thereby assume that it is correct. Therefore, it is difficult for them to improve since they do not receive constructive feedback. One damage inspector for salvaged cars mentioned during an interview that knowledge and experiences about different types of damages simplifies their job to make a good initial calculation. He even mentioned that he felt that he did not get sufficient feedback. At times, he even went to the sheet metal employee to ask if the damage was correctly calculated (and that all spare parts were included from the inspection) during the repair job.

Most managers also mentioned that their damage inspectors are working tight together with the sheet metal employees. But the project group has not got this impression. At one damage center, the manager has created several smaller teams consisting of one damage inspector and a few sheet metal employees. In these teams, the damage inspector can be seen as a coach as he/she also plans the work for the sheet metal employees in these teams. The aim of these smaller teams is to enhance the understanding of the other function. But also, to increase the knowledge gained by systematic feedback. Recurring meetings in smaller groups is said to facilitate an environment where people tend to be less defensive and instead sees the feedback as constructive.

5.3 Verification of the dataset

The dataset has been bought from CAB Group. The data includes damage calculation done in CABAS, and more detailed data from the process steps and planning from CabPlan. The dataset includes information about all repair jobs that Bilia have performed during 2021.

The provided data have been analyzed during the project. The first step of the analysis was to understand what the data actually meant. When the damage center process had been understood, the data was used to gain further understanding of it. During these two steps, the data quality in terms of reliability and how detailed the measurement system captured the process were analyzed. The intention was to develop operational KPIs for Bilia that could be used to monitor the damage centers. But also, to provide further understanding during the project, for example to verify hypotheses and to identify improvement potentials with the usage of both quantitative and qualitative data.

From the data analysis, it was concluded that the data was not reliable. There are approximately 20% of the logged process steps that have been done in one or a few seconds, which in reality is impossible. This finding, that the process steps are not measured reliably, has previously been unknown since much of the process data have not been used before. The project group also understood during the project that there is no reason for the operational employees to log the process step correctly. The explanation for this is that their time spent on jobs, which is an input for the variable salary, is measured in another system.

The data was explained to include all data from CabPlan. Thereby it would be possible to measure all process steps and process events on a detailed level and create KPIs. However, when investigating the data it became clear that this was not the case. The data did not capture the process on a detailed level and far from all process events or process steps were included. This was mentioned, but according to the employees the project group spoke with, all necessary data from CabPlan should be included in the dataset. This meant that the project group further investigated and tried to measure the process steps with the provided data, as this should be possible. There were a few KPIs that the project group saw as important to create, but did not have the required data. Later, it was discovered that CAB Group had already created some of the KPIs that the project group wanted to create. As it was said that CAB Group used the same dataset, it became clear that this could not be the case. During an interview with an employee at CAB Group, the project group's suspicion was confirmed. Bilia had not purchased all process data from CabPlan, instead they had only bought a small portion of all available data. Based on this, it was decided to not further focus on or investigate the data. The reason is that the possible benefit of the data use was deemed very low compared to how time consuming it would be.

The first section includes data about the damage inspection and the calculation. In detail, the section includes data about which damage center made the damage calculation, by whom, when the first and last calculation was sent, and the costs of new and re-used spare parts from the last calculation. However, which parts that are included in the damage calculation are not stated. In addition, it is only information about the final cost for spare parts that can be seen. One of the proposed KPIs is damage calculation deviation (described in detail in chapter 5.8.6), calculated as the deviation between the first sent damage calculation and the final invoice. With the use of current data, this is not possible as it only includes the final amount.

The second section consists of all time registrations made by employees. In the data, one can follow a damaged vehicle from disassembly to assembly. The data includes information of where and by whom the damage is repaired. However, the trustworthiness of the data is low since there are no incentives for employees to log the expenditure of time for each process activity correctly. As mentioned earlier, approximately 20% of the logged process activities have been performed in a few seconds. In practice, this is not possible. The explanation for this has been that employees forget to press start in the software when they begin. When this happens, they press start and then directly after presses finish. Meaning that the duration becomes a few seconds. This problem can be seen both in sheet metal and the pain shop. This means that the logged process activities may not be correct. However, reliably logged process activities are important for Bilia to be able to accurately measure specific process activities as well as the total repair lead time. With a more exact duration of process activities, this can be used as an input to balance the production.

The third section includes dates when the damage center receives the vehicle, repair start- and finish dates, and when the end user picks it up. However, many rows in these four columns include "NULL". The dates in this section are presumed to be incorrect in many cases since the actual lead time measured by the respective insurance company is much higher, and the mean required labor for a job is higher as well.

The last section includes data from both the damage calculation and the actual repair job. It includes the estimated time (from the calculation), planned time, and actual repair time. The estimated time may differ from the planned time since employees have set an individual productivity and as mentioned above, the planned time that is input to the production planning will change from the estimated time. However, these times are on an aggregated level from the whole repair job. Meaning that this section does not include specific repair activities which could be of value to see where in the process, the planned time differs from the actual repair time.

Analysis based the data set

As mentioned in chapter 5.1, there are problems for some of the damage centers related to the booking. Therefore, the project group used the historical data from CabPlan in order to visualize if the booking is skewed. This has been done by using the statistical software JMP for all the damage centers within the sample. The project group used the graph builder in JMP, which is a tool that can visualize data in an easy way. To investigate the outcome of the booking, the project group visualized how many times a certain process step (disassembly, paint and assembly) was performed depending on the weekday. To what degree there is a skewed weekly trend differs between damage centers. But in general, all damage centers show a trend to a degree. One of the damage centers in the sample that shows a clear sign of this trend is visualized in figure 5.10.

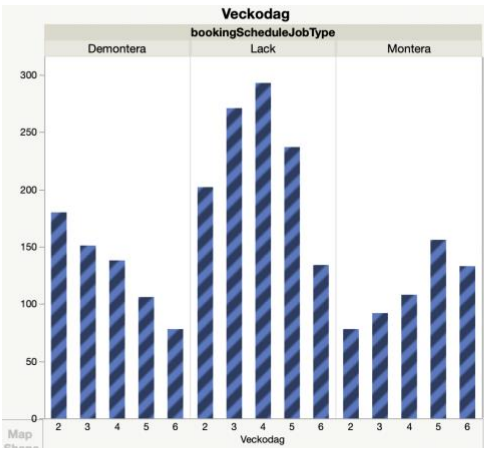

Figure 5.10. *The visualization shows the number of jobs that are performed each day on the y-axis. The x-axis shows the weekday (2=Monday, 6=Friday). The figure shows the outcome for one damage center during 2021. Further, it is divided into disassembly (left), paint (middle), and assembly (right). As can be seen in the figure, there are clear trends over the week.*

The skewed booking means that most of the repairs are planned for the beginning of the week. Figure 5.10 illustrates how this translates to weekly trends depending on the day. At the beginning of the week, most disassembly jobs are performed. These high numbers of disassembly jobs from the beginning of the week will later feed the paint shop, and result in the same skewed demand, but with a delay. The paint shops demand is built up over the week and culminates on Wednesday as the sheet metal employees performs more assemblies.

Managers and paint coaches have explained that there is a low demand in the paint shop on Mondays and Fridays. At the same time, they have said that the paint shop is the system's bottleneck. The data provide clear support for their claim that the paint shop demand is low on Monday and Friday. Based on the distribution, one can say that the paint shop becomes the bottleneck in the middle of the week, but that it is based on how repairs are booked. Presumably, the paint shop is not the actual bottleneck as they perform far less than it is capable of during some weekdays due to low demand. This skewness in the booking results in a high work in process, and long lead time due to the queues that are built up in the paint shop mid-week.

5.4 Current KPIs

As previously described, the autonomy is high for each damage center manager, and there are no clear set of operational KPIs that are used by all damage centers. Some managers use their own operational KPIs that they see suitable for their damage center. But from what has been understood, there are not many that use their own operational KPIs. In this section the intended purpose is to explain what metrics that are used by all damage center managers, and the central organization. The impression is that current KPIs are reactive, and at most can show the process symptoms.

The project group has obtained the KPI values for all Bilias damage centers for the year 2021. But due to confidentiality, the damage center's accounting has not been possible to see. This means that those cost and revenue items that are used to calculate the KPIs have not been seen. Meaning that understanding the reason for the difference in economic KPIs between damage centers is difficult. Thereby, the description of the economical KPI will be explained with the information that have been able to obtain without seeing the actual accounting that is the input for the economical KPIs.

Those KPIs that have been understood that the central organization and damage centers use to evaluate the damage centers performance are efficiency (for sheet metal and paint respectively), gross profit margin (for sheet metal and paint respectively), revenue (for the whole damage center, but also for sheet metal and paint respectively), and total contribution margin for the damage center. These KPIs are presented during the weekly held meeting with damage center managers and the regional operations manager. In case a damage center drifts with regards to these KPIs, the reason will be explained to the regional operations manager. It is this team of damage center manager and regional operations manager that are responsible to improve the results and resolve any issues. The central organization will also look at these KPIs and other economical results each month to monitor the performance of all damage centers. Regarding what actions the central organization does depending on the result is not fully understood, but it is likely highly dependent on the situation. From gaining understanding, central functions tend to look at the monthly results on an aggregated level and it is difficult for them to understand why the results are as they are. However, some of these economical KPIs that the central organization uses can be deceptive and do not necessarily measure the actual performance of the damage center.

5.4.1 Efficiency

The efficiency can illustrate the above mentioned issue. One damage center that has chosen to not participate in this project achieved a paint efficiency of 274% during 2021. Which in reality is not correct. A comparison of the efficiency for different damage centers will be presented in chapter 5.6 resource- and flow efficiency. The mean for the damage centers in the sample that repairs the same vehicle brand is 118% efficiency for the paint shop (range 99-155%). Meaning that the damage center with an efficiency of 274% in the paint shop is a clear outlier. The project group was very skeptical of this efficiency. To understand if this efficiency was correct, their regional operations manager was interviewed as well as a controller. During the meeting with the controller, the project group expressed suspicion about the high efficiency. The controller, that has all necessary data and information of how the metric was built up, investigated if this efficiency was correct. He concluded that the efficiency of 274% was based on the "average hourly earning" that was used 8 of the 12 months during 2021. This was used due to a renovation of the damage center. In cases like a renovation when it is not possible or difficult to earn money the "average hourly earning" can be used instead. The project group has not fully understood "average hourly earning", but the important part is that efficiency is not necessarily the actual efficiency. According to the controller, the financial report showed an efficiency of 131% instead of 274% for the same period. According to the regional operations manager for this damage center, the "average hourly earning" contributed to the high efficiency. But in addition to the "average hourly earning", he explained that the efficiency had been calculated incorrectly for the year 2021. This was due to an employee that had a fixed salary in the paint shop that resulted in a wrongly calculated efficiency. In short, the efficiency for the damage center during 2021 shows the efficiency for the paint group including the work performed by the employee with fixed salary, but excluding the time the employee with fixed salary have worked. Meaning that the efficiency will be higher than it actually is, and subsequently all employees in the paint shop that had variable salary received a higher bonus than they should (since it is based on efficiency).

Besides the flaws in measuring the actual efficiency, the KPI can have an important purpose to monitor a damage center's performance over time. However, it can be difficult to understand why a damage center's efficiency changes, or why it differs between damage centers. The efficiency is calculated by dividing the number of hours from the Cabas calculation (retrieved from CabPlan) with the number of hours that employees have worked (retrieved from the payroll and personnel system Agda PS that is integrated with the damage centers time clock). This efficiency is calculated for individuals, by the managers or coaches to be able to monitor the employee's performance. This is not only done to monitor, it is also done to be able to determine each employee's salary (for those that have individual bonus salary) since it is based on the calculated efficiency. The same calculation is used to determine the efficiency for the sheet metal and paint unit, and the salary is based on this (for those that have a group bonus salary). The manager for the damage centers sends the calculated efficiency to the payroll department, and the business intelligence unit will publicize the efficiency (per group function) and other metrics that can be seen on a monthly basis for the central functions.

The efficiency metric is intended to be used primarily by the damage center managers (partly to calculate the individual or group bonus), but also to central functions. It gives insight into how well the process and employees in each function performs. However, the cause if the efficiency decreases or is low compared to other damage centers can be difficult to understand. The number of hours from the Cabas calculation can vary depending on how good the damage inspection is performed (that all necessary work that generates time is included). If there is work that is performed but not included, the efficiency will decrease. Meaning that one potential explanation to a low or decreasing efficiency can be dependent on the damage calculation. Rework will affect the efficiency negatively as well, since these jobs will generate no additional time from the initial Cabas calculation. However, one cannot see how much time that is actually spent on re-work. The efficiency is also dependent on the inflow of vehicles, if there are periods of time with low (or temporary no) demand the efficiency will be affected.

