CHALMERS
UNIVERSITY OF TECHNOLOGY

Adoption of lean Philosophy in Car Dismantling Industry

Master's Thesis in Production Systems

GUSTAV BERGQVIST
MOHAMMAD HASIBUL ISLAM

Department of Industrial and Materials Science
Division of Production Systems
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2017

Adoption of lean philosophy in Car Dismantling Industry

GUSTAV BERGQVIST
MOHAMMAD HASIBUL ISLAM

Department of Industrial and Materials Science
Division of Production Systems
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2017

Adoption of lean philosophy in Car Dismantling Industry

GUSTAV BERGQVIST
MOHAMMAD HASIBUL ISLAM

Technical report no xxxx: xx
Department of Industrial and Materials Science
Division of *Production Systems*
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone: + 46 (0)31-772 1000

Reproservice
Göteborg, Sweden 2017

Adoption of lean philosophy in Car Dismantling Industry

GUSTAV BERGQVIST
MOHAMMAD HASIBUL ISLAM

Department of Industrial and Materials Science
Division of *Production Systems*
Chalmers University of Technology

ABSTRACT

This thesis investigates how applicable planning and control theories used in vehicle manufacturing industry are to the car dismantling industry, specifically Lean methodology. By observations and interviews at two car dismantling companies in Sweden a basic understanding of the business was formed and the current state was analyzed using Value Stream Mapping (VSM). Waste~~s~~ in the production processes was identified by task analysis and through Root Cause Analysis. Possible solutions of reducing this waste was examined by testing having two operators working on the same car and rearranging the dismantling stations. The inventory-level of the studied car dismantling companies was found to be high, so data was collected through the ERP system (Enterprise Resource Planning). The data was analyzed in several ways, particularly with ABC-analysis to find out crucial parts which would help the companies to formulate business strategy. It was found that, Lean can be utilized to improve the processes of car dismantling companies. However, because of the nature of the business, high uncertainty in demand and supply of the ELV, some of the Lean theories might not be feasible to apply. These barriers can be associated with the boundary line of the Lean theory.

Key words: Lean, Car Dismantling, Barrier of Lean, ELV, Sweden, Inventory analysis, ABC Classification

Contents

Acknowledgement

We would like to thank the research institute that we have been working at, for them entrusting this project to us and their hospitality, offering us workspace from January to June 2017. From Chalmers, we would like to thank our supervisor Malin Tarrar and examiner Björn Johansson for their assistance and support.

The management and operators of the car dismantling companies that we have worked with during this project has been very helpful and cooperative. Most of all to the Car Dismantler-B, which we visited during several occasions and performed several studies. Big thanks to them for offering their time and support.

We would like to express our gratitude to the ERP-developer for providing invaluable input to this project. Without the data we received, it would not be possible to make many of the analyzes that this thesis consists of. Also thanks to the Repair System and Service Company for supporting us with data, valuable for this thesis.

Notations

ASR-	Automotive Shredder Residue
CDA -	Car Dismantler-A
CDB -	Car Dismantler-B
ELV -	End of Life Vehicle
ERP -	Enterprise Resource Planning
JIT -	Just in Time
MISTRA -	Swedish Foundation for Strategic Environmental Research
MTS -	Make to Stock
PFEP -	Plan for Every Part
RSSC -	Repair System and Service
SME -	Small to Medium Enterprises
SPS -	Self-picking-service
VSM -	Value Stream Mapping
WIP -	Work in Progress

1 Introduction

The goal of the thesis was to evaluate the applicability of lean methodology used in car manufacturing industry to the car dismantling companies. Focus was also on identifying the areas of greatest improvement potential and practical solutions for the two dismantling companies that were studied.

1.1 Company information

Car dismantler-A (CDA) is a car recycling company located in Sweden, they process about 3500 cars each year. Car dismantler-B (CDB) is also located in Sweden, processing around 2700 cars every year. Both companies are among the biggest car dismantling companies in Sweden, however, CDA processes more cars than CDB whereas CDB handles more new cars. Both of them have a separate business, a self-picking service (SPS) where private persons come and collect parts by themselves from cars at a lower price but with no warranty on those parts. Both companies have devoted resources for investigations and tests that are conducted in the project.

Both of them use the same ERP (Enterprise Resource Planning) system developed by another company which provided the necessary data required for investigating the inventory of the car dismantling companies.

1.2 Background

This thesis is a part of research project which have been initiated and carried out by several organizations, including Chalmers University, with the goal of adjusting Swedish automotive dismantling industry's role to a circular economy and to create a close cooperation between manufacturing and recycling industries.

In the chain of vehicle recycling process, dismantlers play crucial role where the reusable automotive parts are separated from the End of Life Vehicles (ELV). In general, the dismantling companies separate the hazardous items (like, engine oil, brake fluid, battery, catalyst converter, etc.), look for the reusable items, take those reusable parts from the cars and finally separate different raw materials (like-Steel, Plastic, Aluminum, Copper, Glass etc.) from the car body. The dismantlers revenue comes from selling the materials to different recycling industries and the reusable parts to insurance companies and private persons. Most of the cases, these companies occupy a huge inventory from where the parts are sold. It is because, the incoming cars into the system and the demand of the parts are highly uncertain.

This thesis will be carried out based on one of the objectives of the research project which is to identify how planning and control theories and practices used in vehicle manufacturing industry can be adapted to the vehicle dismantling industry, specifically, what the benefits are and in which areas this adaption has the greatest potential.

1.3 Purpose

The purpose of this thesis was to evaluate how process and warehousing optimization methodologies from industrial engineering and production logistics could benefit the vehicle dismantling industry. Moreover, to identify different types of industrial wastes involved with the car dismantling production system and how those wastes could be reduced.

1.4 Objectives

In order to improve the production system in car dismantling companies, the primary objective of the thesis have been set to investigate how the Lean philosophy, which is widely used now-a-days in automotive industry, can be adopted for this case including the barriers of implementation of Lean philosophy. The secondary objective was to optimize the current inventory system for the companies to suit their business plan. The outcome based on these two objectives was set as follows.

1. Adaptation of Lean philosophy in Car dismantling industry
    a) Analyze current state
    b) Identify Wastes
    c) Reduce waste implementing Lean tools
    d) Limitation of Lean philosophy in full scale
2) Inventory analysis of parts to aid in formulating business strategy
    a) Categorize parts in terms of different parameter
    b) Identify most profitable parts
    c) Investigate the characteristics of sales and customers for car dismantling companies

1.5 Delimitations

To improve production system, it has been focused on only using Lean philosophy as it is current practice in most of the automotive industry.

CDA and CDB were the only car dismantling companies that this thesis investigated. If more companies were to be studied a lot more time would be spent on traveling to these companies and less time could be focused on investigating and_improving current practices. Adaption of Lean have been investigated for CDB, with the same reasoning as above, since better analysis and recommendation could be presented if only done for one company.

For the inventory analysis, parts have been grouped into categories, to make it possible to overview and analyze them. An example of this is all petrol engines, for all car models which are grouped into one category. The sales volume and selling price, etc. is therefore an average of all the included parts.

No implementation in the companies of the findings during the thesis. The findings are presented as proposals for future work practices.

1.6 Outline of report

The report is organized first by describing the ELV recycling process and the production processes in car dismantling company. Then the previous research works followed by different theory to understand the work content have been highlighted. After that, the methodology of this research followed by the result and analysis of result are presented. Finally, the findings from the result and future research content have been discussed.

2 Theory

In this section, the overview of car recycling process along with the production process of car dismantling company will be highlighted. Later, a summary of previous research work in this field followed by the necessary theory to understand the lean philosophy and relevant to this thesis work content have been discussed.

2.1 Overview of ELV Recycling Process

The End of Life Vehicles (ELV) can be categorized into two groups- premature and natural (Mat Saman and Blount, 2006). Premature ELV are usually those vehicles which comes to end of service before their usual life cycle because of accident or damage by another phenomenon. These cars usually contain a lot of valuable parts that can be reused. Whereas from the natural ELV, the cars which have reached the end of their life cycle of service, extracted parts can hardly be reused due to lack of market demand or bad condition of the parts.

The current scenario of End of Life vehicles (ELV) and Crushed Cars (CC) is shown in following Figure-1 which was presented by (Kanari et al., 2015)

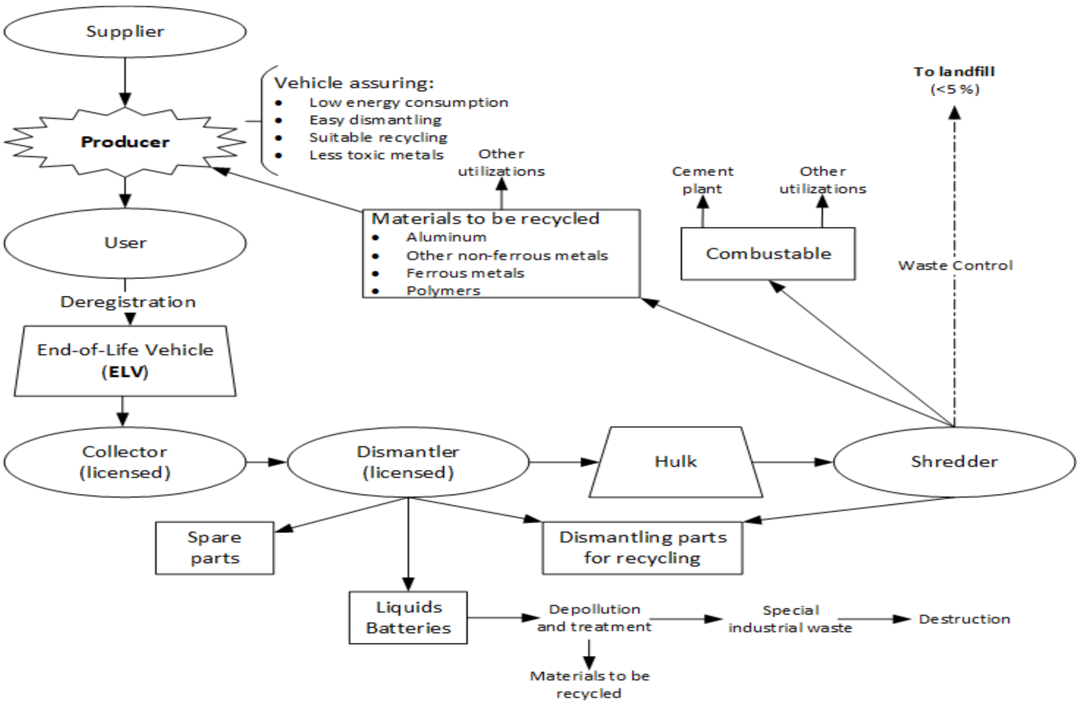


Figure 1: ELV Recycling Process (kanari et al., 2015)

In this chain, the dismantler's role is to depollute fluids and remove hazardous materials, glass, etc. Extraction of reusable parts, selling those parts to value chain again and extracting different materials like- Aluminum, Plastic, Copper, Iron is also one of the main tasks. The general operations of dismantling companies are shown in following Figure-2, mentioned by (Cossu & Lai, 2015)

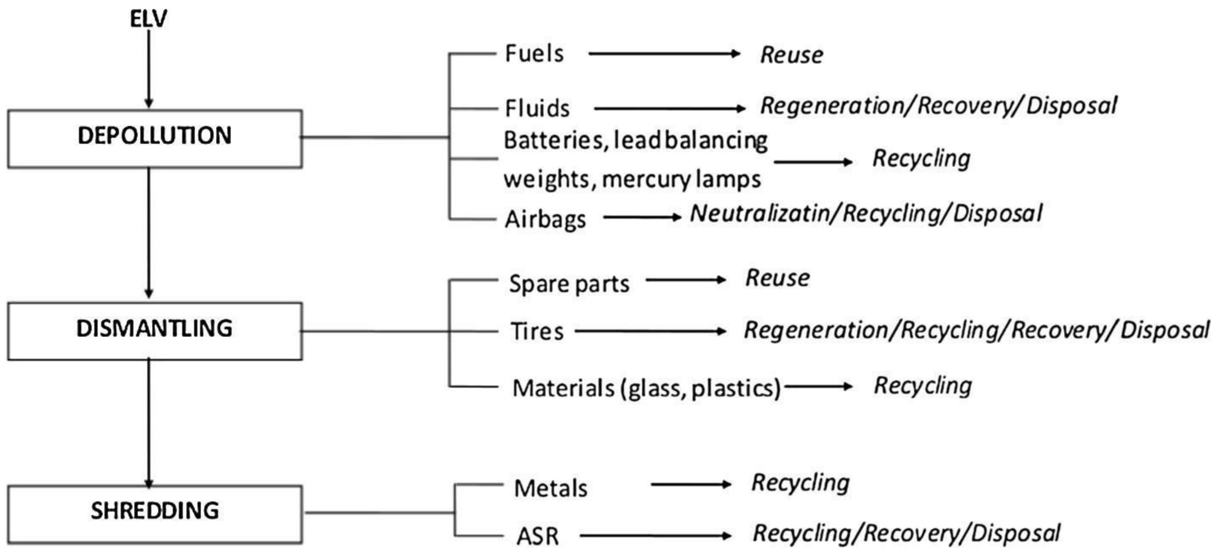


Figure 2: Production Processes in dismantling company (Cossu & Lai, 2015)

Though the operations like- depollution, dismantling, shredding, etc. maintains a flow, however, the tasks in dismantling operation can be classified as craftsman type production system, based on the definition of craft production (Mourtzis & Doukas, 2014) where a skilled operator extracts parts from the ELV and the ELV stays in a fixed position.

The importance of the role of the dismantlers in the value chain can be described in terms of benefit of reuse of parts in product's life cycle. Gerrard and Kandlikar (2007) presented a hierarchy of recovery (Figure-3) where reuse corresponds to higher material or energy efficiency.

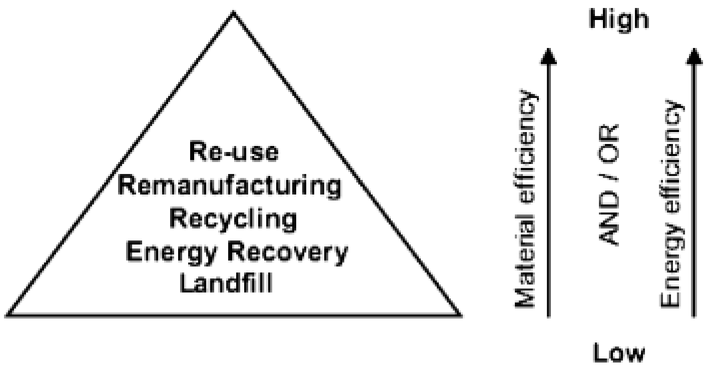


Figure 3: Hierarchy of recovery by Gerrard & Kandlikar (2007)

Go (2010) presented a figure (Figure-4) modified from (Östlin et al., 2009) where the flow of life cycle of products presented from raw material to disposal which indicates that the flow of materials is shorten for reuse compared to recycling and remanufacturing.

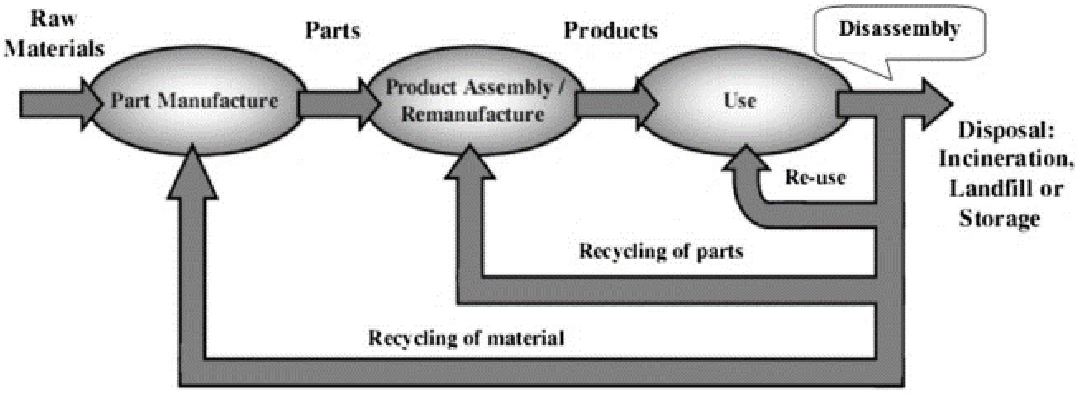


Figure 4: Flow of life cycle of products (Go, 2010)

Therefore, dismantlers play a very crucial role in the reverse logistics chain as they mainly focus on extraction of usable parts from an ELV and putting it back in the supply chain of the products. For this reason, it is very important to improve their operational system.

2.2 Previous Research

In this section, it was aimed to highlight the overview of the previous research outcomes focusing on car dismantling companies, especially if there is any available result based on improving the production system using Lean and/or inventory optimization method.

Kazmierczak et al., (2007), studied the ergonomic issues in dismantling industries in Sweden and found that despite having a lot of manual tasks with bad posture, Musculoskeletal disorders was not significant issue because of the variety of tasks having low repetition.

Go et al., (2012), developed the optimal sequence of engine disassembly using genetic algorithm to increase the efficiency of disassembly process. However, these sort of techniques is hard to implement in dismantling stations because one operator in dismantling station processes diverse types of cars and the dismantling type, tools required are not identical for different cars. Moreover, operator will not extract the part if the part is damaged. Therefore, it’s very hard to implement exact sequence of disassembly.

Kosacka & Golińska (2014), assessed the sustainability of car dismantling companies in Poland and found that the dismantling operation contained the most influence on different perspective of sustainability- social, environmental and economic aspects, compared to other operations in dismantling company. The Rapid plant assessment (RPA) showed that the company achieved a score of below average level and it showed there is scope to reduce different industrial wastes.

In Netherland, a line system aided by conveyor belt was implemented similar as assembly line of cars, and it was claimed that the system will have a high throughput (Car Recycling Systems B.V. (n.d.)). However, this system is not so suitable in Sweden as of currently, because of a regulation in Sweden that demands that there should be a car recycling company within 50 kilometers of each house or within each municipality, (Riksdagen. (2014, December 12), regulation (2007:185)). This results in there being numerous car recycling and dismantling companies, which also means that it is hard for a single car dismantling company to amass such a big number of ELV to make it profitable to invest in a line based system. Also, in case of line based disassembly the work is less ergonomic because of repetitive work, which is harmful for the operators (Kazmierczak et al., 2007).

Therefore, the previous research overview showed that, though much research has been conducted, it has mainly focused on ergonomic, sustainability and operational improvement issues to some extent, however, none have been conducted yet focusing on improving the production system using Lean or other method and to optimize the inventory in car dismantling company.

2.3 Lean theory

The adaption and implementation of Lean in the car dismantling companies has been one of the main part of analysis in this thesis, which is why it is crucial to understand the theory of Lean. A summary of this theory is presented here.

2.3.1 Lean philosophy

Lean Production system, was developed by Toyota. Most of its principles came from Toyota Production System. The basic principle of the Lean is to eliminate waste in all value creating processes. The following Figure-5 represents the house of Lean Production Model. The house is supported by different methods and tools. The goal is achieved not only by removing non-value adding tasks in shop floor level of a factory using tools like- 5S or Kaizen, but also supporting the production system with different principles like Just in time, Jidoka, Heijunka, etc.

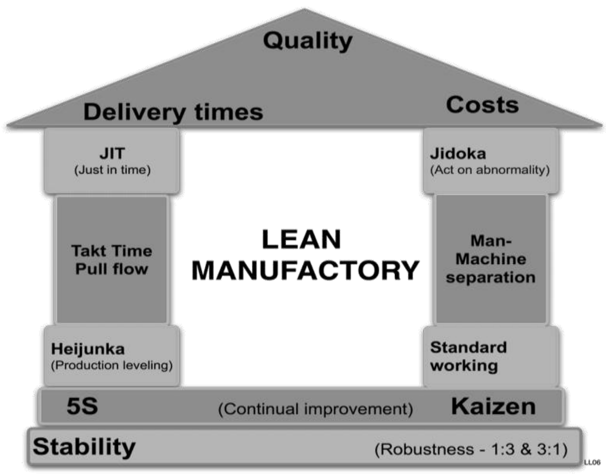


Figure 5: Lean production System

2.3.2 Wastes

According to Toyota production system there are eight types of industrial wastes (Liker, 2004). These are

1. Overproduction: Producing items more than customer requirement
2. Waiting: waiting for work instruction, having no material,
3. Transportation: Moving work in process materials from one place to another
4. Over processing: Extra operation which is not required by customer
5. Excess Inventory: Excess storage of raw material, WIP or finished goods
6. Unnecessary movement: Any movement by employees which does not create value
7. Defect: Quality defects or scrap
8. Unused employee creativity: unable to utilize people's skill, opinion, ideas, etc.

2.3.3 Waste Elimination

In Toyota, the waste is eliminated based on structured way. It focusses on not only problem solving rather understanding the problem and eliminate the problem from the root. The process follows following steps (Liker 2004).

- Develop a thorough understanding of the current situation and define the problem.
- Complete a thorough root cause analysis.
- Thoroughly consider alternative solutions while building consensus.
- Plan-Do-Check-Act (PDCA):
    - Plan: Develop an action plan
    - Do: Implement solutions rapidly
    - Check: Verify result
    - Act: Make necessary adjustments to solutions and action plan and
- determine future steps
- Reflect and learn from the process.

2.3.4 5S

5S is a lean tool which is very effective at the initial stage of identifying the wastes. The 5S comes from the first letter of five words- Sort, Straighten, Shine, Standardize and Sustain. The general theme of these five terms would be as follows.

Sort- Removing all the unnecessary staff from the workplace.

Straighten- Set everything in order so that it would be easier to find and recognize.

Shine- Cleaning the workplace to avoid any incidents

Standardize- Set a procedure for every task and standardize the best practice in the workplace

Sustain- Maintain the standardized procedure and put it in common practice.

This 5S is mainly used to arrange the workplace which seems effective on initial process stability. Also, it helps to reduce the waste involved with the category-motion waste, by reducing the time for finding items, walking extra distances.

2.3.5 Kaizen

Kaizen is a Japanese word which means- continuous improvement. It represents to improve the process or flow or even working procedure continuously. It aims for improvement by identifying different wastes and eliminates those wastes incorporating with different tools like-Root Cause Analysis, PDCA cycle, etc. To improve the processes while applying Lean, a common strategy called Kaizen Event is used where different wastes involved with the operations are identified by the employees and gradually eliminated those wastes properly.

2.3.6 Pull, Kanban & CONWIP system

Pull is a Lean strategy of production planning control system. It is totally opposite to traditional Push system. In Push system, the information for production is given to the work center in upstream and the other downstream work centers processes the parts sent to them from upstream (Figure-6). Whereas, in pull system, the production of the upstream work center is controlled by the usage of that components or parts in downstream work center (Spearman et al., 1990). It can be simply understood by following Figure-7.

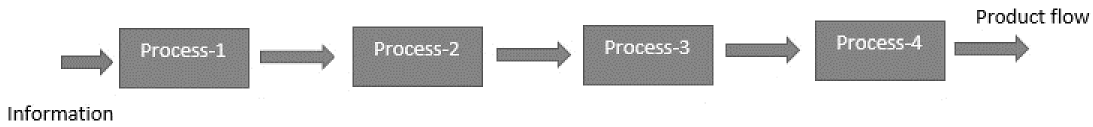


Figure-6: Push System

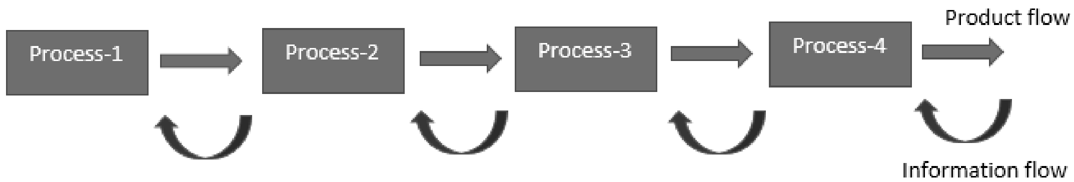


Figure-7: Push System

According to Figure-7, in pull system, the process-1 starts production when a signal arrives from process-2 and the same thing repeats in downstream. The signal can be referred as Kanban. The signal can be electronic, physical card or even visualization.

CONWIP (Constant Work In Process) is a hybrid of pull and push system which can be said as single stage Kanban (Spearman, 1990). The basic mechanism of CONWIP can be described by following Figure-8

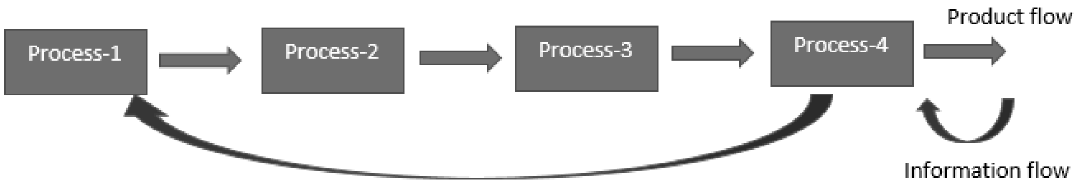


Figure-8: CONWIP System

Here, the Kanban signal is sent to the process-1 from process-4 based on the consumption of parts of components in process-4. Process-2 and process-3 follows push strategy which means whatever comes to them from upstream they perform operations to them and send them to downstream.