In one region, the paint shop employees are frequently allowed to work overtime, given that there is demand. The reason for relatively few employees and frequent overtime in that region is that the physical space in the paint shop is small at some damage centers, which makes it impractical to increase the number of employees. In addition, some of the damage centers in this region have had an under dimensioned paint box, which would not allow for a greater output if the amount of employees increased. This means that the most suitable solution has been to allow employees to work much overtime if they wish to. Based on gained understanding, employees in the paint shop at these locations want to work overtime, since it will increase their salary and especially their group bonus salary that is based on efficiency. The majority of the damage centers in this region have recently renovated the paint shop, and the paint box capacity has increased. This will enable them to employ more people at some of the paint shops. However, according to the regional operations manager, employees at these paint shops are resistant to an additional paint employee as this would affect the efficiency and subsequently greatly reduce their group bonus salary. In fact, the regional operations manager sees the high efficiency as a problem, according to him it would be more economically beneficial to employ one extra person. This would mean that the efficiency would reduce, but according to him the total amount spent on employees for the paint would reduce (due to a decrease of the group bonus). A quite contradictory statement that a lower efficiency due to more employees would be economically beneficial. The project group does not have access to the details of the group bonus that this statement is based on, but the regional operations managers are deemed trustworthy. In addition, increasing the employees will also mean that the capacity increases. As mentioned, the paint shops in this region are slightly understaffed which minimizes the risk of low demand. Once the demand is too high, employees are willing to work overtime. Thereby, the efficiency can be kept high regardless of variation in demand.

Given that the efficiency is correct, the data shows that the paint shops in the region where employees are said to often work overtime achieves a higher efficiency than the rest. The mean efficiency for the paint shops in this region is 169%, compared to 118% for all damage centers that repairs the same vehicle brand (excluding the damage centers in the above-mentioned region). But it is important to mention that the previously mentioned paint shop that “achieved” 274% efficiency is included in the region where paint shop employees work much overtime.

Based on the flaws in the efficiency measure, a proposed way of measuring efficiency will be proposed. It is interesting that an apparent “easy” metric such as efficiency can create so much confusion. As described, the project group was suspicious about the efficiency of 274%, the interviewed controller later said that from the financial report showed an efficiency of 131% (if one does not account for the “average hourly earning”). It is possible that decisions have been made based on the high efficiency of 274%, especially since no one seems to know if it should be 274% or 131%. This is an identified issue for one damage center, and there can be similar issues for other damage centers. But since the project group is dependent on the help from others to see some of the financial reports and all necessary information, all damage centers will not be investigated. It is fair to say that the efficiency metrics are not used for the intended purpose, and that decisions cannot be based on it. There should be no room for confusion regarding what an efficiency metric is or how it should be calculated. As described, the fact that it is the same calculation that is used to decide the group or individual bonus seems to confuse things. The efficiency metric should show efficiency (CABAS hours / hour employees have been at work). If any adjustments need to be made such as “average hourly earning” for the employees to get the correct bonus compensation this should be done, but it shall not affect the efficiency.

The proposed idea is to instead use the actual time that employees are clocked in on jobs (using CabPlan) as attendance time in the efficiency calculation. This would provide a more reliable efficiency measure. Based on the data for 2021, 20% of the jobs were not logged in CabPlan correctly with regards to time. This is because the actual attendance time is based on timelog from another system, meaning that employees will not be affected if they do not log process activities correctly. If this change is implemented, it would make people highly motivated to log the time for each job correctly, as it would affect their salary otherwise. In addition to creating a reliable efficiency measure it will also contribute to higher data quality that can be used for further analysis. As for now, doing for example an in-depth bottleneck analysis would not be suitable based on the data quality.

5.4.2 Gross profit margin

The second KPI that the organization uses is gross profit margin (in percent), this is also measured per function at each damage center. This metric will be dependent on the efficiency of each function, but will account for both the revenue and cost. The variables that are used are the revenue (R) and the variable cost (V). The revenue is what the insurance companies pay the damage center based on the CABAS damage calculation, excluding the revenue for spare parts. The variable cost in this context can generally be said to include the cost for "preformed labor and material (excluding the cost for spare parts) that is on the vehicle once the repair is finished". Meaning the direct labor cost for sheet metal and paint shop employees respectively, and material cost such as filler, primer coat, and color coat will be accounted for. The formula for the gross profit margin is (R-V)/R [%]. This measure is said to be the best operational KPI that is currently used as it will give insight into the profitability of the damage center per function. In addition to efficiency, it takes into account the variable cost such as labor cost, and the direct material cost. Like the efficiency metric, rework will affect the gross profit margin negatively as well. But one cannot see the amount of rework in this metric either. Some indications regarding the amount of rework can be seen using the gross profit margin and the revenues and cost items that it is based on, but in practice this is not much better than a guess.

5.4.3 Contribution margin

The contribution margin is simply speaking what is left of the revenue when all costs have been accounted for. This metric shows the performance of all parts of the damage center (except the spare part unit). In contrast to gross profit margin for sheet metal and paint, this metric includes the labor cost for all employees at the damage center (including damage inspectors, and manager). What makes this metric difficult to use when comparing damage centers is that their costs can be vastly different. Investments in machineries and tools will affect this metric. But also premise lease and renovation of the facilities. Meaning that if we look at two different damage centers with the same revenue and variable cost, they will show the same gross profit margin for paint and sheet metal. If we instead consider the contribution margin for the same two damage centers, they can show vastly different results. This can for example be because one damage center is newly renovated, and the other is not.

5.5 Lead time

Lead time is measured in CabPlan and is accessible by all damage center managers. In addition, managers regularly get emails from respective insurance companies regarding lead time. The lead time is a reliable measure that can show improvement potentials, but it can also be used to evaluate an implemented improvement. However, when the lead time, efficiency, and economic measures are analyzed and compared, the damage centers in the sample that do not repair Volvo will be excluded. The reason for this is that, only comparing damage centers that primarily repair Volvo means that the repair centers have very similar availability of spare parts, the damaged vehicles require a similar amount of labor, and their revenue and expenditure per vehicle are similar. Most of the damage centers within this so-called Volvo sample also repair other vehicle brands, meaning that the proportion of Volvo and other vehicle brands will differ within the Volvo sample. Contextual data about the damage centers in this sample is presented in table 5.2.

The lead time is broken down and expressed in three different metrics. The results can be seen in figure 5.11. Firstly, the "received to start" lead time is measured as the time between when a damage center receives a vehicle (and marks it received in CabPlan) until the sheet metal employee begins (marks that the job has begun in CabPlan). Secondly, the repair lead time is the total time the actual repair takes, from the point when a sheet metal employee begins to the point when it is ready to be handed over to the end user (both events logged in CabPlan). Meaning that the repair lead time captures queue time within the production process. While the received to start lead time shows the queue time into the system. Lastly, the total lead time is the sum of received to start and repair lead time. This last metric is the most important for the end user and the insurance company since it is the time that Bilia has the vehicle.

Table 5.2. *Contextual data about the Volvo sample. All data are taken from CabPlan for the calendar year 2021. Large (L)> 4000 number of repairs, Medium (M) 2500-4000, Small (S)< 2500.*

	S2	M1	L2	S3	L1	S1
Number of repairs [-]	1 824	3 417	4 010	1 581	4 350	2 061
Total invoiced [hours]	22 267	37 071	54 611	17 426	49 802	30 763
Mean invoiced hours per repair job [hours]	12,21	10,85	13,62	11,02	11,45	14,93

In addition to these three lead time metrics, contextual data is presented in table 5.2. The number of repair jobs is presented for each damage center. This is intended to provide an understanding of the size of the damage center and based on how many jobs the three metrics are calculated based on. With the number of repairs and total invoiced hours, the mean invoiced hour per repair job can be calculated. This mean time per calculation can be one of the explanatory factors for the differences in lead time.

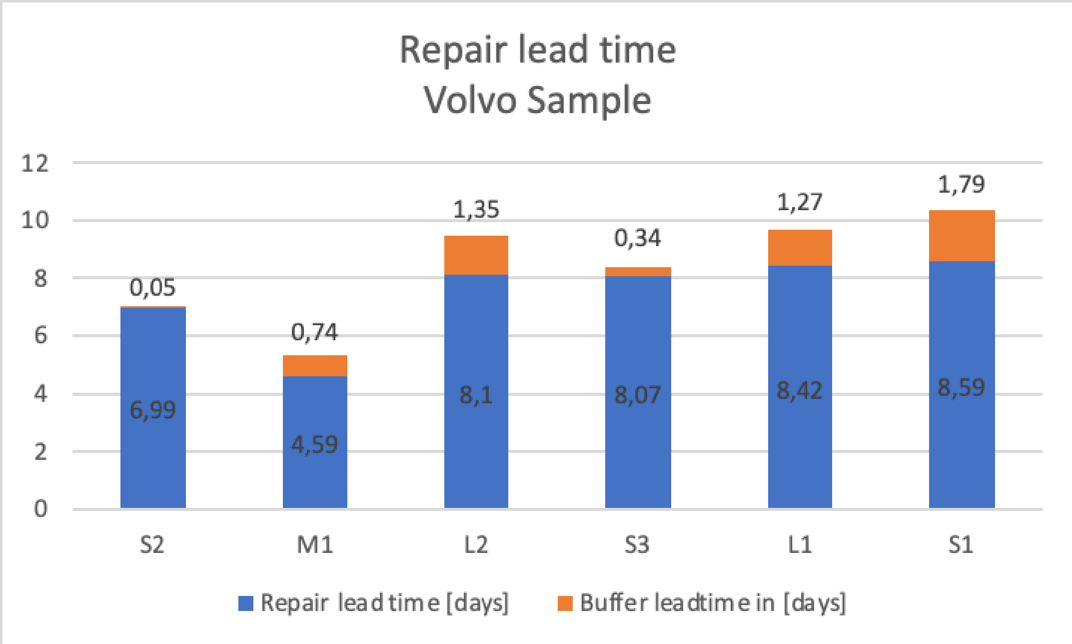

Figure 5.11. *The total lead time broken down into received to start, repair lead time and total lead time. The total lead time can be seen on the y-axis for each damage center. The data is from CabPlan and based on all repairs during the calendar year 2021, for the damage centers in the Volvo sample.*

As can be seen in figure 5.11, there are large differences in lead time between damage centers. The primary cause for the differences in lead time can be explained by the amount of non-value adding time. This time is when no one actively works on the vehicle in a way that increases value for the customer. Based on gained understanding, the majority of this time is caused by waiting time due to queues from the large buffers in the system. But also, waste such as waiting time due to a missed spare parts and rework. The difference in lead time can also be explained by the required labor for each repair job, this will later be accounted for in the analysis.

Looking at the received to start metric, it can be a sign of how well the production is planned. S2 is a clear outlier, and it can be explained by the fact that they do not receive any towed vehicles or larger damages. This means that they plan the date and time for all the incoming vehicles. On average, a vehicle repair job at S2 will begin in 1,2 hours (0,05[days]*24 [hours/day]) after it has been dropped off by the end user.

For the other damage centers, the received to start metric varies from 0,34 to 1,79 days (sample mean is 0,92 days). The data cannot show the proportion of towed vehicles (per damage center). Not either the proportion of vehicles that have been received before or without an agreed drop of day. This is naturally a factor that will affect this metric. Towed vehicles are received at the damage centers without notice. In addition, vehicles can also be parked at the damage center by the end user (before or directly after the damage inspection) if they do not view the vehicle as safe to drive. Once these vehicles are received, the damage inspection needs to be performed, spare parts need to be ordered and arrive, and there must be an available time to begin. Meaning that there can be a lot of days until the repair actually can begin if the vehicle has been towed or received in advance. Based on this, it is difficult to say what the primary cause is for those damage centers that have a long time between receive and repair start. It could simply be a large proportion of towed vehicles and vehicles that are received in advance. Another contributing factor is how well the production has been planned. For this metric to be useful, the planned drop of day (or time) needs to be compared with the actual repair start. This would give insight into if the planning of the drop of day needs to improve depending on the buffer lead time between when a vehicle is received and actual production start.

The mean repair lead time for the damage centers varies between 4,59 to 8,59 days (figure 5.12). A degree of the variation can naturally be explained by the required labor for each job. To account for this, the average invoiced labor hours per repair job have been calculated for all damage centers. This calculation has been done by dividing the number of jobs for a damage center with the total number of invoiced CABAS hours. This is deemed important, especially if the damage centers are to be compared. As an example, in one metropolitan area, all larger damages (and towed vehicles) are routed to L2 instead of S2. In addition, L2 does larger and structural damage repairs for S3. This has been said to be a contributing factor that explains why L2 has (and should be allowed to have) a longer lead time.

With the average invoiced hours (required labor) per job known, the theoretical lead time can be calculated. In order to express the required labor in days (as the mean repair lead time is), the calculated invoiced hours for an average job is divided by 8 (the employees work around 8 hours per day). This gives the theoretical lead time for an average job at each damage center. This theoretical number is based on the assumption that the last sent damage calculation includes all the performed work, that there is no waiting time (or other non-value-adding activities), and that the required time is the same as the calculated. This results in a theoretical lead time between 1,36 days and 1,87 (Figure 5.12). The theoretical lead time can be viewed as value-adding-time since the CABAS calculation only includes active labor.

Based on the theoretical lead time (mean time from cabas calculation) and the repair lead time, the flow efficiency can be calculated. The flow efficiency is the ratio between active time that is spent working on a unit compared to the total time for the unit in the system. It shows how smooth a unit flows through the different process steps. It is calculated using the following formula: Mean time from CABAS calculation [days] divided by Repair lead time [days]. The theoretical lead time is generally larger than the actual repair time spent by employees (active labor). But since actual repair time, in terms of active labor cannot be calculated, the CABAS calculation is used for all damage centers. This calculation results in a flow efficiency between 17,0% and 29,54% (figure 5.12). The conclusion is that most of the repair lead time is waiting time between process steps and other non-value adding activities.

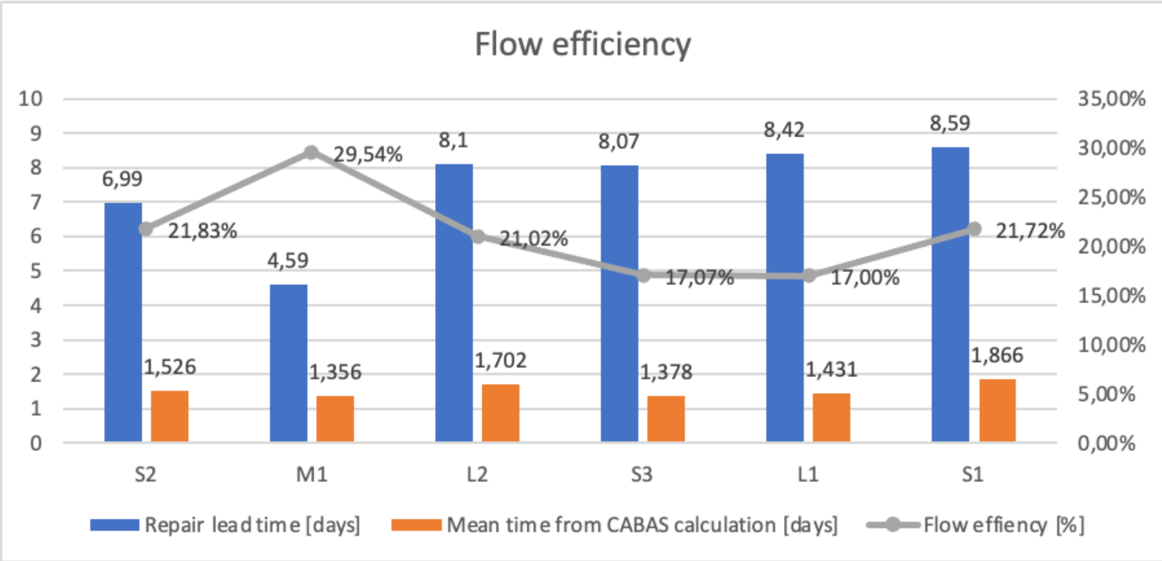

Figure 5.12. *The graph shows the total repair lead time, theoretical lead time (mean time from CABAS calculation), and the flow efficiency in percent. These calculations have been done for every damage center in the Volvo sample.*

It is possible to argue that the types of jobs will influence the actual repair time and subsequently also the flow efficiency. There are two main reasons for this, firstly it has been said by managers that larger damages (and especially structural damages) can be difficult to earn money on. Meaning that it is difficult to perform the job under the calculated time. Secondly, for larger damages, it can in many cases be impossible to include (and have photo evidence) for all damaged parts. Meaning that additional spare part orders often need to be placed during the disassembly step, which means that they need to be available at the assembly step. The lead time for spare parts is generally not the contributing factor to a poor repair lead time (or flow efficiency), as they most often arrive in time for the assembly step (if placed during disassembly). Meaning that what type of jobs a damage center receives can have a minor effect but is not deemed as important in this measure.

The flow efficiency shows large differences between damage centers in the sample. The main cause for the difference is the waiting time and other non-value-adding activities. Since all damage centers in this sample have similar prerequisites, it shows that it is possible for all damage centers to achieve a flow efficiency near that of damage center M1. To achieve this, the buffers need to be reduced. As for now, the waiting time (or other non-value-adding activities) is not measured by Bilia. Measuring the waiting time, and the cause of it would provide valuable insight into how the lead time could decrease. High repair lead times can be caused by poor planning between the functions (sheet metal and paint), resulting in large buffers between process steps. It could also be that there are too many repairs simultaneously performed (Work in Process).

Meaning that it is not possible to gain any understanding of the reason for the difference in repair lead time for different damage centers. The only thing that can be said for certain is that there are very large differences in lead time between damage centers that repairs the same type of vehicles. Presumably this difference can be explained by the prerequisites (facilities and technology) that is used, the employees and the processes. To a degree, the inflow (both in terms of number of repairs and the required labor) will also affect the repair lead time.

5.6 Resource- and flow efficiency

According to interviews with damage center managers, they are mainly focused on economic measures such as gross profit margin per function and gross profit margin for the damage center. In line with this, it is the resource efficiency and a sufficient inflow of vehicles that they are focused on to achieve these economic targets. However, the project group has got quite mixed answers from managers regarding lead time, which is closely related to flow efficiency. Some damage center managers have said that they do not focus, or really care about lead time. Others have said that lead time is an important metric, but still, they do not seem to work actively to reduce it or even measure it. Of those that seems to genuinely focus on it, there are still some questionable aspects. For example, within the sample, almost none seems to gather the lead time data themselves, measure it over time, or communicate it with the employees. Instead, damage center managers regularly receive an email from insurance companies about the lead time. When it comes to economic measures, they monitor it more closely and communicate it with the employees daily and they regularly present it to their managers.

Figure 5.13. "*The efficiency paradox matrix". From N.Modig & P.Ahlstrom (2013). This is lean. Rheologica publishing.*

Flow efficiency and resource efficiency can be seen as a trade-off (figure 5.13). As described in the theoretical framework chapter, there is an efficiency paradox. However, both resource efficiency and flow efficiency are possible to achieve. But it can be difficult to achieve since flow efficiency in practice can contradict resource efficiency in many cases.

For Bilias' damage centers, the resource efficiency (what Bilia calls efficiency) is achieved with buffers both in terms of vehicles that are on the parking lot that can be begun but also buffers within the system between process steps. This ensures that every function "always" has something to do, and thereby resource efficiency can be achieved. These buffers also reduce the consequences of process variability. It is likely that the process variability does not reach the surface, and these issues related to variability are hidden by the buffers. To concretize, the reliability of the production planning, poorly performed damage inspections, and missing spare parts are all issues that would cause serious problems if the buffers were drastically reduced. The issues would then be clear for all involved, and it becomes an urgent need and motivation to resolve these issues. These issues can be seen as secondary needs and occurs as a consequence of a previous step that has not been done correctly. As for now, the resource efficiency does not become heavily affected. For example, if a spare part is missing for a job, the sheet metal employee can take a job where all spare parts have arrived. Likewise, the function is regularly overbooked, meaning that even if the jobs are performed faster than planned, there are still vehicles to repair.

The flow efficiency is, as described earlier, calculated as the CABAS calculation time divided by the repair lead time. Meaning that the repair lead time is an important factor in this calculation. The repair lead time is heavily influenced by the work in process, which affects the buffers and other non-value-adding activities. Reducing the work in process will automatically reduce the lead time. But this can happen on behalf of resource efficiency as earlier explained.

The resource efficiency for the damage centers is calculated by dividing the calculated time (invoiced to the insurance company) by the working hours. This is a metric that is used by the organization today, and it is calculated per function (sheet metal and paint). However, this measure is not reliable and there are some questionable factors, as explained in chapter 5.4.1 Efficiency. For example, the paint shops in the one region, where damage center S1 is located, have efficiency numbers that simply cannot be true. But one needs to be aware that there might be additional flaws in the data that the project group has not yet understood. The efficiency of the damage centers within the sample will be presented per function. The intention is to analyze if there are any clear trade-offs between efficiency and lead time based on the data.

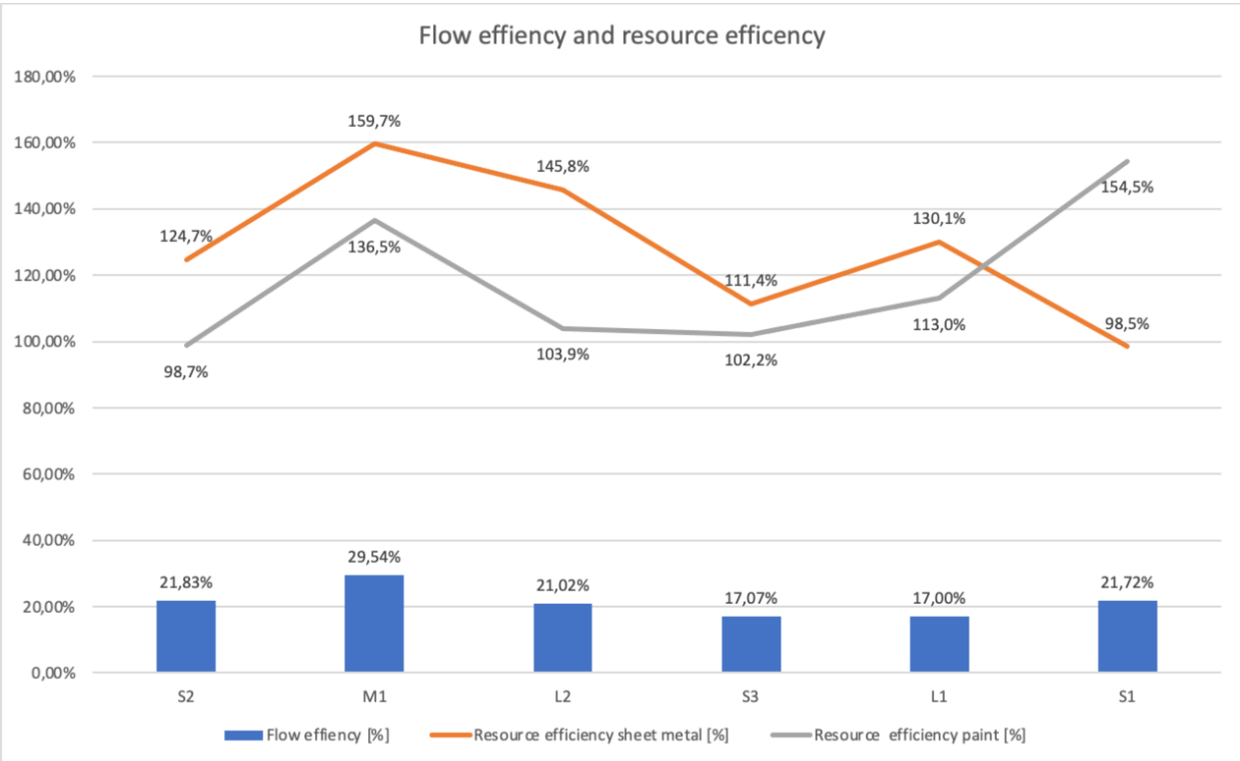

Figure 5.13. *Flow efficiency and resource efficiency for sheet metal and paint for the damage centers in the Volvo sample.*

Damage center M1 has the highest flow efficiency and the highest sheet metal resource efficiency and presumably the highest paint shop resource efficiency (5.13). In addition, it also has the highest flow efficiency (and shortest repair lead time). For the remaining damage centers, it is not possible to draw any meaningful conclusions. Based on the data, there is no clear correlation between resource efficiency and flow efficiency. It is important to stress that, due to the data quality and lack of correlation, the results are inconclusive. But since it is viewed as inconclusive, there is not any evidence that suggests that flow efficiency (or repair lead time) would affect resource efficiency negatively.