2.3.7 Value Stream Mapping

Value stream mapping is a graphical representation of material and information flow throughout a system, from the material receiving to the end of customer delivery (Rother 1999). According to (Liker 2004), it is not just a picture rather a tool to improve the system by understanding the whole processes in one figure. The figure basically represents all the processes involved in company, the cycle time and processing time of operations, batch size, number of operators, push/pull flow, material movement, how and which information is transferred between different processes. Drawing the current state becomes a basis to further improvement as continuous development.

2.3.8 Root cause Analysis

There are various tools to identify the root cause of an effect or problem. Common tools are used as- Fishbone diagram, Five-Why analysis, pareto chart, etc. Among these fishbone diagram identifies the most potential causes and sort them into different categories. Five-Why analysis is most suitable for a single phenomenon or incident. Pareto chart works with numerical data and shows which factor is most important.

2.3.9 Value adding and non-value adding tasks

According to Lean philosophy the tasks which adds value to customers is a value adding task. The non-value adding tasks can simply be said as the activities in the operational process for which customers has no value of it. The non-value adding tasks can be divided into two categories- Required non-value adding and pure wastes (Almström & Kinnander, 2011). Required non-value adding is like the task for which customer does not pay or done by company to ensure product quality whereas the pure waste can be classified as stated above- the seven types of task related waste. These classification is very necessary for task analysis to find out what tasks gives value to the customers and what tasks can be reduced or eliminated. In general, during task analysis, color code- usually Green, Yellow and Red, is used to represent these categories respectively. The following Table-1 represents the respective color code for these categories.

Table 1: Color code of different tasks

Color Code	Definition	Example
Green	Value adding task	Task to make the product or service
Yellow	Required non-value adding tasks	Taking tool, Quality inspection
Red	Pure waste	Motion, unnecessary transportation, waiting

2.3.10 ABC Analysis

The general form of ABC analysis is to identify the vital few from trivial many. It is applicable in various fields like inventory control, sale analysis and so on. The following chart represents the summarized representation of class- A, B and C (Tony Wild). According to the cart (Table- 2), 10% of an item which is sold contributes to ⅔ of the total sale. These parts are considered to be the most crucial parts and named A class parts. Whereas, rest 20% which contributes to rest 23.3% of the sale marked as B class and rest as C class parts. It is a simple analysis to understand the contribution to profit by different items in order to formulate better business strategy.

Table 2: ABC Classification rules

Class	Item	Sale
A	10%	66.6%
B	20%	23.3%
C	70%	10.1%

The ABC classification is widely used in inventory management to find out which items contributes to the profit most and which items are very important. In general, A class represent the most important object which contributes to the profit most or crucial for company’s business strategy. Class-B represents the less important objects and class-C relatively unimportant objects. This tool is widely used for inventory management to identify the main contributing items to the business so that Managers can optimize the inventory by prioritizing the service level and availability of the Class-A products. However, it requires to constantly monitor the Sales, Demand or other parameters.

3 Method

This chapter will present the methodology, including the various methods and software that were used in this project. Figure-9 shows the different activities that the thesis did consist of. In the (Figure-9) they are listed in a linear order, however, in some cases, they were parallel to each other. This was because when new information was introduced the analyses needed to be revisited and updated.

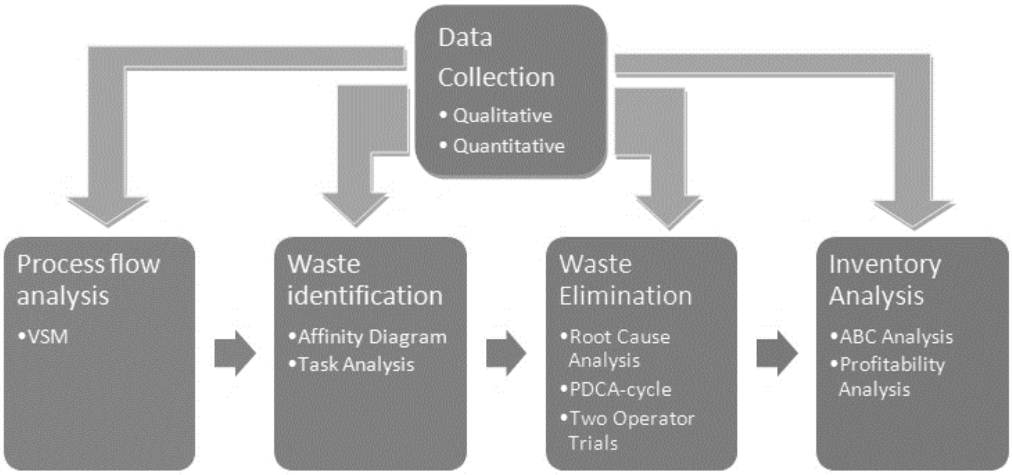


Figure 9 Methodology of this research

3.1 Data Collection

Throughout the project data collection was a key activity. It was conducted to gather both qualitative and quantitative data, which was necessary to make the different analysis. Due to the variation of the car dismantling industry, e.g. condition of cars and customer demands, it was troublesome to collect some data. This resulted in data that was more generalized, such as part categories instead of a certain part for each type of car model. Also, measuring points had been taken over longer time in order to accommodate for variations. In addition, data was collected from multiple sources and analyzed which can be referred to as triangulation of data to strengthen the validity of the data (Yin, 2004).

3.1.1 Qualitative data

Most of the qualitative data were collected manually through interviews and video recordings. For interviews, were in the form of non-structured and semi-structured, often depending on how much information that was needed. Fully structured interviews were not considered, since it in some sense would limit the answers to how the questions was formulated and not explore the full knowledge of the employees of the dismantling companies. Most of the interviews were conducted at CDB with employees working at different parts of the car recycling processes. It was important to get a good understanding how the work was performed and if the operators did feel that there were any problems or improvement possibilities for their work assignments.

Data for analyzing the dismantling time was both collected by interviewing the production manager of CDB and through dismantling times from the RSSC database. The database of the RSSC contained operation times of service workshops (mounting and dismantling) for numerous parts of many different car models. The dismantling times vary a lot depending on type of car and in what order the parts are taken, so being able to triangulate this data with the RSSC was very helpful.

3.1.2 Quantitative data

The quantitative data was almost exclusively collected from the ERP-developer, which has developed ERP softwares that are used extensively in the dismantling companies that was visited. The initial idea was to collect this data direct from the dismantling companies, though they had not done this before and therefore found it quite cumbersome to extract data from the program. So, it was a breakthrough in the project to be able to cooperate with the ERP-developer, since they knew how to access the data.

This data would be the basis of the data analysis including the ABC analysis, which will be described later in this chapter. It was collected in three datasets, each set including more parameters as more factors were investigated. The data was collected by the ERP-developer from their software and it was presented in Excel format. This made it very easy to calculate and sort the data in whatever way that was needed. Being able to manipulate the data in this way was crucial, due to the size of the documents with almost 700 rows of different part categories, e.g. petrol engine. Manually exporting a text document to Excel of such size would have been very time consuming.

3.2 Value Stream Mapping

Due to the complexity of the dismantling industry, it was necessary to get a better understanding of how it is operated. This was done by making a Value Stream Map (VSM) of CDB, which was based on the findings of the visit to the company.

Updating the VSM several times and asking for additional information was crucial to get a good understanding and accuracy of the VSM. This was extra important because there were different flows for the cars, depending on their classifications.

The classifications of the cars indicate the condition of the car, which determines how it should be processed. In the case of CDA they have colors and for CDB they have numbers for their classification system, but they fill the same function.

Because of the variability of the incoming cars it is not possible to get one definite cycle time of the operations, but interviews with the shop floor managers gave average cycle times for each label of the cars.

3.3 Waste Identification

In lean theory identifying and removing waste is a central concept and was therefore also an important part of this thesis. The waste was identified based on the VSM, observations and task analysis. The wastes and the problems found during the first visits were grouped together through an Affinity diagram. Causes and factors of the identified wastes were explored using a root cause analysis.

3.3.1 Affinity Diagram

From knowledge gained based on the first visits to CDB and CDA and the VSM a Brainstorming session was done to highlight found problems and opportunities. According to an Affinity Diagram, the ideas and opportunities were written down on post-it notes individually and then grouped with notes that were related until all notes had been grouped. Based on the Affinity Diagram and discussions the areas of further waste and opportunity analysis were identified.

3.3.2 Task Analysis

In order to identify the waste at the different stations at a dismantling company a task analysis was performed utilizing the software Avix. A recording of operations on a dismantling station, sheet metal processing and barcoding area was filmed at CDB. These videos were imported into Avix and analyzed in terms of value adding, supportive and non-value adding time. The non-value adding tasks were further distinguished between required and waste.

3.4 Eliminating Waste

After identifying wastes the continuous improvement tools in Lean methodology was used. As described in theory, at first, the situation was understood to get complete idea about the current state. Then Root Causes of the wastes have been defined based on Fishbone diagram to identify the crucial factors. Later, alternative solutions were generated taking account of the crucial factors found from Fishbone diagram.

Finally, PDCA (Plan-Do-Check-Act) cycle was followed to investigate the consequence of the alternative solutions. At first, the measuring unit was defined to compare the alternative solutions and a rough plan was set to execute in the production area. During execution, necessary data were taken to calculate the parameters. Finally, the outcome was analyzed and the effectiveness of the alternative solution were defined. The Act stage of PDCA cycle was excluded as it would be a part of company's action plan to execute the proposed solutions.

3.5 Data Analysis

In the data received from the ERP-developer there were several different attributes that was listed for each part, so there were many different ways to compare the different parts. The main way was comparing the revenue and amount sold, which was done using an ABC-analysis. The method of this along with the other ways that was used to analyze the inventory is presented in this part.

Throughout the data analysis units will often be described in terms of sale and sold, of which sale will refer to the revenue of parts and sold will refer to amount of parts sold.

3.5.1 ABC-analysis

The data obtained from ERP-developer would represent the amount sold and selling price of all part categories of CDA and CDB. The data was taken over the last two years, which should give a good representation of customer demand and not be sensitive to fluctuations. In total, there were about 650 categories for both companies of which some of them were sold in low amounts or had a low revenue. Therefore, a limit was set to remove parts that had less than five sold and total revenue of 1000 SEK. This would remove more than 220 categories so that more than 400 categories were left.

In the first part of the analysis parts were compared in terms of sale revenue and amount sold. The sale revenue was calculated by multiplying average selling price with amount sold for each part category. Based on comparison of sale revenue the classifications were made according to the theory. After this was the customer distribution plotted, both in terms of revenue and amount of parts sold.

From the classifications of A-class parts in the previous section a compiled list was made. This combined part categories that were similar to each other, such as doors (combining four categories) and engines (diesel and petrol). Another list was also created for each company where the parts were sorted in terms of amount sold. To match the A-class parts list the items did correspond to 67% of the total revenue. For this list, the same part categories that were similar to each other were also compiled.

These two lists were plotted against each other comparing how many part categories they contained and the percentage of the total amount of sold parts for both companies.

3.5.2 Inventory turnover analysis

The dataset included number of parts sold over the last two years and current amount in inventory for each part category. This data was used in the following equation to calculate days until sold out.

$$\frac{current\ amount\ of\ inventory}{total\ amount\ of\ sold} * 2 * 365 = \text{Days until sold out} \qquad (1)$$

This equation assumes that the demand is constant over time and that all parts within each part category is of equal demand. Even with these assumptions it gives some indications of which parts there are a surplus of.

3.5.3 Service level analysis

Calculating service level of the different parts was done by dividing number of sold parts with the number of customer requests. This would indicate how well the car dismantling companies are able to meet customer demands.

3.5.4 Dismantling time analysis

One scenario that was investigated was if the dismantling companies only did focus on extracting A-class parts for newer cars. By doing that they could reduce their dismantling time and reduce the size of the inventory. It was then necessary to find out the dismantling time of these parts so a list of the A-class parts and some of the top selling items were made.

The data was collected by interviewing the production manager at CDB. It was understood that the dismantling times did vary a lot depending on how advanced the car to be dismantled was and also in what sequence were extracted. An example of this is parts that are connected to the engine like the turbocharger, which takes about 30 minutes to extract when the engine is not lifted outside of the car, but only a quarter of the time if it is outside. This list was later cross referenced with time measurements from the RSSC, a software developer that supplies insurance companies and service centers with time estimations for changing parts.

3.5.5 Mathematical Model of Profitability Analysis

The profitability calculation was done using the following model:
The general equation of the profit is as follows

Profit = Total Income - Total Cost (2)

The dismantling company gets money in two ways, by selling the extracted parts to insurance company and private persons, and by selling raw materials from the ELV to dismantling industry. As the price is different for different parts, therefore, the sum of average selling price of these parts, considering the data of last two years, were considered as the total income from the extracted parts. It should also be noted that, in practical not all of parts are sold. Therefore, it is necessary to consider the scrap rate (lost sale) to calculate the total income. As the scrap rate varies among different parts, therefore, the overall value of lost sale was calculated based on the ratio of scrap rate of different parts.

Total Income = sum of average selling price of parts - Lost sale + sale of recycling material (3)

In order to calculate cost, several parameters were considered like the purchasing price of an ELV, operation cost and the inventory cost. The Operation cost is calculated based on the dismantling time and overhead cost of each unit hour.

Therefore, Total Cost = Purchasing Price + Operation Cost + Inventory Cost (4)

Operational cost = Time to dismantle (hour) * Overhead cost per unit hour (5)

Inventory Cost = Inventory overhead cost per year * Number of years stays in inventory (6)

Inventory Overhead cost per year = land value per year per unit + Other overhead cost (7)

4 Results

This chapter will present the results of step by step approach mentioned in methodology with detailed explanation of different tasks.

4.1 Value Stream Mapping

A Value Stream Map was conducted for CDB which can be viewed in Appendix-A. The production system of CDB found to be quite complex as there are many different flows for the cars depending on what label is set on the car. This can be viewed in Figure-10 that displays the decision point and where the different labels come afterwards.

In the case of CDB they utilize numbers for the labels. Label-1 and Label-2 are premature ELV cars, where Label-1 is usually the cars of a certain model that they have not processed before. From Label-1 cars they take as many parts as possible (more than hundred parts), while less parts (+50 parts) are taken from label 2 cars as they already have processed a number of those before. Then, there are Label-3 cars which are natural ELV cars that they still can take some parts from, but no engines and gearboxes. Label-4 corresponds to caravans and recreational vehicles, which are processed completely differently and is not part of the main business. Label-5 cars are also natural ELV cars that don't have parts of value at all. Label-6 cars are cars that has been damaged in a way so that they don't can take any of the electrical components, caused for example by water damage.

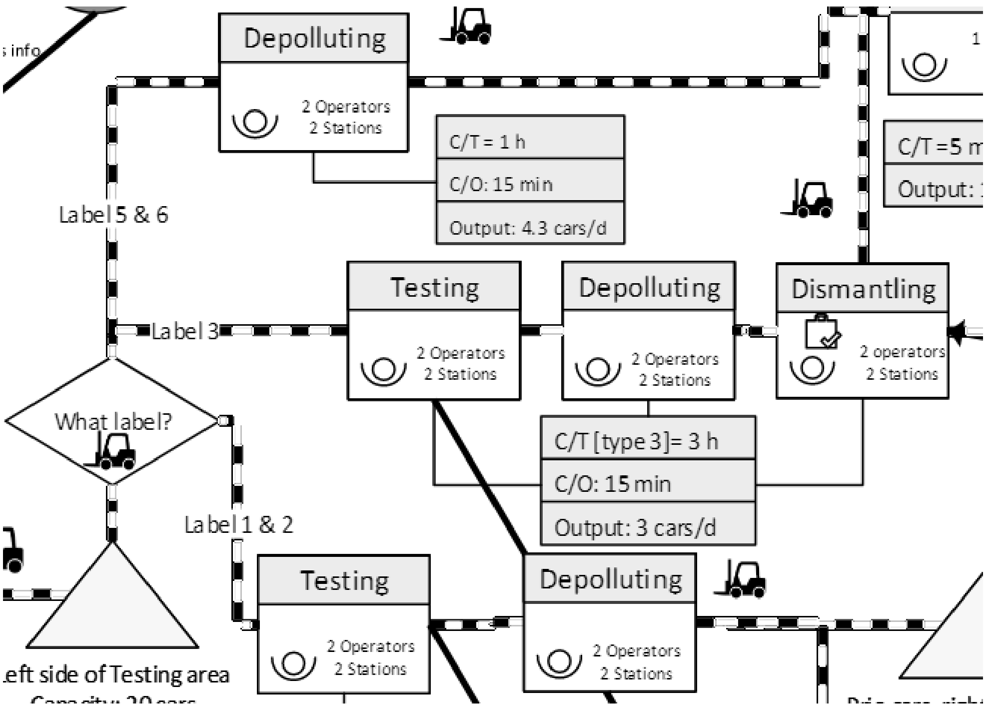


Figure 10: Part of VSM

In the VSM the cycle times and output are listed for the activities. Initially it was planned to measure uptime, cycle-time, process time and changeover-time for all activities, but as the VSM was a tool that mainly was used to understand the processes of a car recycling company it was found to be excess.

All of the circle icons represent the different parts of the ERP systems that CDB utilizes. This is the software created by the ERP-developer with information about the cars, pick-list and sales program. The forklift icons, represents the all the transportations done using a forklift. This was added to the VSM as the forklift is a key asset to the production system, moving cars between stations, buffers, SPS and the crusher.

Another key point of the VSM is the end treatment of the cars, which is shown in Figure-11. After activating all the airbags of the cars, they either go to SPS (a place where some ELV are kept, public goes there and extract their preferred parts from an ELV) or directly to the crusher. As the cars are stored outside at SPS they need to have all windows and all of the bodywork intact so that no water leaks in. For the newer cars (Label-1 and Label-2) parts of the bodywork are often extracted, such as doors and therefore most of these cars go directly to the crusher even though they might have valuable parts left. The customer pick-up point is also displayed in following Figure-11

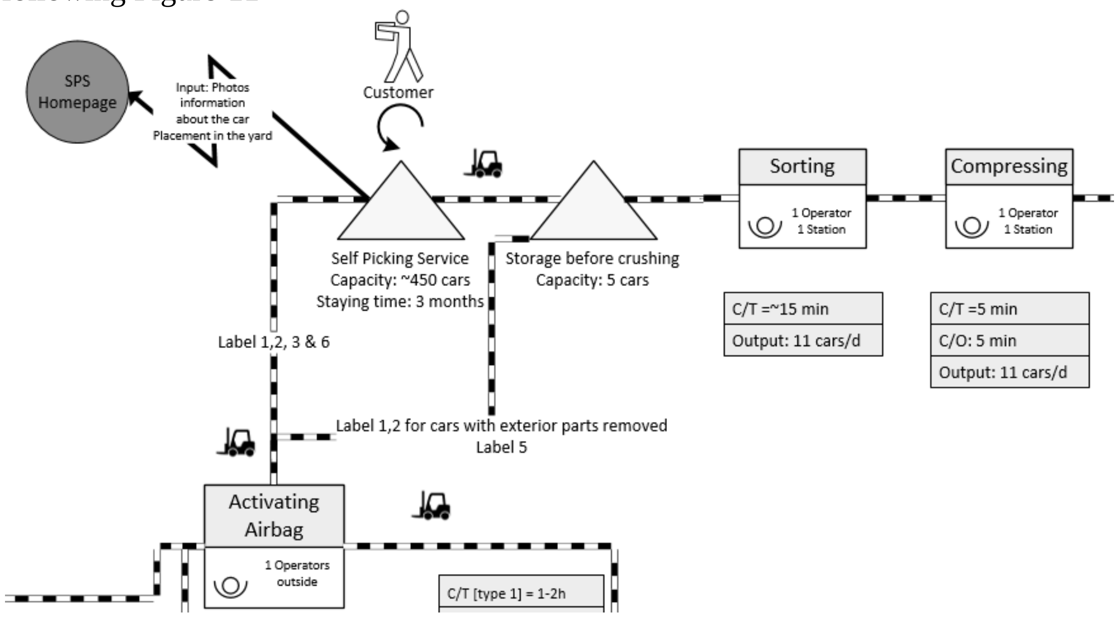


Figure 11: Part of VSM

4.2 Waste Identification

From the VSM and observation of the processes, several wastes were identified initially with the help of affinity diagram. It was found that, the excess inventory of finished goods and work in process (WIP) is the most crucial factor here. Overproduction is another important issue as every year on average 30% of the stock in warehouse is thrown away. Other sorts of wastes like- quality problem, transportation inside factory, waiting for materials or instructions and unnecessary processing existed to some extent, however, not affecting much into their production system. As the operations were manual, therefore, initially it was assumed that there must be some waste regarding excess movement which can be identified by task analysis.

4.2.1 Task Analysis

The operations in different processes like dismantling, sheet metal processing and quality checking were analyzed using the software named Avix. The operations were filmed and the tasks were separated into three categories like- value adding, required non-value adding and pure waste. The summary of the task analysis is presented on following Table-3 and Figure-12

Table 3: Summary result of Task Analysis in Dismantling Station

	Task	Total Time	Value adding	Supporting	Loss
1	Door Disassembly	7 min	55%	40%	5%
2	Rear Side disassembly	11 min	62%	23%	15%
3	Dashboard equipment	10 min	60%	35%	5%
4	Engine Disassembly	62 min	74%	16%	9%

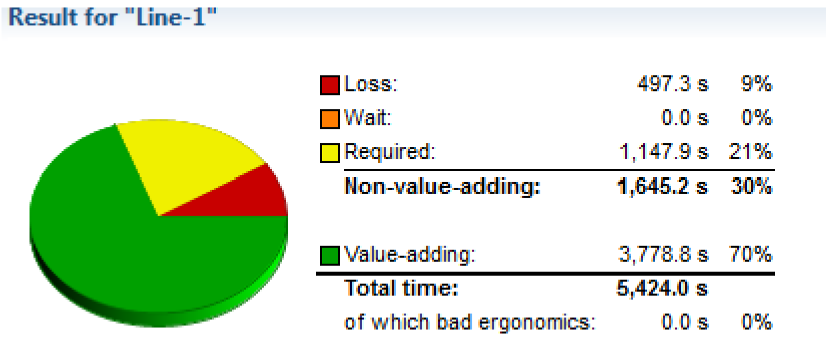


Figure 12: Summary result of task analysis in dismantling station

As seen in Figure-12 there is a loss of 9% in total, which mainly consists of the operator walking to get new tools or put extracted parts on the trolley. As the operator moves randomly, therefore, the walking steps of the operator is simplified as following Figure-13 where the whole walking path is divided into four category-A, B, C and D. The category-A, indicates when operator moves to nearby work table to put the power screw driver, category-B represent when he goes towards waste bin to throw away unnecessary items, Category-C represents his movement to get the required tools from the tool box positioned there and finally, category-4 represents when he moves to put the extracted parts into the trolleys placed there.

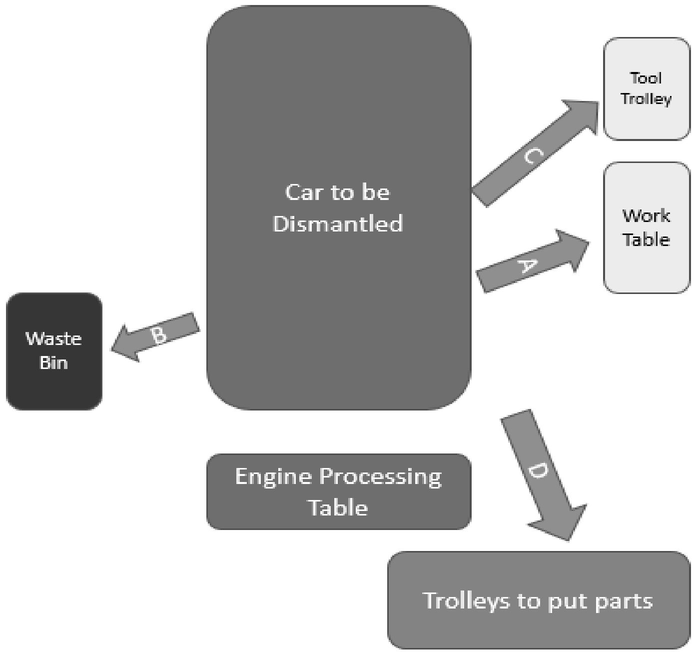


Figure 13 Layout and Movement diagram of operator in dismantling station

4.3 Eliminating Waste

In this section, the results from the root cause analysis will be presented. The findings of the two-operator experiment and the workplace rearrangement are also presented.

4.3.1 Root cause Analysis

After identifying the wastes, causes severe impact in the production system, the root cause of these problems was identified in order to solve it through Lean way. The root cause was identified based on interview to CEO and the Production Manager of CDB. The root cause analysis of different major wastes like Excess inventory, over production and Motion (involved with dismantling station) is shown below Figure-14 and Figure-15.