It is important to understand the damage centers manager’s rationale for their way of working that premiers resource efficiency on behalf of flow efficiency. From the project group's understanding, there are two primary reasons. Firstly, upper management (regional operations managers and their managers) mainly focuses on short-term economic measures. Damage centers are primarily judged on a month-to-month basis in terms of gross profit margin and contribution margin. More operational KPIs such as lead time, buffer levels, or WIP are up to the damage center manager to use if he/she sees it suitable in order to achieve the economic metrics. Secondly, because of the process complexity and the stress, it can be understandable that they “play it safe”. Large buffers and many damaged vehicles in the parking lot mean that the employees and machinery will be fully utilized at least one or a few days ahead whatever happens. A phrase that has been said by almost all is that “when we have sufficient inflow of vehicles, there is no issue for us to be profitable”. Paradoxically, this does not seem to be the way to increase the inflow of vehicles, as they neglect the end user and insurance company's need (a short lead time).

5.7 Voice of customer - Lead time

The importance of lead time has not been communicated clearly, or that damage center managers have neglected it. The insurance companies measure Bilia’s performance according to different metrics, and they have also specified target values. Repair lead time is one of the targets that are relevant for this project. Insurance companies have different target values for each vehicle brand. The repair lead time that the insurance companies have a target for includes the weekend days. The data the project group has been provided, include targets from four insurance companies. Their repair lead time target is the shortest for Volvo vehicles and is between 5 and 7 days. The damage centers that are included in the Volvo sample often repair Renault/Dacia and/or BMW/mini. For these brands, the target value is generally 1-3 days higher than Volvo depending on the brand.

The provided target values are important to achieve, and preferable to overachieve. This is because the metric is used as a basis during negotiations between Bilia and the respective insurance company. A high performance according to the target can mean that the hourly invoiced amount will increase for Bilia. In addition, the inflow of damaged vehicles will likely increase if Bilia performs well according to the insurance companies’ targets. The reason for this is that if the insurance company is satisfied with Bilia, they will likely route more vehicles to their damage centers. As described earlier, damage center managers are constantly stressed about the inflow of vehicles, as the inflow in terms of volume is important for the damage center to be profitable (resource efficient). From gained understanding, damage centers do not work to satisfy what is deemed the most important customer need (short lead time) in order to increase the inflow. Of course, all involved in the damage process understands that the lead time is important for the customer. But to what degree, or that contracts with the insurance companies are based on it have not been communicated.

During the project, a few managers have expressed dissatisfaction and skepticism towards the insurance companies. The main reason for this is the routing of vehicles to their damage center. According to what is known by managers, and what they are told from the insurance company is that the routing is based on geographical factors. Meaning that when the end user contacts the insurance company, the damage center is decided by the insurance company based on the shortest distance from the end user's home address and a damage center. Some managers are skeptical of this official explanation, as they anecdotally have seen a large reduction in the inflow of vehicles. From the project groups point of view, insurance companies will make decisions that benefit themselves and their customer (the end user). Regardless of the official explanation that managers receive from the insurance company when they confront them regarding the inflow. Lead time is explicitly expressed as a target value from the insurance companies, and they update (through emails) each damage center manager weekly regarding their last week's lead time. Additionally, a short lead time will benefit both the insurance company and the end user in terms of decreased cost for rental vehicles. Therefore, from the project's group point of view, it would be unthinkable that lead time is not one of the factors that is looked at by the insurance company when they actively decide on behalf of the end user which damage center will get the job. Of course, the geographical factor plays a role, but it is presumably not the most important factor.

One damage center manager explained that the inflow of vehicles had drastically reduced recently. The manager contacted one insurance company and was told that the main criterion for routing was geographical factor. But the manager did not believe them since the geographical customer base was still the same although the inflow had reduced. Thereby the manager concluded that it was not based on geographical factors, he instead suspected that the reason was that other damage centers were cheaper. But what the manager did not mention or saw as a possible explanation was repair lead time. The manager that expressed the most skepticism about routing had one of the worst repair lead times of all damage centers in this project. This needs to be seen as anecdotal evidence that insurance companies do not decide damage centers based on mainly geographical factors. But most of the people in the organization that have been interviewed had a similar experience that the inflow of vehicles was not in practice not based on geographical factors.

The end user of the vehicle can actively choose one of the damage centers that the insurance company has a contract with. If the end user is satisfied with the quality of the repair and repair lead time, he/she will likely choose Bilia again, but also recommend it to others.

5.8 Newly identified KPIs

Based on the findings, the project group has identified new operational KPIs that are intended to provide a better understanding of the damage centers performance. Many of the proposed KPIs are created so that employees and managers at the damage centers can be responsible for the results. Meaning that if a damage performs well regards to a KPI, it is since they have performed well. The KPIs that previously have been used measure a damage center in economic terms and are often dependent on many factors (some factors that the employees performing the daily tasks cannot affect). All the currently used KPIs are totally dependent on the inflow of vehicles. This is not necessarily bad, but it means that the result for a damage center can in fact be bad although each function has performed well. Due to this it can be difficult to understand what the driving factors are that result in good economical results. The idea is that the new KPIs will be able to explain some of the variation between damage centers. The intention is that best practices can be identified by using the proposed operational KPIs. They should reflect the economical KPIs that currently are used and help employees to get a better understanding of the present operations.

When new measures and routines are proposed it is important to free up time so that the people who will perform the tasks have time to perform them. Otherwise, there is a risk that the KPIs will not be measured. Or that they are measured, but no one has time for improvements based on the outcome of the measures. If this happens, much of the intended value of using the proposed KPIs will be missed. This is an inherent risk when additional work tasks are implemented. The project group has tried to understand what old measures or routines that can be removed to free up time. Unfortunately, the project group has not yet gained the enough understanding to recommend what of the existing tasks that can be removed. But it is believed that improving the outcome of some of the proposed KPIs will, eventually, free up much time for damage center coaches and managers.

The majority of the suggested KPIs are based on what employees and managers at the damage centers have explained to be important. Thereby, it is thought that the acceptance for implementing them will be high. The organization should continuously evaluate if the suggested KPIs are of value and suggest new ones that might be better. One needs to collect data and analyze the result before a conclusion can be drawn. The most important measures might not yet have been found.

The project group suggests visualizing all below mentioned KPI at a kanban board in the sheet metal- and the paint shop. A kanban board is a board that helps to visualize and manage for example operational KPIs and improvements (Appendix 2 visualizes how a kanban board can look like). The KPIs are recommended to be updated with different frequency depending on what is most suitable for the specific KPI. As mentioned above, it should visualize operational KPIs and improvement suggestions but can also include an action plan of how to achieve the improvement suggestions. Having the daily management (departmentally) close to the board enables employees to get a reminder of improvements and the operational KPIs. Since the board is placed in each function, it will be visible for employees during work. Further, it will enable employees to see the operational KPIs and which metrics that they should focus on. In addition, all KPIs should be understood by all employees at the damage center. However, since the employees at the damage center are responsible for the outcome, a meeting once a week should be held where all employees at the damage center are present. During this meeting, the outcome of the KPIs should be presented, actions based on the last weeks and historical performance should be discussed and follow up of already implemented improvement should be done.

5.8.1 Lead time

The first proposed KPI is the repair lead time. This can be seen as obvious, since it is a KPI that insurance companies use to evaluate Bilia's damage centers. The lead time is as earlier mentioned a very important metric for both the insurance company and the end user. It can also be seen as an important metric for Bilia's damage centers, especially during the period when the repair lead time and its variation is reduced. As discussed in the section about lead time, there is presumably one or a few days that can be reduced just by planning the production in a better way. This can be seen as a fast and relatively easy way to reduce the lead time. By minimizing wasteful activities such as re-work, additional spare part orders (during the disassembly and especially assembly step) will also reduce repair the lead time, and subsequently also increase the efficiency. Meaning that the repair lead time interrelates with the currently used KPIs and those that are suggested in this subchapter. Monitoring the repair lead time in isolation will give some insight, but it becomes truly powerful when employees in the organization use it to identify assignable causes of variation when the metric drifts. These identified causes should be input for improvements.

The proposed KPI is the mean lead time per week. As the project group has understood, the repair lead time and other KPIs will be visualized in Microsoft Power BI. But this will likely not be available in the near future (since the business intelligence department needs to be involved), therefore a Microsoft Excel sheet has been created to be used in the meantime (Appendix 1). Meaning that the KPI can easily be monitored and visualized from this date. The only thing that needs to be done by a manager or coach is to write the mean weekly repair lead time in the excel sheet. The repair lead time data can be retrieved from CAB or by the email sent by the insurance company. However, one needs to be consistent regarding if the lead time sent by insurance companies or data from CAB is used, in case they measure slightly differently. The repair lead time will then be plotted in a control chart (Shewhart Chart) in the same Excel spreadsheet. It will visualize the individual weekly mean repair lead time (figure 5.14) as well as the moving range (figure 5.14). There are control limits and mean value for both the individual weekly lead time as well as for the moving range. These limits and the mean value are automatically calculated in the provided Excel sheet and changes based on the input (mean repair lead time).

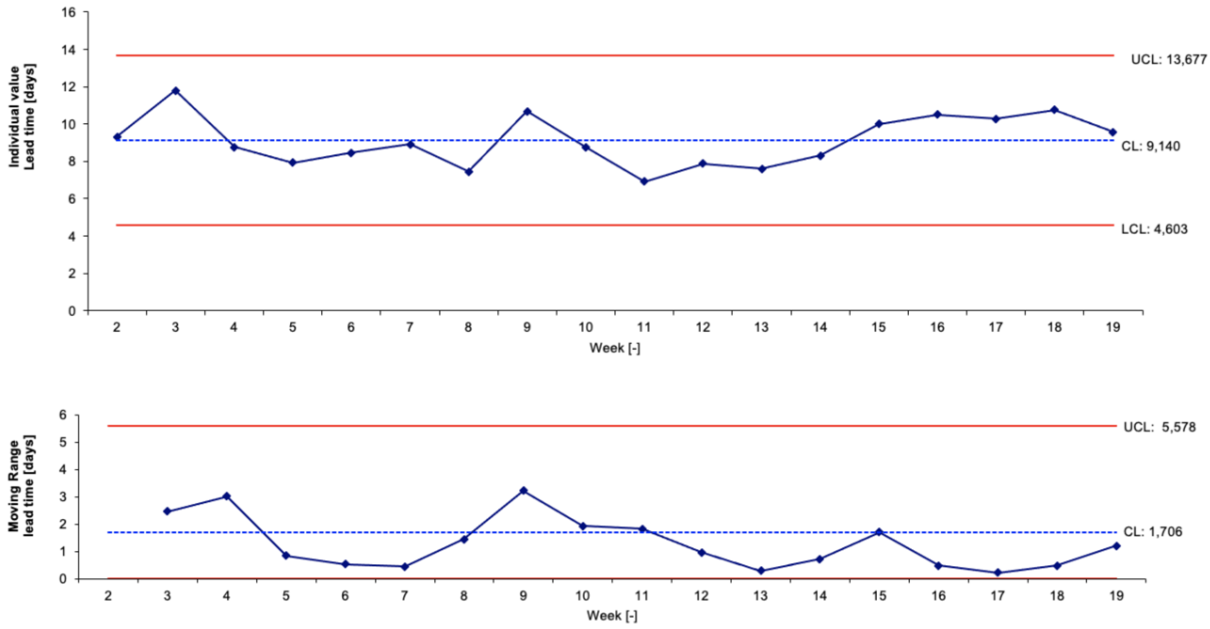

Figure 5.14. *An example of a control chart for the repair lead time. It is based on actual lead time data for damage center L2. The blue line is the repair lead time and the two red lines in each graph are the calculated control limits (that are based on the damage centers historical performance). The limits are calculated based on mean values for seven weeks (repair lead time, and variation for week 2 to week 8). The upper diagram shows the mean repair lead time in days for each week. The lower graph shows the mean moving range of the repair lead time.*

Once any point is outside the control limits in any of the two graphs, it means that the variation is beyond the process' natural variation. Meaning that there is an assignable cause that can explain the variation. It does not necessarily mean something bad, it could also be that the lead time has decreased beyond what is normal for the process. However, when a data point is outside the control limits, it is important to understand the cause that has resulted in this change. A process can be said to be predictable and that the process performs as it is designed to do if it fluctuates between the limits. Meaning that the variation can be seen as random, and that there is no need to act. However, there are a few patterns that indicate that the variation is not random although the data points are within the limits. There are different rules that can be applied, Western Electric have a set of rules that are frequently used to identify assignable variation (Hunter, 1989). Since the organization is not used to statistical process control, the project group's advice is that the organization start with a control chart and two of the rules (that will capture the majority of the assignable variation). Later, when the organization's knowledge has increased, more of the Western Electric rules can be used.