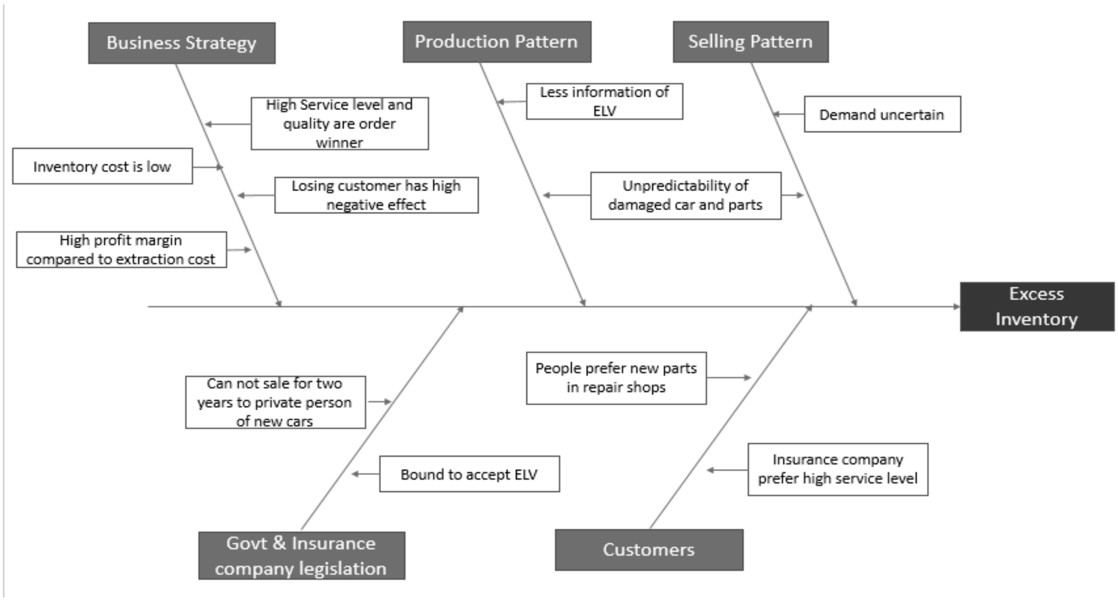


Figure 14: Fish-bone diagram of Excess Inventory

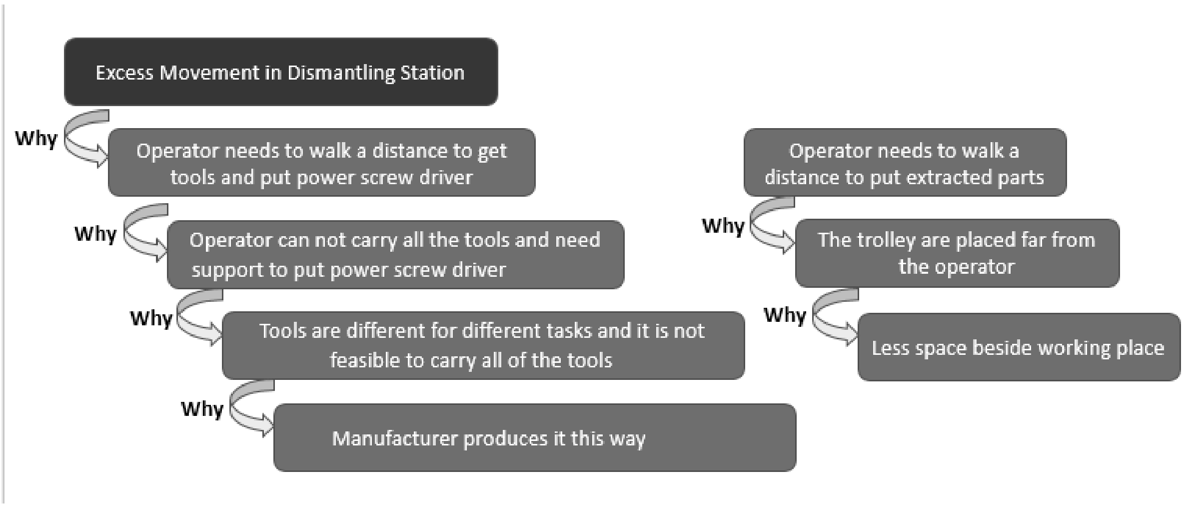


Figure 15: Five-Why analysis of Excess movement of operator in dismantling station

Based on the fishbone diagram (Figure-14) it was found that, the major factors affecting the high inventory are- the Selling pattern, Production pattern, Business Strategy, Government & Insurance company's legislation and customer behavior.

For workplace-like dismantling station, the reason for extra movement by operator was to get access the tools from tool box and putting the extracted parts to trolley. The tool box and trolley remains in fixed position.

4.3.2 Generate feasible solution

After root cause analysis, understanding the main factors which cause the wastes, feasible solutions were generated to eliminate the waste. In order to reduce motion wastes in dismantling station, possible solutions would be

1. Working two operators in one work station
2. Arrangement of the workplace to put the tools and trolleys nearby operators

4.3.3 Experiment with having two operators in one station

The experiment was initiated considering judging the feasibility of working two operators in one work station. During the experiment, the difficulty level of the disassembly of a car was also considered. For this reason, two different types of cars were selected- VW Polo and Audi A4. VW Polo in general easy to disassembly whereas the Audi A4 is very complex to extract the parts because of their respective design by the manufacturer. At first, two operators disassembled one car together and then one operator, from previous experiment, performed disassembly alone for similar type car. The disassembly time and number of extracted parts were recorded. Following Table-4 represents the result of the experiment.

Table 4: Comparison the result of dismantling using one and two operators

Category	Car Model	**Two Operator**			**One Operator**			Difference of man time /parts
		Time	Parts Taken	Man time /parts	Time	Parts Taken	Man time /Parts	
Easy	VW Polo 2010	1 hour 50 min	38	5.78 min				**4.1%**
	VW Polo 2011				3 hour 20 min	36	5.55 min	
Difficult	Audi A4 2009	4 hour 45 min	70	8.14 min				**4.3%**
	Audi A4 2007				6 hour 30 min	50	7.80 min	

4.3.4 Workplace Improvement

It was observed that, to reduce the movement, the best option would be to set the position of the required tools and trolley closer to operator. As it requires different tools to perform different tasks, therefore, the position of tool box and trolley to put extracted parts were needed to place in suitable position so that the walking steps of the operator could be reduced. Based on these observations a new workplace design was conceived through discussions, that could be one way of lowering the losses in dismantling. This design and movement of the operator is shown in following Figure-16.

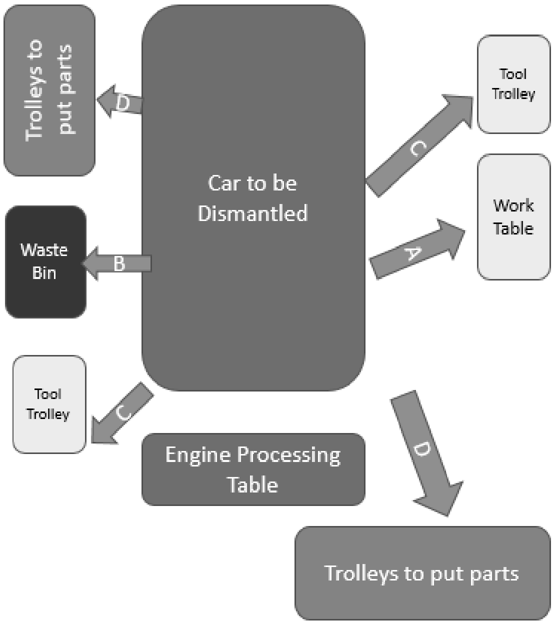


Figure 16: Improved Layout and movement path of operators in dismantling station

4.4 Inventory Analysis

In this section, the results of ABC analysis, profitability analysis of A class parts and the comparison of different parameters will be presented.

4.4.1 ABC-analysis

The first part of the analysis was to calculate the total sale revenue, which was done by multiplying average selling price with amount sold for each part category. This is presented in the following Figure-17 & Figure-18 for CDB and CDA separately. The X-axis is number of part categories and the Y-axis is the percentage of total sale for each company. The areas of the different classifications are also displayed.

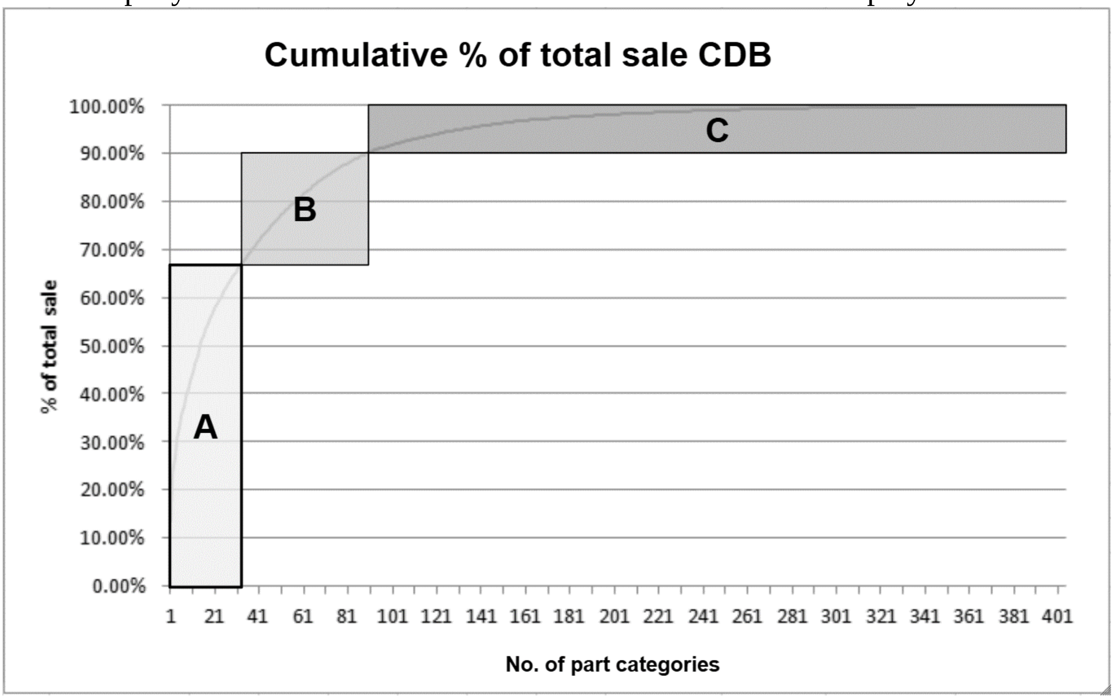


Figure 17: ABC analysis of CDB based on total sale

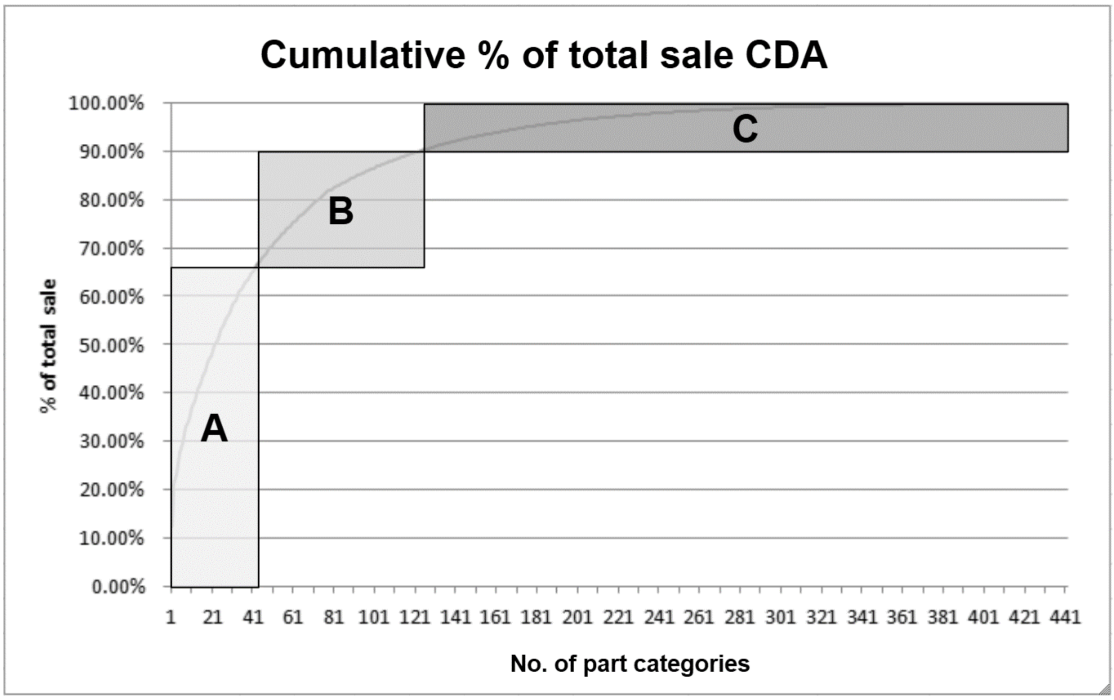


Figure 18: ABC analysis of CDA based on total sale

From the graphs, the different classes of the ABC analysis were identified. These are presented in Table-5 that also displays the number of parts each classification contains and the percentage of the total it corresponds to.

Table 5: Summary of ABC analysis for CDB and CDA

	CDB			CDA		
Class	Number of Part categories	% of Part categories	% of Total Sale	Number of Part categories	% of Part categories	% of Total Sale
A	33	8%	67%	44	10%	67%
B	57	14%	23%	79	18%	23%
C	314	78%	10%	318	72%	10%

The parts were also sorted in terms of amount sold. As it is also important for the company to know which components are sold in the greatest amount so that they can keep high inventory levels on them and meet customer demands. In Figure-19 and Figure-20 this is displayed for each company. The X-axis is number of part categories and the Y-axis is the percentage of the total amount of parts sold for each company.

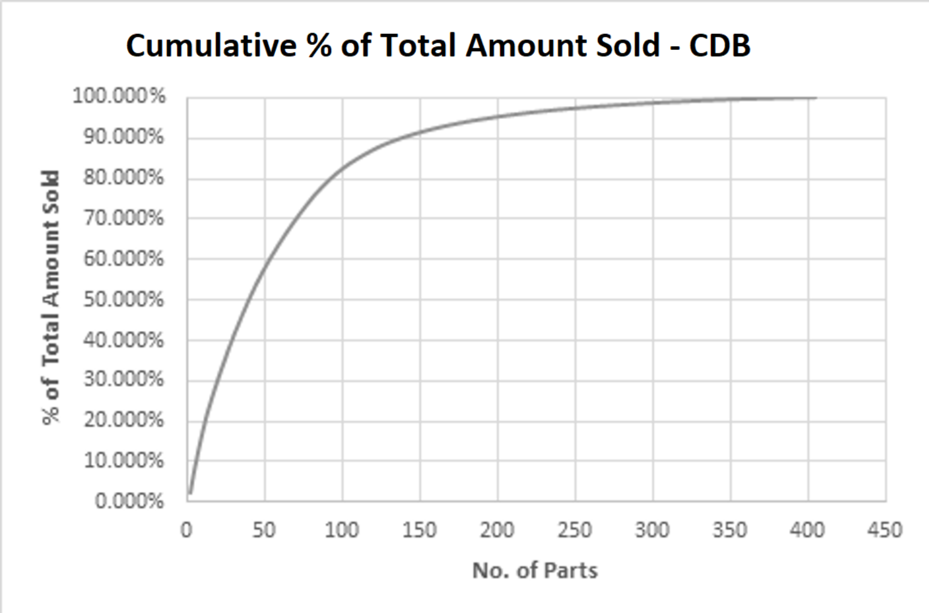


Figure 19: ABC analysis of CDB based on number of parts sold

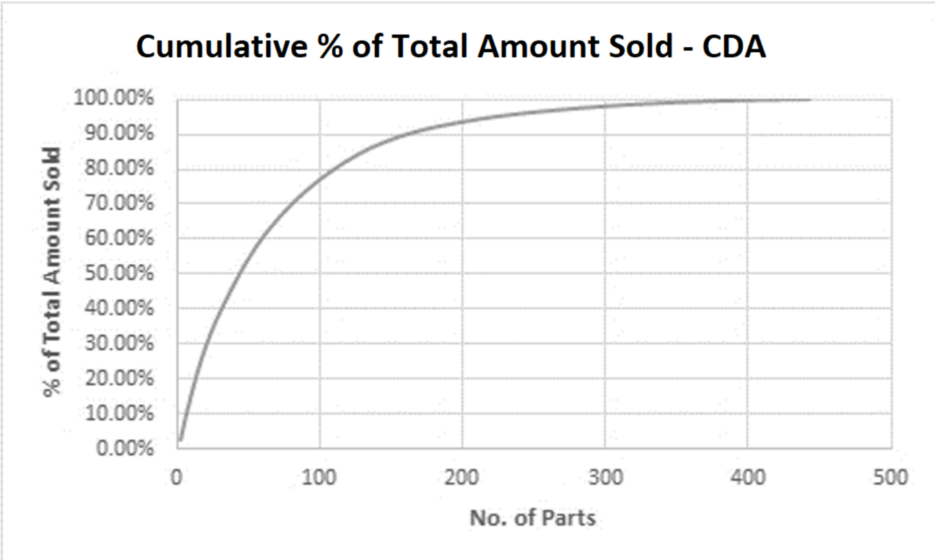


Figure 20: ABC analysis of CDA based on number of parts sold

The result of this analysis is presented in Table-6 for both CDB and CDA.

Table 6: Summary of ABC analysis based on number of parts sold for both CDB and CDA

CDB			CDA		
Number of Part categories	% of Part categories	% of total amount sold	Number of Part categories	% of Part categories	% of total amount sold
64	16%	67%	72	16%	67%
74	18%	23%	89	20%	23%
266	66%	10%	280	64%	10%

Although the results (Table-6) are also presented in a similar way to that of the sale, there are no classifications made. This is because the parts that gives the companies the greatest revenue is of most importance.

4.4.2 Comparison among different customers

The distribution of the different customer basis was also investigated, both in terms of revenue and number of parts sold. The results are displayed in Figure-21 for both companies.

For CDB, the data was divided in four different customers- Insurance companies, Private persons, Business and Export. The business data corresponds to various service centers for cars and export is parts sold to other countries, like Germany or Poland. Though the service centers are sending the orders for parts, they are repairing cars of insurance companies and private customers. Therefore, in reality, it is only three types of customers that buy parts from car dismantling companies, Insurance companies, Private persons and Export customers. In the case of CDA they only have insurance, private persons and export.

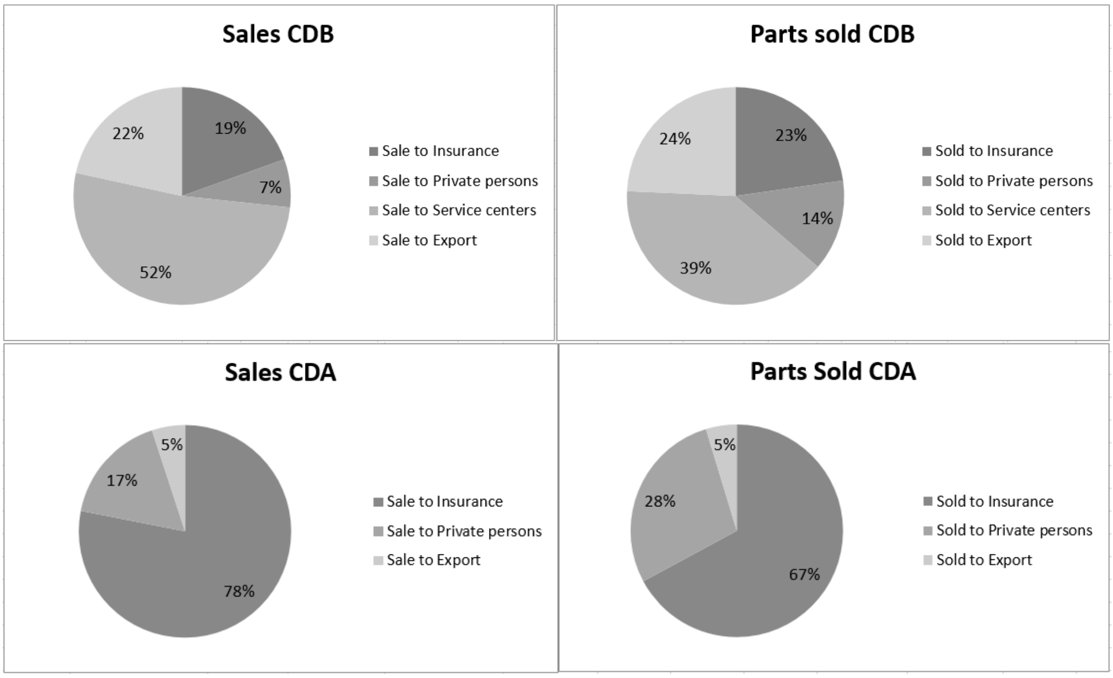


Figure 21: Distribution of total sale based on different customers

From the Figure-21, we can identify that for CDB the greatest revenue comes from service centers, though it represents a lot less of parts sold. The opposite is true for the private persons, which contribute more to parts sold than the revenue. Similarly, for CDA Insurance has higher revenue than amount of parts sold, while private persons has greater amount of parts sold than the revenue.

4.4.3 Compiling the list of A-class parts

From the classifications of A-class parts in the previous section a compiled list was made. This would reduce the number of categories to 20 from 33 for CDB and 31 from 44 for CDA. For this list, the categories that were the same for both companies were highlighted, which would amount to 17 categories.

The second list based on sorting the parts in terms of amount sold was also compiled for each of the companies. In the case of CDB, it was reduced from 43 to 30 parts and for CDA from 65 to 53 parts. These two lists correspond to the same amount of sale revenue (67%), which makes it easier to compare them.

The results are plotted in Figure-22, where the blue and gray lines correspond to the A-class parts, while the red and yellow lines is the list of the most sold parts. On the X-axis is the part categories and on the Y-axis, is the percentage of the total revenue.

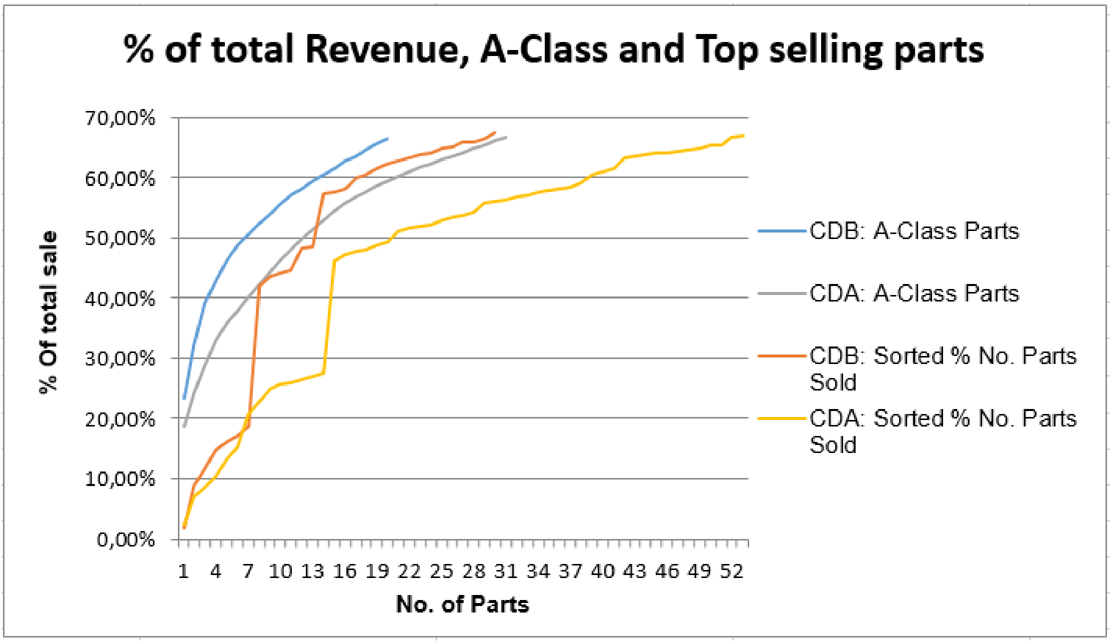


Figure 22: Percentage of total revenue of A class and top selling parts

From this Figure-22, there is a significant difference in how many parts that contribute to 67% of the total revenue for the two companies. CDB has fewer parts both in terms of the A-class parts and when sorting parts in terms of amount sold.

The same data was also compared in terms of how much of the total parts sold that they contribute to. This is presented in Figure-23 where the color of the lines represents the same as the previous figure. On the X-axis is the part categories and on the Y-axis, is the percentage of total amount of parts sold.