The first of the two rules that is recommended is that once any single point in either the individual value or moving range is outside the limits, the variation is beyond random variation (meaning that it has an assignable cause). The second rule is that if nine consecutive points in the individual value graph are on the same side of the process mean (either above or below) it is not random variation, it is a trend. If any of the events described in the two rules can be seen in the data, an assignable cause needs to be identified since the process has drifted. Once the root cause is understood, there might be a need to take actions to prevent this from happening again. But it could also be a confirmation that an improvement can be seen, and that the result is beyond random variation (in case nine consecutive points is below the mean or a single point below the lower control limit). Regardless, if any of the patterns in the rules can be identified in the data, one needs to calculate the new mean and control limits. This since something in the process has changed compared to when the previous mean and limits were calculated. Thereby the old control limits and mean cannot be used to predict the future. To calculate new control limits 6-8 data points that represent the new normal situation should be used. This new mean and limits should be fixed and used until a new drift is identified.

It is important to distinguish between the specification limit and the control limit. The upper and lower control limit is set according to how the process has performed historically (Voice Of the Process). The specification limit is set by the customer (Voice Of the Customer), and has nothing to do with control limits. Regarding Bilia and the repair lead time, the specification limit is set by the customer (insurance company). For them there is only an upper specification limit, a lower specification limit is not relevant. Looking at the control chart in figure 5.14, although the repair lead time for this damage center is within its control limits it is not within specification limits. For the damage center in the example, the upper specification limit (based on insurance company and vehicle brand) would be roughly 6-7 days.

Preferably the process should perform in a way that results in control limits that are within a shorter distance from the mean compared to the specification limit, as this allows for a drift without affecting the customer (figure 5.15). The distribution of the process data will dictate the control limits. As can be seen in the lower part of figure 5.15, if the process variation is large, the control limits will become wide. If the variation is low, the control limits will be narrow, as can be seen in the upper part of figure 5.15. Meaning that a control chart, with control limits that are calculated based on the Voice of the Process are suitable to use for different types of data distributions.

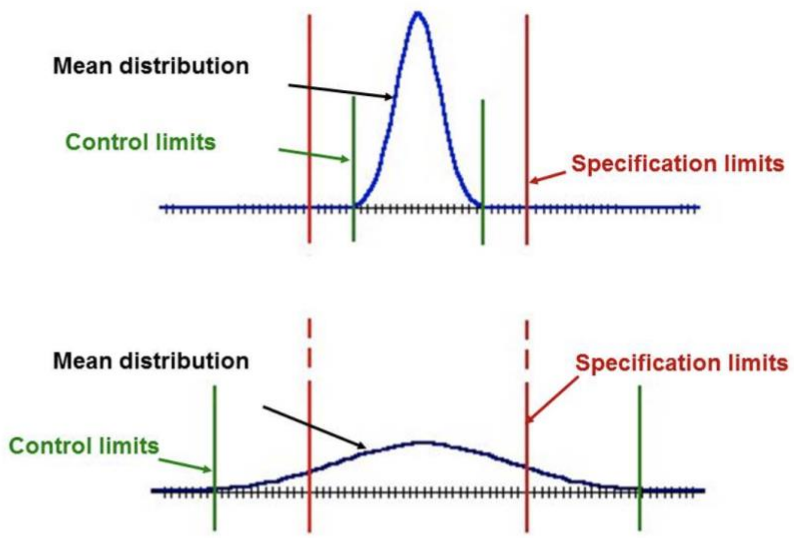

Figure 5.15. *"Distribution of mean values, specification and control limits". Adapted from Stoiljkovic (2019). The illustration shows that the process can be within its control limit but still be outside specification limits. In this illustrated example, one can see that the customer's specification limit is the same, but the control limits are dependent on the distribution of the process data.*

Control chart to monitor the KPI repair lead time is viewed as the most suitable. Since input data is needed once a week, managers and coaches will actively monitor it. It will be both visual and easy for them to see how the repair lead time varies over time. In addition, it can be used to evaluate if improvements or changes can be seen to affect the repair lead time. Damage centers need to reduce their repair lead time, during this improvement phase the control limits need to be recalculated. As long as any of the events described in the two rules cannot be seen in the data, the process is under control. Improvements can still be necessary, but it is important to understand that an action towards improvement needs to be done, otherwise the process will continue to perform within the control limits.

A control chart is useful for all damage centers, as it accounts for the damage centers historical performance. If the variation is high, the limit will be wider. If the variation is low, the limits will be narrower. Meaning that a clear and realistic initial goal can be set from this date. For example, damage centers should achieve a point under the lower control limit or nine in a row below the mean. This ultimately means an improvement, and all damage centers have a goal that is fair (based on historical data). The KPI lead time and the control chart should be understood by employees at the damage center.

5.8.2 Arriving weekday

An identified problem is the distribution of the scheduled repair start (which is often the same as the arriving day). As explained earlier, the end-user often wishes to get a planned repair start at the beginning of the week since this normally implies that the vehicle will be available for them to pick up before the weekend. But satisfying the end users demand in this case will likely have negative implications for both the damage centers performance and end users on an aggregated level. The logic for this statement is that there is a clear trend in the data that most vehicles arrive at the damage centers at the beginning of the week. This means that the majority of the sheet metal employees perform disassembly tasks at the beginning of the week, and the input to the paint shop can almost be said to come in batches (since sheet metal employees begin with similar tasks at a similar time). Similarly, most of the sheet metal employees perform assembly tasks on Fridays. This means that there is almost a one-way flow of material between the functions these days. The system cannot handle this, and as a result unnecessarily large buffers (queues) that are built up during certain days in the week. In addition, the paint shops at some damage centers pay the price for this skewed booking as it results in very low demand during Mondays and Fridays. This can be explained by the fact that the paint shop's task is between the first and last step. Since the data in chapter 5.5 shows that the majority of the repair lead time is waiting time this KPI is intended to reduce the negative effects of a skewed booking over the week. On an aggregated level, the repair lead time will likely reduce if ingoing vehicles are evenly booked over the week, because the buffer does not increase to the same extent in the middle of the week.

Another aspect of a more even booking is that the front office personnel (the ones who perform the damage inspection and calculation) are often stressed during the days when the most end users come to pick up or drop off their vehicles (Mondays and Fridays). For the front office personnel this means a disturbance when there are lots of end users that need help. They will get interrupted and stressed which increases the risk of a mistake in the damage inspection and subsequent damage calculation.

Most damage centers are aware that a skewed booking over the week results in problems, and they wish to get an even booking over the weekdays. This problem continues even if the damage inspectors that schedule the arriving vehicles are constantly seeing the distribution in CabPlan (figure 5.16). Which makes it somewhat difficult to understand that the issue is still present to the degree that it is. To a degree, the project group understands that one cannot even out the booking totally over the week, and that it can be difficult to “disappoint” the end user.

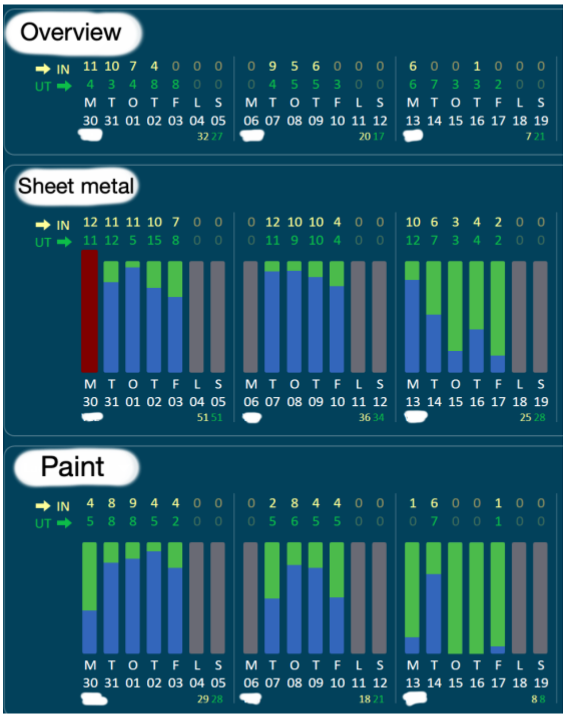

Figure 5.16. *Print screen of the production schedule that damage inspectors use when they book upcoming jobs. This is taken for one of the damage centers in the sample for the upcoming three weeks. Looking at "Overview" one can see the total number of vehicles that are planned to arrive each day (top row where it says "in") and the total number of vehicles that are planned to be picked up by the end user each day (the row where it says "ut"). In this example, it is possible to identify the skewed booking pattern for the upcoming week (day 30 - day 05). Monday and Tuesday are the days where most vehicles are scheduled to arrive, and Thursday and Friday are the days where most vehicles are scheduled to be ready to be picked up by the end user. In this example, one can also see the unbalanced demand for sheet metal and paint for Monday. And the skewed booking trend of ingoing vehicles is deemed to be a highly influential factor.*

The proposed KPI is to measure the distribution of the scheduled arrival (repair start) per weekday. This metric cannot be used in isolation since an even booking of ingoing vehicles (based on weekday) does not necessarily mean that the workload over the week is even. This can be explained by the fact that all ingoing jobs will require a different amount of labor in sheet metal and paint. Therefore, the booking measured in terms of calculated time for each day needs to be compared with the capacity in addition to the distribution of ingoing vehicles over the week. This can be viewed in bar chart for sheet metal and paint for each day in figure 5.16.

The KPI is already available as a line chart for some of the damage centers, those that use CAB Group's KPI service (figure 5.17). Those who do not have it can easily fill in the scheduled arrival in an excel sheet to visualize it in a line chart. The ingoing data can be retrieved from CabPlan (figure 5.16). This should be measured and evaluated every week by the damage inspectors, since the result of the booking is based on how they schedule the jobs with the end user. As for now it seems like they try to do it "as good as possible", but they do not have any target value, they do not reflect on the historical results, how it can be improved, or the consequences the booking can have for the damage center process. The weekly meetings are intended to measure the previous period's result, and if there is a need to change or improve for the upcoming week. It is deemed important that this KPI has managerial support to succeed. Especially since the problem (but maybe not the magnitude or clear trend) is known by the whole organization and damage inspectors constantly see the distribution in CabPlan, but the issue remains. The managerial support is also thought to be important since it is a task that will have implications for the production in sheet metal and paint. This KPI is thought to affect the repair lead time, and can have implications for efficiency as well. Meaning that this KPI also needs to be monitored together with the other KPIs (especially the lead time and efficiency) to be meaningful. The investigation into the cause and effect needs to be present, and the support of data to motivate changes to improve the operations, but also to ensure that the improvements are sustained over time.

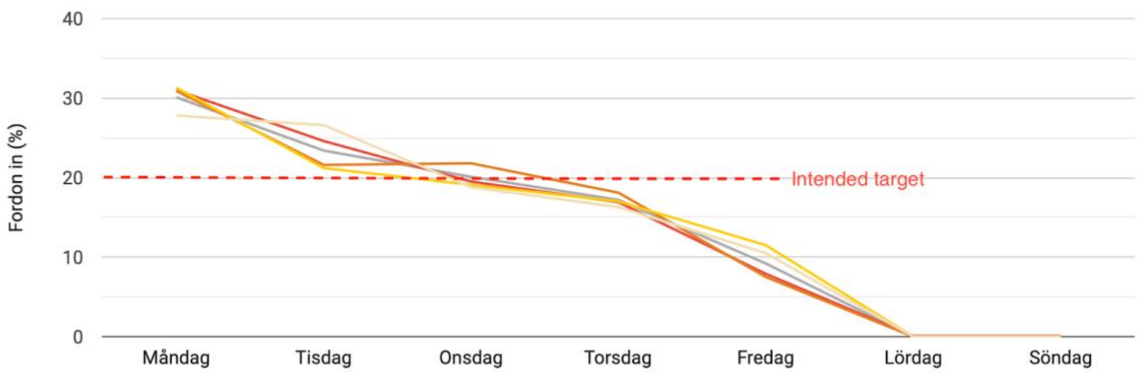

Figure 5.17. An example of how *the proposed KPI can be visualized. The line chart shows the distribution of arrival day based on the weekday (Monday - Friday) for four damage centers within the sample during 2021. To illustrate the skewness of the booking, the project group has added a line at 20% that would mean a totally even booking. The data and visualization shown in this figure can currently be seen for those damage centers that subscribe to additional service from CAB Group, that have their own key performance indicators that they measure and visualize.*

5.8.3 Number of orders made after disassembly

One of the findings is that both the lead time and efficiency is negatively affected by spare parts orders that are done by a sheet metal employee once the repair job has begun. As described previously, this means that a coach (or managers) needs to be contacted in most cases, often new photos need to be taken for the insurance company, the additional spare part order needs to be placed, wait until it arrives to the in-house warehouse, and lastly transport it from the in-house warehouse to the sheet metal worker. There is no doubt that this will affect the damage center negatively. However, no one knows how frequently this happens and therefore not how much it affects the process.