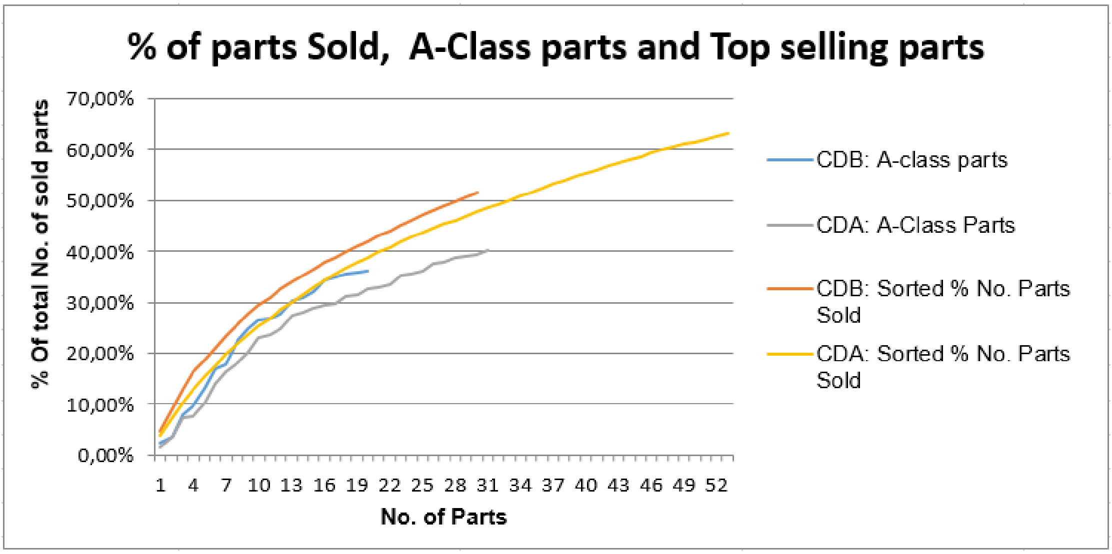


Figure 23: Percentage of number of parts sold for A class and top selling parts

In this Figure-23, all the lines constitute 67% of the total revenue, but it is a clear difference in how many parts that they represent. The result is presented in Table-7 showing the scenarios both for CDA and CDB. It can be found that the parts from CDB gives a lot more revenue compared to CDA.

Table 7: Summary of A class and top selling parts for both CDB and CDA.

CDB			CDA		
	A-Class Parts	Top selling Parts		A-Class Parts	Top selling Parts
No. of parts	20	30	No. of parts	31	53
% of total Sold	36%	52%	% of total Sold	40%	63%

The customer basis was also investigated for the A-class parts and was very similar to that of all parts, shown in Figure-24 The only difference is for CDB where the service centers have 5% more of the sale coming from private persons and export.

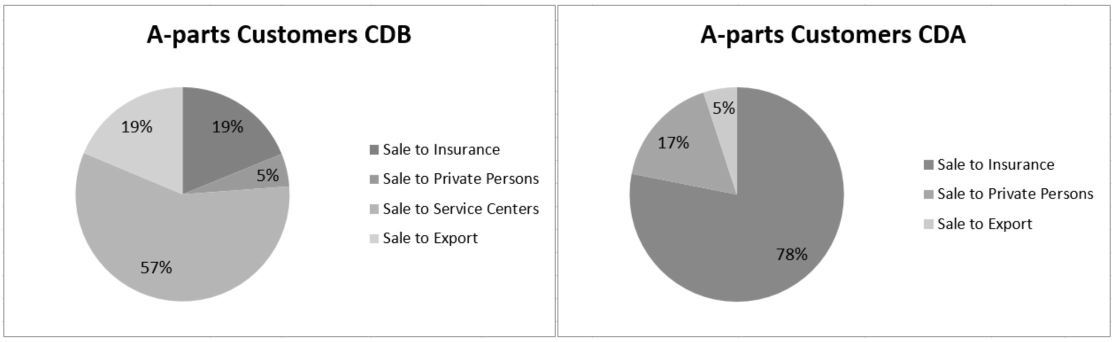


Figure 24: Distribution of sale to different customers for A class parts in CDB and CDA

4.4.4 Inventory turnover analysis

Excess inventory was one of the wastes that was analyzed in the Root Cause Analysis and though to some extent it is necessary to have a high inventory to meet customer demands. Although it was necessary in some way to compare the amount of parts sold to how much they have stored in the warehouse. Using equation (1) the number of days until sold was calculated.

The results of this analysis for both CDA and CDB is presented in Figure-25. The values have been divided into distinct categories so it is easier to comprehend.

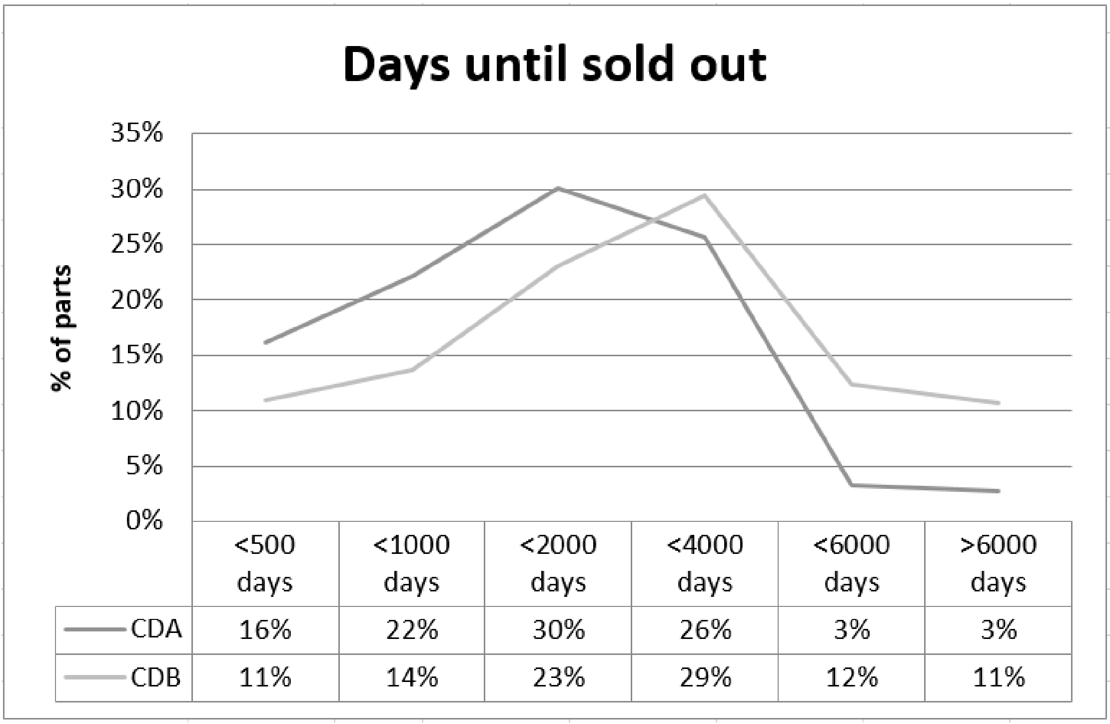


Figure 25: Inventory turnover analysis

It can be seen that CDB has values that are a lot higher than that of CDA. This was further investigated and it was found that CDA had more parts sold than CDB and CDB had more items in their Warehouse, compared to CDA.

4.4.5 Service level analysis

An analysis of the service level was to be a central part of the inventory analysis. By dividing the number of sold items by the number of customer requests a service level can be calculated. From the data received from the ERP-developer it was understood that the number of requests did not match the actual case as the average service level was found to be about 55% for CDA and 26% for CDB. This was investigated further and it was found that in the old sales-system the searches made by the sales-department of the car dismantling companies also counted as requests. This has been changed with an updated version of the system, but since the data contained sales statistics of the two last years it was not representative.

4.5 Profit Analysis

The viability of only picking out A-class part was investigated, as a potential strategy which companies could use if they would like to lower the throughput time of their cars. This was done by collecting data of the processing time of A-class parts and utilizing the mathematical model that was introduced in Chapter-3.5.5.

4.5.1 Data of Processing Time

The processing time was collected from interviews with the production manager at CDB and is presented in Table-8. The time of all activities were included to get as complete picture as possible and in the case of dismantling it is the sum of the time for each part to be extracted on average.

Table-8: Processing time data for different operations

Operation Time	
Activity	**Time (min)**
Testing & depolluting	60
Dismantling	300
Cleaníng	20
Sheet metal processing+barcoding	270
QC+Photo+Barcoding	150
Warehousing	30
Selling and Packaging	120
Others (e.g. transport)	30
Total operational time	980
Very Light Gray	Data from Interview
Light Gray	Data from Interview with minor assumptions
Gray	Assumed values

As seen in the Table-8 most of the time is spent on dismantling and processing the parts so they are ready to go into the warehouse. When comparing the dismantling time of this case (300 minutes) which is lower than that of current practices, where a label-1 car takes about 11 hours (660 minutes) and a label-2 car takes 8 hours on average (480 minutes). Though it is also to be said that there are some cases where virtually only A-class parts are extracted from label-2 type cars.

As the dismantling time varies from car to car, therefore, to validate the data of dismantling time, data from RSSC was used as a cross-reference. The data is based on work done by repair shops, which is different from car dismantlers in terms of the care that needs to be taken when working with the car. A comparison of the different data can be seen in Table-9, based on extracting parts from a Volkswagen Golf.

Table-9: Comparison of Dismantling time between RSSC and CDB

Volkswagen Golf (09-13)	RSSC (min)	CDB (min)	Difference:	
Engine Diesel	159.6	90	69.6	56.39%
Gearbox 5 speed	95.4	60	35.4	62.89%
Door front left	7.8	7.5	0.3	96.15%
Steering Servo-Worm	50.4	25	25.4	49.60%
Headlamp Left	27.6	10	17.6	36.23%
Mirror Exterior Electric Left	13.8	5.5	8.3	39.86%
Turbocharger	106.8	30	76.8	28.09%
Tail Lamp Left	7.8	2.5	5.3	32.05%
Alternator	48	12.5	35.5	26.04%
Drive Shaft Front Left	20.4	10	10.4	49.02%
Bonnet Front	9	3.5	5.5	38.89%
Brake Caliper Rear Left	9	7.5	1.5	83.33%
ABS Hydraulic Unit	29.4	7.5	21.9	25.51%
Bumper Trim Front	21	7.5	13.5	35.71%
AC Compressor	25.2	12.5	12.7	49.60%
Tailgate Estate	19.2	7.5	11.7	39.06%
Derailleur-Differential	57	20	37	35.09%
Total:	707.4	319	388.4	783.53%

It can be seen that there are big differences for internal parts such as motor parts and less difference for external parts such as doors. This is mainly due to cables and hoses which the internal parts are connected with, which in the case of repair shops they need to be careful when removing so they still can use them when inserting new parts. This is not necessary for the car dismantlers that can just cut the cables and more easily remove the parts. In the case of doors and brake calipers the extraction process is very similar for both businesses.

4.5.2 Profit analysis of A-class parts

Using the mathematical model and the collected processing time it was possible to make the profitability analysis, which was based on data of the last two years from CDB. The following Figure-26 and Figure-27 represent the breakdown of total cost and revenue.

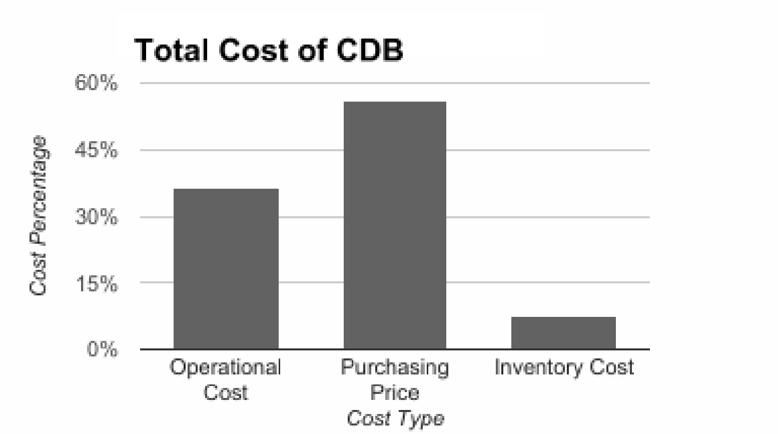


Figure 26: Cost breakdown for CDB

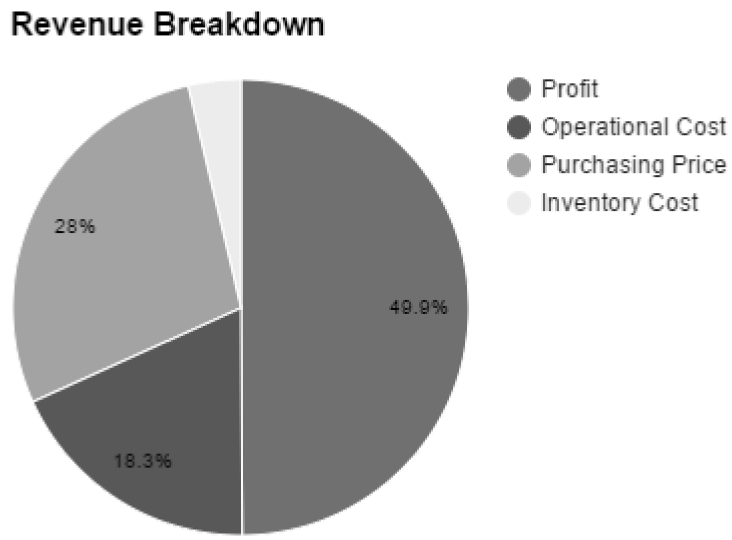


Figure 27 Revenue Breakdown for CDB

Figure-26 & Figure-27 show that most of the costs are connected to the purchasing price and operational costs and that it is possible to make a profit by only extracting A-class parts. Though there are several drawbacks if the company would have this strategy for all cars, which will be discussed in the evaluation of results.