To propose a KPI regarding this, it is important to understand the damage center process and where the focus should be. With this being said, spare part orders during the disassembly step will always be present. In fact, damage centers are not allowed to include parts in the damage calculation that they believe is broken (insurance companies require photo evidence). Since the car is disassembled for the first time by the sheet metal employee when all the spare parts have arrived, some damaged parts cannot be identified before this stage. Apart from this explanation, there could also be spare parts that were visibly damaged at the damage inspection, but the inspector forgot to include them in the damage calculation (thereby it will not be ordered). The reason could also be that the spare part unit has forgotten to order a needed spare part. The last reason that could require a spare part order during the disassembly step is that the spare part unit has ordered the right spare part, but the wrong specific variant.

The project group would highly recommend all damage centers to measure how many spare parts orders that are placed during the disassembly step. But also include the reason for why an additional order was needed. Thereby managers can quantify the problem and take actions to improve where the issues occur. However, based on gained understanding of the organization, the project group believes that this will be difficult to motivate employees to do, especially over time. Meaning that measuring spare part issues in the disassembly step can be incorporated in this KPI later on. As for today, managers and employees claim that "there is no issue if one places additional spare parts orders in the disassembly step". Although the project group strongly disagrees, it can be difficult to motivate them to do it when they do not really see the issue in contrast to the extra administrative work it would require measuring it. Extra administrative work and time that the project group thinks will be less than the time spent on these additional spare parts orders in the disassembly step. However, from a customer's perspective, the lead time will in most cases not be affected. This can be explained by large buffers between sheet metal and paint, which means that the spare parts will be able to arrive before the assembly step if one places the order in the disassembly step. Once the repair lead time is reduced, spare part orders during disassembly will increase the lead time since they cannot arrive before the assembly step. It is deemed difficult to motivate and implement this measure for the disassembly step before employees and managers can clearly see the negative consequences. And these will likely become clear first when the repair lead time has reduced.

Additional spare parts orders during the assembly step have been mentioned as a serious issue by many coaches and managers. But no one has a clue about how frequently this happens or the magnitude of the problem. A few managers have even mentioned that he reminds the employees during every morning meetings (daily management) that all additional spare part orders must be placed during the disassembly step. Regardless of this, employees are still ordering spare parts during the assembly step. The reason is said to be negligence, or that employees are stressed and simply forgets to do it during the disassembly step. Another reason is said to be that some employees at times instead perform tasks in the assembly step that should have been done in the disassembly step. Thereby damaged parts cannot be identified until the assembly step. The project group has not yet received a reason for why it would be beneficial to do more than only assemble the painted parts during the assembly step. Meaning that spare part orders during the assembly step can only be viewed as pure waste that decreases the efficiency and increases the lead time. Once a spare part order in the assembly step is done, it means that the sheet metal employee must pause the current job and pick up a new vehicle at the parking job which reduces efficiency. The waiting time until the spare parts arrive is one or a few days and increases the repair lead time. Based on interviews with employees and managers, there is no valid reason for placing the additional order at the assembly step

The recommendation is to quantify how many times a week it happens during a week. The person responsible for the data collection and for the measure will be the sheet metal coach. Once it happens the coach will mark it in the Excel sheet with the other KPIs. The outcome should be clearly communicated at once a week. It is recommended as a KPI since it is believed to have a greater impact on the employees than simply saying "don't forget to order spare parts during the disassembly step". Employees cannot neglect it as it becomes clear how often it occurs, and coaches and managers can take actions once it drifts. Previous weeks results will be plotted as a line chart to visualize trends in the historical data and compare the previous weeks results with the historical. Managers can also use historical data from the metric and see if or how it affects the other metric such as lead time and efficiency.

However, this KPI can be seen as a great metric to start counting the amount of additional spare part orders. It is easy to use and visualizes the problem in an understandable way (figure 5.18). The metric will gain knowledge about how many late orders that disturb the process. In addition to this, it can be implemented directly at all damage centers. Since additional spare parts in the disassembly most often do not affect the lead time, it is not recommended to count the additional spare part orders made in disassembly. But when the lead time decreases, the process will likely be more sensitive to noise such as spare part orders made in the disassembly. Therefore, it is recommended to count all additional spare part orders when the lead time has decreased, and one can see that the lead time is affected by additional spare part orders.

Check sheet for additional spare part orders

Week .... Damage Center..............

Inspector ....

Process step		Frequency
Assembly		
	Total	

Figure 5.18. *A developed check sheet for visualization at the kanban board*

5.8.4 Rework

There is naturally an organization's wide consensus that rework has a negative effect on the damage centers performance. Presumably there is a large variation when it comes to the amount of rework between damage centers. This might explain some of the difference in economic performance and lead time, but this can only be guessed since no one knows or measures the amount of rework. Currently, there is no damage center that can quantify the rework in terms of the number of orders that need to be reworked, time or money spent on rework. Managers have explained that quality defects often become visible after the paint step during the quality inspection after the painting box. Once a quality defect is identified, the individual (or group) that is responsible needs to take the cost for the rework. The extra time and material required to resolve the quality issue is naturally not invoiced to the insurance company. However, in many cases it can be difficult to determine who (if any function) is responsible for the defect result.

Regardless of who is responsible, it is interesting that damage centers do not measure rework. A rework does not only mean additional material cost and that extra labor is performed without compensation from the customer, it also creates a capacity loss. In case it is not possible to determine who is responsible for the quality defect, the one performing the rework will get compensated for it at the expense of the damage center's profit. However, if it is possible to determine who the responsible are, it will affect the group or individual bonus salary negatively. This is due to an overall decreased efficiency, but material cost or capacity loss is not accounted for. Meaning that all reworks will directly affect all the currently used KPIs (efficiency, gross profit margin, and contribution margin). But the rework's effect on these metrics cannot be traced.

The project group has asked controllers and managers how rework can be traced, but it is not possible to quantify it in either the damage centers accounting or in CabPlan. One can make guesses based on the used material in paint, but this can at most show that it is likely that there has been more rework than usual. Meaning that it is just a guess based on the amount of paint that has been bought for that month. Paint material is bought to stock, and there are lots of factors that can explain an increased or decreased amount of paint material during a month (even if one measures it against the amount of customer paid paint jobs). A damage center manager has instead recommended looking at the rental car cost to get an understanding of the rework. The logic is that if a car needs rework, the repair lead time will increase beyond the “promised” repair lead time (since it in most cases needs additional work and needs to go through the painting cycle a second time). The function responsible for the quality issue will pay the end users rental cars for the additional lead time days that the rework has caused. But then again, it is a guess and functions also pay this cost if a vehicle is late, that is not caused by a rework.

It has been said that some of the managers have measured rework (not sure in what metric). But this is stored on personal computers and not shared with the group. It is only used to be able to talk with the responsible individual if needed. Information about rework is not shared with central functions. Based on gained perception of the organization during the project, information about rework (or other “weaknesses” in the operations) is something that managers do not want others to be able to see. This ultimately means that managers can hide any trace of rework.

The proposed KPI is to measure all rework in terms of frequency and a form of classification that describes the quality issues such as poor paint job, uneven sheet metal surface etc (figure 5.19). This will give an understanding of what causes the rework, and the data can ensure that the damage centers can investigate the most relevant quality issue, find a solution, and can measure the outcome of the change. To motivate the organization to act, the calculated CABAS time that the rework takes should be calculated, as this measures the direct economic loss (the work that has been performed without compensation from the customer). Due to the reduced capacity from the rework, one can argue that the economic loss should be multiplied with two to account for the opportunity cost. Given the culture and focus of the organization, the project group believes that measuring the monetary loss is a great way for damage centers to be motivated to monitor and work to reduce rework.

Check sheet for rework

Month: ______________ Damage Center: ____________________
Inspector: ____________________

Reason for rework	Process step that caused the issue	Quality issue classification number	CABAS TIME	DATE
Sheet metal looks wavy	Disassembly	2	550	01-jan
Primer does not covered the	Paint	1	750	08-jan
Wrong color compound	Paint	3	800	14-jan

Total time= 2100

Figure 5.19. *A developed check sheet for rework. Every damage center has one employee that is responsible for filling in the rework, preferably a coach in sheet metal or paint. It will be filled in by writing the reason for rework (in detail) followed by the process step that caused the rework. The next column, quality issue classification number. It is a list of quality issues that often arise. This list makes it easier to know where an improvement is needed. The “cabas time” fills in by writing the rework repair time (CABAS periods). Lastly, the responsible employee writes when the performed work that led to rework was done.*

5.8.5 Buffer between disassembly and paint

As mentioned in the chapter 5.1 production planning, the inflow of vehicles is based on the needs of sheet metal, which is the first step in the process. This is done regardless of the needs of the paint shop, that is the subsequent process step. The paint shop is simply supposed to "fix it" regardless of the situation. The result of this is that the buffers increase during periods of high demand in the paint shop, which increases the non-value adding waiting time for vehicles. At times of low demand in the paint shop, the efficiency gets negatively affected, and employees at times perform jobs usually performed by a sheet metal employee to increase the inflow of paint jobs.

This problem can (for some damage centers) partly be resolved if the repair start is more evenly spread out over the week, that is measured in the proposed KPI "Arriving weekday". But since this will not directly translate to the actual buffer level between disassembly and paint, this measure is recommended to use simultaneously and more frequently than the KPI "Arriving weekday". Additionally, front office personnel can book jobs that do not require sheet metal employees during the days of low paint shop demand. Based on interviews, it has been said that sheet metal and paint shop employees can collaborate to reduce an unbalanced demand between the functions that at times occurs. This can be dependent on the facilities and paint box technology, but many of the damage centers would benefit from a flexibility between the sheet metal and paint shop. This flexibility could for example be that sheet metal employees detach the parts that need to be painted instead of the paint shop receiving the whole vehicle. As described in the chapter 5.1, receiving a detached part is said to increase the efficiency during the whole paint process.

The buffer between disassembly and paint is currently an unknown parameter. Of course, the manager and employees in the paint shop will know if the current demand is high or low by visually looking at the physical amount of work orders. But no one counts the number of current orders in the buffer between the disassembly and paint step. The current buffer level does not seem to be communicated to damage inspectors that plans the production, or sheet metal employees. Naturally paint shop employees or managers cannot communicate the number of orders in the buffer as this is not measured, but they do not seem to communicate whether the current demand is low or high either. But it would be possible to quantify if anyone involved in the damage center process would be interested in it. As described earlier, all except one damage center only trusts physical papers when it comes to the paint jobs that will be performed. This means that the buffer can be measured by counting the physical work orders that have arrived from sheet metal employees (figure 5.20). This could presumably be done in CabPlan as well (but the project group have not figured out how), but since paint shops only seem to trust physical work orders this way of measure is recommended for now.

The project group made a test and measured how long a vehicle, on average, was in the buffer between disassembly and paint. The sample in this test was five random vehicles spread out over three months, on a random weekday, repaired at one single damage center. Based on this test, the mean time that a vehicle (or part) spent in the "buffer" between the disassembly and paint step was 2,83 days (excluding weekend days). Meaning that there are large improvements opportunities to reduce the repair lead time by reducing this buffer time. Based on the result of this test, the project group is opposed to calling it a buffer. Rather it should presumably be considered as a queue in this case.

The buffer between disassembly and paint is recommended to be counted once a day (during the same time of the day). This is simply done by counting the number of physical work orders. The result of this is recommended to be presented during the morning meetings (daily management) and written on the kanban board. Meaning that all employees at the damage center will be aware of it each day (sheet metal employees, paint shop employees as well as damage inspectors). The metric should also be measured over time using a line chart, so that one can identify trends depending on the weekday and more general trends. In addition, it is also important to measure the effects that changes such as a more even booking over the week or sheet metal employees detaching parts has on the buffer.

Figure 5.20. *How all damage centers within the sample (except one) schedules the jobs in the paint shop once they have arrived as a physical work order from the sheet metal (disassembly step). To the left in the picture the planning board can be seen. To the right is the backlog of jobs that will be portioned out for employees. Although not all use a planning board, they use physical work orders to determine if a vehicle is ready to be painted or not.*

Presumably, there are trends in the buffer level over time, for example trends with regards to which weekday it is, or seasonality trends. This has been said, but one cannot get an understanding for how much it affects since no one measures the buffer level, or the time a vehicle spends in buffers. During the data analysis the project group was able to quantify the proportion of jobs that were performed depending on the weekday. This showed that the most paint jobs were performed Tuesday to Thursday. During interviews, employees at paint shops explained that they at times had very low demand during parts of Mondays and Fridays. The data strengthened their claim and showed that the least paint jobs were performed on Monday and Fridays. For some damage centers, this trend was extremely clear. This implies that the buffer builds up, and non-value adding time increases during the weekdays when paint shop has a lot to do (Tuesday to Thursday). This trend can be explained by the skewed booking during the week.

Measuring the buffer each day and using it as an KPI will not solve the above-described problem. But it will become clear for all involved in the damage center process what the current situation is. This will give managers the possibility to identify when the buffer level drifts, and resolve the issue once it happens. It will also justify changes such as temporarily increasing the amount of detached parts, that sheet metal employees prefer not to do. Based on the data, it can become clear that the repair booking must be more spread over the week in order to fulfill the customer demand regarding lead time. Additionally, it can be used to book jobs that will be performed solely by the paint shop. The data might show that the buffer is constantly low on Mondays and Fridays, which would be days where such a job should be booked. But more importantly, depending on the damage center, measuring the buffer might reveal that the buffer "never" goes under a specific level. Meaning that the buffers are constantly unnecessarily large (and instead is a queue), which increases the non-value adding time for the customer without any benefit for the damage center.

There are many possible benefits and improvements that can be made based on the buffer level between sheet metal and paint. But the first step is to simply quantify the metric over time and follow up when it drifts, or a change is made. As for now, there are many speculations, and the project group has not been able to grasp why the non-value adding time needs to be so long. The project group has not either heard anyone in the organization talk about the buffer levels, or how long a vehicle spends at each buffer. This can be seen in CabPlan for individual vehicles (like the test that the project group did), but no one seems to do it.

Since one can see each process step and the date and time for start and stop in CabPlan, this can be calculated automatically. As mentioned in the subchapter verification of the current dataset, there are issues related to the data quality and that there is much information missing. But the bought data set can be used to measure this KPI and visualize it in Bilias upcoming Power BI solution. During the build of their new Power BI solution for operational and economic measures, it is recommended to include more measures of the buffers. It would be beneficial to also measure the buffer between the preparatory work before the paint and the paint done in the paintbox and the buffer between the paint and the assembly step. But these buffers are not recommended now, as it would take up time to do it manually and is believed to be less important compared to the buffer between sheet metal and paint.

The focus should be to begin measuring the buffer between disassembly and paint. It is viewed as a very important KPI as it will highly affect the repair lead time and the paint shop efficiency. The repair lead time KPI, and especially this buffer KPI is also seen as important as they require a collaboration between sheet metal, paint, and damage inspectors. This can be vital in the process of creating one damage center that works collaboratively between functions to achieve common objectives. The project group’s view is that the collaborations between functions are limited, and employees only focus on their own or the functional groups gain. But this is understandable, there are no meetings regularly for the whole damage center and there are no metrics or monetary bonuses that are based on the whole group's performance.

For the central organization, it is recommended to measure the time that a vehicle is in the buffer. One can see the time log in CabPlan and compare when sheet metal has marked it finished and when paint has marked that they have begun. Measuring the buffer in time as well as number of orders is believed to be important. This since it will provide a more fair comparison between damage centers, the number of orders becomes misleading if one does not account for the capacity. But measuring the time in buffers will be important for damage centers as well. By doing this, they can get an understanding of what buffers are most important to reduce.

5.8.6 Deviation of damage calculation

Many interviewees have mentioned the importance of doing a good damage calculation. According to them, there are often spare parts and damages that are not included in the initial damage calculations. Thereby, the currently used KPIs (efficiency, gross profit margin, and contribution margin) will be affected by the initial damage calculation. From what the managers have mentioned, this is mainly since there is a risk that employees perform tasks that are not included (or more labor intensive) compared to the calculation. If the employee does not notice this deviation, the damage center will not get correctly compensated for the performed work.

Currently there is no metric that measures and visualizes the performance of the initial damage inspections. Missing spare parts and unidentified damages further implies a lot of unnecessary work. The sheet metal employee has to contact a coach or manager to make an addition to the calculation, the spare part employee has to order and receive the spare part once again, the sheet metal occasionally has to drive out the vehicle and lastly, the job might need to be rescheduled with regards to when the spare part will arrive. Therefore, the project group has developed a KPI that contributes to increased feedback in order to increase collaboration and to continuously improve competence of the damage inspectors. The feedback can take place both between and within several functions such as damage inspectors, spare part employees, and sheet metal employees. The KPI "damage calculation deviation" [%] is described as the difference between the first approved calculation made during the damage inspection and the last calculation that is sent to the insurance company. The last sent calculation includes all eventual additional work and spare parts have been added during the repair. Basically, a low percentage of the KPI can result in a higher sheet metal efficiency and a decreased lead time. Additionally, if the KPI is used to compare damage centers, towed vehicles have to be excluded from the metric since some damage centers are not repairing towed vehicles.

The first way to calculate the metric is with the number of spare parts that is included in the last sent calculation compared to the initial calculation, measured in percentage [%]. It will be calculated with the total number of spare parts at the calculation. As the metric is measured, a missed clip that will arrive the next day will yield the same KPI result as a missed wire harness that has a lead time of approximately four weeks. One can argue that the metric should account for the consequences of the missed spare part. However, the unnecessary work that occurs from a missed spare is the same. The unnecessary work increases the total repair lead time and may result in a decreased customer satisfaction. The KPI will support management to get information of how many percent of included spare parts that are not included in the first calculation.

The second way to calculate damage calculation deviation [%] is with regards to the amount of labor. The deviation of the total amount of labor will describe if there are any unidentified damages that have been missed during the damage inspection. But it could also be that the damaged area has been miscalculated, which can result in extra labor. This KPI can be seen as similar to the previously mentioned KPI (deviation of spare parts), but it shows the accuracy of the performed damage inspections. Meaning that this KPI shows how well the inspector has estimated the damaged areas in comparison to what was actually repaired. From interviews and damage center visits, the project group has identified that sheet metal- and paint shop employees often search for unidentified damages or miscalculated areas as this can increase their bonus salary. This is mainly done because sheet metal employees do not trust that the damage inspectors have included all damages in the damage calculation. However, if the damage inspectors consistently identify and include all damages in the calculation, this metric would show a low percentage value. This means that there is no need for the sheet metal employees to search for additional damages and can instead focus on doing their job. In addition, it is important to decrease this KPI since the production planning is based on the time that is included in the first calculation. In cases where new damages are identified or a damaged area is calculated wrongly, the calculated expenditure of time will change, and the production plan will therefore be unreliable.

Moreover, it is highly recommended to include these metrics during morning meetings (daily management). The metrics will be visualized as a percentage of yesterday's performance. By including the KPIs in the daily morning meeting, different functions can talk about improvements and can enable feedback between functions. The gained feedback may enable damage inspectors to start thinking about new ways to improve the inspection. This in order to improve the calculations and decrease the KPI. For further investigation about trends and see improvements, the project group suggests the damage center manager to visualize the data as a line chart. This will enable employees to see changes in historical data. To be able to find causes of variation, the damage center manager is highly recommended to have monthly meetings with the damage inspectors. This meeting will allow the damage center manager to find causes of variations since the employees might have contextual information that can explain drifts in the KPI. It will also allow damage inspectors employees to give suggestions that can improve their work that may need a decision from higher management. However, having a value of the performance can increase the motivation for the damage inspector to strive for improvements and be more meticulous when performing the damage calculation. They can instead collaborate and increase damage inspectors' knowledge about characteristics for different damages.

However, the project group has not been able to calculate these KPIs since the existing data set only provides information about the last sent calculation and cost of spare parts. In addition, it does not include the number of spare parts. To be able to calculate the two above mentioned deviations, additional data have to be gathered. It is further recommended to start working with the development of these KPIs since the KPIs are believed to be very important for damage centers to increase efficiency and decrease the repair lead time. Further, the project group suggests making the KPI automatically updated from CABAS because it reduces the work to gather data and calculate the values every day. Further, it is recommended to visualize the KPIs in a line chart for damage center managers, preferably in Microsoft Power BI.

6. Conclusion & Recommendation

The purpose of this thesis is to expand the knowledge about the damage center process and identify what the driving factors are that result in a high-performing damage center. Additionally, the study is intended to identify improvement opportunities and best practice. To be able to do this, the project group conducted several factory visits, interviewed damage center employees, damage center managers, regional operations managers and other people in the organization knowledgeable about Bilias damage centers. Further, to be able to answer the research questions, the project group has access to damage centers booking and planning system CabPlan. In addition, quantitative data such as historical economic data and the existing KPI have also been used to complement the qualitative data. To achieve this, three research questions were developed and the answers are described below.

RQ1: What is the current state of the organization regarding process improvements?
The study can conclude that Bilia is currently measuring three metrics (sheet metal and paint gross profit margin, contribution margin, and sheet metal and paint efficiency). The central organization is using these to make comparisons between damage centers performance. However, the metric does not necessarily give insight into the actual day-to-day performance since there are other economic factors that will affect these.

In addition, every damage center has high autonomy and a high degree of freedom to design the process. This has led to a non-standardized process where there are a lot of differences between damage centers in layout, technology and machines, production planning, and type of bonus salary (individual, group or none). The study can further conclude that the measures that are currently used do not give sufficient insight into the operations, which means that decisions regarding process improvements cannot be taken based on it. The differences and currently used measures has led to a poor understanding about where in the process an improvement is needed. Since the revenue from insurance companies is more or less fixed, it is very important to continuously improve the process efficiency in order to increase profitability.

The study can further conclude that Bilia is currently doing process improvements, but since there are no operational metrics, it is difficult to understand and quantify the actual outcome of it. Especially since there are many factors that will influence the result. Based on the gained understanding, managers and coaches at times implement improvements that have shown good results. But in fact, it is not possible to determine if it is an improvement. This can be explained by the many factors that influence the economical results that are used to evaluate improvements. In other cases, the project group has heard that coaches have measured certain metrics, but that this slowly died out due to lack of time or perceived effect. Due to this way of working, with ad hoc decisions making and lack of endurance, it is difficult for the organization to understand and solve the root cause of their problems. Rather, they measure and frequently try to improve the process symptoms. To illustrate this issue, if the inflow of vehicles is low the organization tries to become even more efficient to solve the current situation. Managers claim that the reason for low inflow is that insurance companies instead route vehicles to cheaper damage centers. The project group believes that the root cause that results in low inflow (the symptom) is that the damage center does not satisfy the customer needs, especially when it comes to lead time. But during this thesis, the project group has never heard anyone speculate that the low inflow of vehicles can be caused by their performance.

The lack of operational KPIs have made it difficult for damage center coaches, managers and central functions to gain an understanding of what drives good economical results and customer values. In addition, the lack of operational KPIs makes improvement projects reactive since the economic measures are measuring historical and often aggregated results.

RQ2: What can be considered best practice for Bilia's damage centers?

The best practices that have been identified are intended to increase the damage centers performance, and decrease the lead time which is an extremely important aspect for both the customer and end user.

There are a few considered best practices that almost all managers have mentioned and have a wide consensus in the organization. They are simple and to a degree even self-explanatory, and they will increase the efficiency and customer value (in terms of lead time). These are:

- Minimize and measure the damage calculation deviation
- Spare parts should be delivered to the sheet metal employee
- During the disassembly step, employees must control that all spare parts have arrived, and place eventual additional order during this step
- The employee at the damage inspection and spare part unit must receive feedback on the calculation and spare parts, especially from the sheet metal employees. It is a shared responsibility for all actors involved to achieve a low deviation
- Clear guidelines for what are allowed to do in the assembly step, as much as possible should be performed in the disassembly step
- Spare parts orders during the assembly step should not be allowed or happen, measure it
- Minimize and measure rework
- Flexibility when it comes to the tasks that can be performed by sheet metal and paint to balance the workload at times. This should not be a choice for operational employees or a coach (in sheet metal or paint). It should be a managerial decision based on what is best for the whole damage center

In addition, the project group has identified best practices that all do not seem to agree upon, but can be seen at high performing damage centers or are based on what the literature suggests. These are:

- Identify and measure the key operational factors that drives the performance
- Create a culture where decision is made based on facts and data not ad-hoc decisions based on personal preferences
- Collaborate with other damage centers to find and share ideas and improvements
- Measure and reduce the lead time, as this will increase customer satisfaction and reduce waste in the process. Although the evidence is weak in the sample, the repair center with the shortest repair lead time also has the highest overall efficiency
- Schedule the work for an employee in sheet metal during the damage inspection
- An even inflow of vehicles over the week, measure and visualize the inflow
- Minimize the work in process, and measure and visualize the buffers
- The damage inspector that has made the calculation should do all additions instead of managers or coaches, no matter where in the process it occurs (this to facilitate feedback)
- Talk about and present the metric that employees actually can affect that leads to the economical results such as the proposed operational KPIs. Do not focus on and ask employees to improve the symptoms (economic measures should be of interest as an input for improvements for the manager)
- Unify the functions sheet metal, paint and damage inspectors with measures that requires a collaboration between the functions such as repair lead time and buffer between sheet metal and paint

RQ3: How can the organization work to reduce repair lead time without negatively affecting the efficiency?

This thesis has shown support that the repair lead time can be reduced without negatively affecting efficiency for Bilia's damage centers. If any meaningful conclusions can be drawn from the flow and resource efficiency analysis for the Volvo damage centers in chapter 5.6 it is that decreasing the repair lead time will increase the efficiency. This claim has widespread support in the literature, that decreasing lead time will in many cases have positive effects for the efficiency. This can be explained by the elimination of non-value-adding activities.

To be more specific, the project group is convinced that working actively with the proposed operational KPIs will decrease the repair lead time, and possibly also increase the efficiency. It is believed that the lead time can be reduced by a few days just by making sure that damage centers do not book more repair jobs than the system can handle. Based on a sample of five vehicles randomly selected over three months for a damage center, the average queue time between disassembly and paint was 2,83 days. This can presumably not be considered a buffer, it is believed to be a wasteful queue (for both the end user, insurance company and the damage center). But to be certain, the buffer needs to be measured over time. Reducing the mentioned "buffer" will likely not pose any negative consequences to their efficiency. Apart from this, there are buffers from the paint to assembly and into the system that also can be reduced. Meaning that there are believed to be "easy" gains that will not affect the efficiency. But this will require courage and persistence from the leaders in the organization. It will require some trial and error from the respective damage center to find suitable buffer levels, and target values for some of the proposed KPIs. But also, they need to find suitable actions to improve the outcome of the proposed KPIs. It is recommended that damage center managers collaborate with others in this process when they begin to work with our proposed KPIs, and the lead time is to be reduced. This can become a starting point to break the silo culture that the project group at times have experienced between functions and damage centers. Managers and regional operations managers need to dare to focus on actually identifying and improving the root cause of the problems, even if it can lead to temporary negative economic effects.

The proposed KPIs are quite simple, but are believed to be powerful to reduce the lead time, and to increase the efficiency. At a certain level, decreasing the repair lead time will be challenging without negatively affecting the efficiency. It is therefore important that central functions and managers at damage centers have operational KPIs that can explain factors that result in (or influence) the efficiency and lead time. The measures can be used as a basis for damage center managers to share ideas and insight with other damage center managers and central functions. This will enable greater possibility to explain their way of working, and their designed processes that have yielded the results regarding the KPIs, and subsequently also lead time and efficiency. These ways of working can then be transferred to improve the performance of other damage centers.

Recommendations
This thesis is intended to inspire and become a starting point for the organization to monitor and improve the factors that they can control. Begin to work with data to quantify what is important and drives the results, but also to base decisions on data. Unfortunately, the data provided was not deemed reliable enough. It did not either capture operational activities with enough details to be useful. The project group has identified operational KPIs and improvements based on what people in the organization have said, and based on the existing literature. It is believed that the people who can suggest and implement the most meaningful improvements will be the operational employees and damage center managers. These people are the ones that are most knowledgeable about the process and their specific prerequisites. But this improvement culture must be nourished, and the environment must encourage improvements. Hopefully, this project will be the basis for further improvements.

As mentioned earlier, best practices are believed to have been identified during the project. It is recommended for Bilia to perform a pilot study to evaluate the outcome. Many of the proposed best practices will contribute to increased efficiency and reduced lead time since many unnecessary work steps will be eliminated. Based on the gained understanding of the damage center process, the project group believes that there is a best way of working that suits most damage centers. There is a need for flexibility, to let managers design processes that are most appropriate based on their prerequisites, but this should be based on more than personal preferences. As for now, personal preferences with regards to operational employees and damage center managers seems to be the basis for their way of working. No one has data or any clear explanation to back their statement up regarding what the best way of working is according to them, or what drives good results. In fact, they implement “improvements” and keep them if it feels like it yields good results. Some ways of working that are deemed critical for the process should have clear guidelines to make sure that people follow what is considered the best way of working. This could for example be what is allowed to do in the assembly step and how the damage inspection should be performed and calculated. Clear guidelines, that are followed by all, enables every damage center, and each employee to come up with improvement proposals that will benefit all. Improvements that later can become the new standard way of working for all damage centers.

The project group has suggested several operational KPIs. These KPIs are advised to be implemented as soon as possible. It is important that higher management (such as regional operations managers) focus on these as well. They need to show that they believe in the proposed KPIs. It is critical to make sure that managers and coaches have enough time to work with the proposed measures, analyze the outcome and come up with improvements. Otherwise, most of the value of the proposed KPIs will be lost. To reduce the risk of this, it is important to consider how sufficient time can be freed up, especially in the beginning. It is recommended to begin with all KPIs simultaneously. If this is not possible, lead time is regarded as the most important to monitor closely since it measures one of the most important customer needs. Since lead time is a result of several other operational activities, it is important to put focus on the other KPIs simultaneously. Reducing the lead time will eventually lead to a reduction of non-value-adding activities, meaning a greater efficiency. As the data analysis showed, the damage center with the shortest lead time also had the highest overall resource efficiency.

In addition, operational activities (for example detach parts) and the outcome of the proposed KPIs have to be the basis for the daily management meetings (instead of economic measures). The topic for the meetings should only be factors that employees can directly affect and drive the performance of the damage center. A coach or manager needs to present and visualize the KPIs to inform everyone about the current state. Based on this, focus should be on the ones that deviate (both good and bad). Depending on the current situation, the managers and employees should collaboratively put forward improvement actions. At daily management, the coach or manager has the responsibility to follow up the already suggested and implemented improvements.

Further research

The project group has identified implement opportunities that could not be investigated or proposed in this thesis. Naturally, the company needs to investigate if the proposed KPIs yield the intended result. But also, if they can be used to actually explain the difference in performance between damage centers.

Based on the understanding gained through this project, the bonus compensation, that is based on individual, or the functional groups performance is believed to contribute to sub-optimizations. An investigation into how an economical bonus based on the whole damage center's performance is something that the project group sees as important. This can encourage further collaboration between functions and make sure that decisions are made to benefit the whole damage center. For example, one part of a bonus can be based on the lead time, since it is a measure that all employees and functions can influence.

It would be valuable to break down the lead time KPI into lead times for the specific process steps (disassembly, paint, and assembly). In addition, waiting lead time between all main process steps would also be valuable to measure. It is thereby possible to gain an increased understanding about the repair lead time. These sub-processes and buffers can also be analyzed in individual control charts. The control charts for the specific sub-process steps can be used in combination with the total repair lead time. This will enable a better understanding of where in the repair process the repair lead time drift has occurred. In addition to this, the project group sees first pass yield (FPY) and rolled throughput yield (RTY) as valuable metrics to be introduced in the future. RTY quantifies the probability of the entire process producing zero defects. The metrics show the losses related to rework, both for the specific process step (FTY) and for the whole process (RTY). These metrics enable one to identify the poorest performing process steps (related to quality defects). Thereby, one gets an understanding of which process step is most important to improve in order to reduce the amount of rework.

It would be interesting to conduct a pilot study where a damage center does not give the end user a drop of date during the damage inspection. This idea has met resistance, and the reason can be that it challenges a way of working. All employees say that the end user expects and really wants a specific drop of day during the damage inspection. The proposed pilot study is to give the end user a “drop of week” during the damage inspection. Meaning that the drop of day can be decided and communicated to the end user a few days after the damage inspection. This could fulfill both the needs of the customer and improve the damage center’s performance. Today, the production planning (deciding the drop of day) is done in approximately ten seconds in CabPlan based on available time in the sheet metal, when the end user is present. Postponing this decision gives the damage center time to plan the production. Meaning that there is a possibility to achieve a deliberate mix of different types of jobs that are balanced with regards to both sheet metal and paint. This mix will increase the efficiency of both functions and reduce the queue (buffer) between them (due to the better balance). For the end user this means reduced lead time due to decreased queue.

In addition, since one has time to plan, the reliability will likely increase. This since it is possible to assure that the needed spare parts will arrive before the planned repair starts, then the drop of day can be communicated to the end user. If the project group was end users, a reliable and faster finished date is more important than leaving the damage inspection with a repair date. Lastly, if the end user receives the drop off day at a later point of time, there might be a reduced risk of dissatisfaction and wanting to contact Bilia to reschedule the repair job to the beginning of the week (if the given day is at the end of a week). To reduce this risk further, it is important to have a good explanation of the given drop of day and ensure the end user that the vehicle repair lead time is the shortest with the proposed drop of day.

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Appendix 1

Control Chart - Test i region X
Hör av er om ni undrar något eller behöver hjälp

Syftet med detta:
Följa ledtiden varje vecka på era verkstäder, på ett sätt som gör de tydligt för er att identifiera trender och avvikelser via grafer. Detta blir viktigt då ledtiden påverkar er effektivitet och försäkringsbolagen och Bilias avtal delvis är baserat på er ledtid. Vid förändringar ska ni tydligt kunna se hur ledtiden blir till följd av detta.

Vårt förslag är att ni i region X presenterar era ledtider och tillsammans varje vecka och hjälper varandra att förstå hur detta Excelblad (ett Control Chart) fungerar. Dela med er av insikter kring variationen och förslag på metoder för att minskar ledtiden.

Själva grundsyftet med ett Control Chart är att följa variationen. Man säger att variationen mellan de röda gränserna (Upper- and Lower Control Limit) kan hänföras till vanlig variation som naturligt finns och ni inte behöver agera på denna. Fås ett värde utanför dessa gränser behöver ni agera då det finns en orsak som kan förklara variationen.

Beskrivning:
Ert uppdrag blir att agera på avvikelser, förstå varför de sker och förbättra (om värdet på individual value är över den övre gränsen). Hamnar ledtiden under den undre gränsen på individual value blir uppdraget att istället förstå varför (förbättringen har ju redan inträffat).

Om något värde kommer över eller under gränserna i något av de två graferna betyder de som sagt att någon förändring har skett. Detta gör att man behöver räkna ut nya gränser och medelvärde. Säg till när detta händer så hjälper person Y eller vi er med att räkna ut dessa.

Vi har räknat ut gränser och medelvärden för er i region X. De enda ni behöver göra är att fylla i reparationsledtiden som finns i CAB rapporter för varje vecka.

Praktisk information:
Fyll i reparationsledtiden (från CAB rapporter) i Kolumn B, skriv för vilken vecka i Kolumn A. Detta kommer uppdatera den övre grafen (Individual Value) där varje veckas reparationsledtid visas.

Kolumn C räknar ut absoluta skillnaden (variationen) mellan ledtiden för de två senaste veckorna. Detta visualiseras i den nedre grafen (Moving Range).

Hur ska graferna läsas av?
Börja alltid med den nedre grafen “Moving Range”, som visar variationen. Här kan ni se eventuella trender gällande variationen, och såvida inte värdet är över den röda gränsen behöver man generellt inte agera.

Sedan kollar ni på den övre grafen “individual value” som visar ledtiden för varje vecka. Här kan man också se eventuella trender och behöver agera om följande händer:

- En veckas ledtid är utanför den övre eller undre gränsen.
  Anledning: Detta indikerar att något hänt som kan förklaras och inte hör till vanlig variation, och nya gränser behöver räknas ut.
- Ledtiden hamnar på samma sida av (antingen enbart över eller enbart under) medelvärdet under 9 veckor i rad.
  Anledning: Detta indikerar på att trendskifte har skett, och nya gränser behöver räknas ut.

Det finns fler regler, men börja med dessa två då det är de två viktigaste.

Appendix 2

An example of a Kanban Board including operational KPIs with clear colors (red/green) that visualize improvements. Operational suggestions are also stated and how to proceed to achieve the improvement.

Name of the Damage Center Sheetmet/paint	
KPI	
Last week	This week
v 19	v 20
LEAD TIME	LEAD TIME
Goal of 6 days	
Visualization, Control Chart v 19	Visualization Control Chart v 20
9,4 days	8,3 days
Number of order made after disassembly	Number of order made after disassembly
Goal of 5 order	
25	21
Buffer disassembly-paint	Buffer disassembly-paint
25	
35	20

Improvement suggestions	OK/ NOK	How to get there?	Time	Responible
Tighter collaboration between sheet metal and production planners	NOK	Have daily management togheter	until v25	Sheet metal and planners
Maintence on a lift nr 5	OK	Do a service	v19	Sheet metal coach

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