5 Evaluation of results

This chapter will focus on detail analysis of the experimental result of process improvement along with the ABC classification.

5.1 Value stream mapping

From the VSM (Appendix-A), it was found that, there are basically two main flows of the ELV. The natural ELV moves to crushing zone after depollution. On the other hand, premature ELV goes through dismantling station where the parts are extracted. It was found that, the cycle time of different processes varies a lot and for a particular process cycle time also varies for different cars. This makes it harder to plan the production and is one of the main reasons why such big buffers are necessary.

5.2 Waste Identification

Based on the result of task analysis in dismantling station (Table-3) the value adding time is around 50% which is higher in general compared to assembly line of car manufacturing company. It is because, for this case, the consideration of value adding tasks were deviated from the car manufacturing industry. For example, in car assembly line, while attaching a screw, taking the screw, taking screwdriver, attaching screw time and putting back the screw driver is considered as required non-value adding tasks. Only value adding task is considered to put the screw in the whole which is only couple of seconds. On the other hand, for dismantling case, company gets money by extracting a part and only way to do so is by removing the fastener or screw. Therefore, here removing the cables, fastener or screw is considered as value adding tasks. Changing tools, putting extracted parts into trolley, adjustment of car and so on is considered as required non-value adding tasks. The pure wastes were considered the excess movements by operators to get the tool and put the parts. Another important thing is, the depolluting, sheet metal processing, quality checking, cleaning is considered as required non-value tasks as for this sort of processing do not add any value to customer.

Based on the results it was found that, for dismantling operations, there is 9% of pure waste due to movement. Since the dismantling process is between 3 and 11 hours for each car, the waste becomes quite a lot of time over a period. Therefore, it should be one of the main priorities to make this process more effective.

5.3 Root cause Analysis

Before analyzing the root cause of high inventory and overproduction, it is necessary to understand the scenario of this business. Usually the demand of a part is created when that part is damaged in a vehicle and most of the cases, it is uncertain. Similar way, dismantling companies extract parts from a premature ELV which is uncertain to say when a ELV will be available and if so either a specific part will be good enough to be extracted. Because of these uncertainty, it is difficult to make exact forecast which leads to have high inventory. On the other hand, to get competitiveness in this business, it is required to have a high service level and because of uncertainty in demand the extracted parts which remain unsold for long period are removed from the inventory as scrap. This scrap can be considered as overproduction which is very hard to diminish.

5.4 Eliminating Waste

In this section, different perspectives of the generated solutions will be discussed. At first, the result of experiment of engaging two operators in one dismantling station will be discussed along with its pros and cons. Then, the possible benefits of rearranged workplace will be discussed.

5.4.1 Experiment with Two Operators

According to the result of disassembly time (Presented in the table-4) the disassembly time of working with two operators is almost half of the time when only one operator disassembles the cars. Therefore, the output rate would be same for both options. However, the experiment indicates that, there are scope to increase the flexibility such as increase the production by hiring extra operator, disassemble a car within short time, utilize the space by minimizing stations and so on. However, there are some negative impact on both options. The following Table-10 shows the benefits and cautious factors on both options.

Table 10: Advantage and cautious factors for working single or multiple operators in one dismantling station

Option	Benefits	Cautious situation
One Operator	• Operator can work freely	• For new operator needs training
Two Operator	• Space utilization by less work station • Fast processing of urgent order • New operator can learn from experienced operator	• Operators might collide with each other • Sequence need to be followed • It might be hard to memorize sequence for different types of car • New operator learning might be hampered if they do not perform complex tasks.

5.4.2 Workplace arrangement

Theoretically, it is assumed that by organizing workplace and increasing the accessibility of the tools, operators would need to move on average 6 steps on path C and D. For Path A and B, it is assumed that, the walking step is within control limit. The comparison of two state has shown in following Table-12

Table 12: Walking step analysis for improved work station

Path	No of repetition (a)	**Current State**		**Future State**		
		Average footstep (b)	Total Step (a*b)	Average footstep (c)	Total Step (a*c)	**Step reduced by**
A	15	5	605	5	330	**45%**
B	3	5		5		
C	22	13		6		
D	18	13		6		

Therefore, reduction of 45% of movement distant will reduce the total waste involved with dismantling station from 10% to 5.5%, in other way, it indicates that, on average 15 min will be saved from each car. It would result two more cars can be processed on each month.

5.5 ABC analysis

The datasets that was the basis of the ABC analysis originally contained more than 650 parts categories. A lot of these categories did have a low amount sold and little sale value. Therefore, it was good to have criteria of which data that would be removed from the dataset. Though on one hand it is good to have as complete as possible dataset when making the analysis it is also not good to have too many outliers. With the limit set at less than 5 pieces sold and less than 1000 SEK sale over the last two years it was economically almost an insignificant part with only 0.5% of the total sale and representing more than 220 parts.

This analysis did not take into account the variation of selling price and amount sold between different items in the same part category. If all parts of different car models and variation would be listed then it would have been too many data points, probably more than 10 000 different parts and the number of outliers in terms of low selling items would have been numerous.

One of the parameters in the dataset was standard deviation of the selling price and it was often very high, almost as much as the actual selling price. If the selling price of each part category was a standard distribution it would mean that a lot parts was to be sold at very low and even negative values. Instead it is very likely that some parts are sold for a lot more than the average selling price and that the median value is below that of the average.

From table-5 it shows that CDB has fewer A- and B-category parts, which suggests that CDB parts are more profitable, selling at a higher price. This is not so strange as CDB dismantle newer cars to a greater extent than CDA. As for Table-6 the distribution of parts sold it is more similar between the two companies.

When it comes to the customer basis it is tricky to make the analysis for CDB. Since the service centers are both representing sale to insurance companies and private persons. From the data, it is not clear how much each part corresponds to and this extra relevant as the service centers represents a majority of the sales of CDB. Still the trend is that private persons are buying less expensive part compared to insurance companies and export. On the other hand, it was found when investigating the distribution of each part category that private customers are often buying other types of parts than insurance and export. Example of this is spark plugs that is a very inexpensive part and had a very high representation of private customers.

One possible strategy could then be to prioritize insurance companies and export, leaving out private customers and parts like spark plugs. This would mean that they could cut down the dismantling time, as fewer parts need to be extracted. Also, the work that the sales department does would be reduced as they have to handle one less customer basis. At the same time, at least 7% of the sales for CDB and 17% of the sales for CDA would be lost. When interviewing the manager of the sales department at CDB he did feel like they currently didn't prioritize any customer and did treat all of them equally. If such a change would be initiated further analysis would have to be made of the possible benefits and drawbacks.

Combining parts in the compiled list of A-class parts did make it easier to overview the items. Though a lot of them wasn't combined and therefore the positions of a lot of parts was changed. From Figure-19 it is clear that CDB get a lot more revenue of their A-class parts as they dismantle a lot of newer cars, which is also why their A-class parts consists of fewer volume sold than CDA.

5.5.1 Inventory turnover analysis

The turnover analysis was made using a lot of assumptions, like the demand being equal for all parts within the same category. Also, it doesn't consider the refill rate of new parts, which is one parameter that has not been investigated in the inventory analysis. Still it displays the trend of high inventory levels that has been found a central part of the business of car recyclers. This is because they want to be able to meet customer demands for all parts so that they don't lose any customers.
In the collection of data there also was a number for average number of days in inventory until a part is sold. This value should be able to be linked with the calculation of number of days until sold out, but no such correlation was identified.

5.5.2 Service level calculation

Calculating the service level was one important analysis that could display the need of a high level of inventory. If this connection was found then it would be possible to justify having a big inventory is a crucial part of the business. Unfortunately, the data was inconsistent and it was not possible to calculate the values. One factor that could make the service level calculation misleading is the variety of parts within the same part category. For example, spark plugs only exists in a few different variants, so it's easy to match the demand even with a low inventory. Compare this to engines, where it needs to match the customers' cars very precisely and even if there are numerous different engines in inventory, it might not still be possible to find an engine that works for the customer.

5.5.3 Profitability analysis of A-class parts

The profitability analysis showed that it was possible to make a profit by only picking the A-class parts. A lot of assumptions was used in this analysis as well as some estimated values from the CEO and the production manager of CDB, therefore, the profit margin might not be as much as calculated. Despite of the lack of accuracy, it was still interesting to understand the revenues and costs associated with only A-class parts and how much they might contribute.

In total, the list contained 50 parts, which was, at later visits, found not to be too far from the number of parts that CDB pick from Label-2 cars (usually around 70 parts). For Label-1 cars they need to pick a lot more parts since they don't know which parts that will be of demand.

6 Discussion

In this chapter the result will be discussed more in detail and some of the points brought up in evaluation of results will be expanded further.

6.1 Adoptability of Lean philosophy

Based on the result of improving process through Lean philosophy, it was found that there is a high potential to reduce wastes and improve processes by applying different Lean tools like-5S, Kaizen. The result showed that in dismantling stations there was roughly 10% time of pure waste which is mainly occurred due to the movement by the workers to get the required tools and to put the extracted parts. Later, to reduce these wastes a better design of the workplace have been proposed which estimates the possibility of reduction of the walking distance of operators by 45%. These reductions of wastes would result 10% of increment of output from the dismantling stations. Also, it was found that using multiple operators in one dismantling station would increase the flexibility and some space might be saved from dismantling area.

In order to implement Lean tools to improve the processes, best strategy would be to follow ‘Kaizen Event’ (Liker, 2014), where employees from different functional groups actively participates to learn about Lean techniques and use those techniques to identify different sort of wastes involved with different processes and find a way to eliminate those wastes. According to (Liker, 2014) the Kaizen Event proved very effective for several reasons, like, employees from shop floor to management involve with it, people learn so quickly, they get every resource easily to implement changes, potential barriers of implementing Lean can be found easily and the progress rate is faster. Therefore, car dismantling companies can follow this strategy to improve the processes.

6.2 Barrier to apply Lean

Though Lean tools can make a positive impact to improve the processes, however, there are some limitations to apply Lean in full scale on achieving smooth flow (like-one piece flow), implementing pull or Kanban system, leveling production. The main barriers can be discussed as follows.

6.2.1 Instability of the dismantling processes

In order to maintain a flow, it is required to stable the processes first (Liker, 2004). Here in dismantling process is highly unstable because, different types of car have different way to disassembly, output rate varies based on car’s complexity level to disassembly. For example, extracting parts from VW Polo is easier whereas from Audi 2010 is difficult. Moreover, operator’s skill level is another important factor. Operators learn gradually by working with different cars and it takes years of practice master on disassembly of different types of cars. Also, it is not possible to follow exact sequence in every car as the damage of the cars varies randomly and the damaged parts are not extracted. Because of this constraint, instability of the process in dismantling station, makes it difficult to attain the smooth flow.

6.2.2 Uncertainty of Demand and Production

The impact of uncertainty of the demand and supply was highlighted by (Dora, Kumar & Gellynck 2015), where they studied the main barriers of Lean implementation in food processing SMEs and mentioned the volatility of the demand and supply of food item is crucial factor that often hinders the production planning. Similar behavior observed in car dismantling companies too where the customer demand of the parts is uncertain as well as the production. What makes the car dismantling companies special compared to other companies is uncertainty of production of a part, for example, it is unknown when a car will be crashed and will be supplied to them, if a certain part can be extracted from the ELV or not depends on the condition of the parts. In general, for new car model, parts remain in the stock for two to three years whereas for old cars it would be around six months. It is very uncertain when a part would be sold as it depends on failure of a parts by internal or external factors. As the demand is uncertain and customers require low delivery time, therefore, in general, the best point to supply parts to customer would be from the warehouse and to fill the warehouse, systems like CONWIP or Kanban can be used which reacts upon the order from customers (Jonsson, 2009). However, for the car dismantlers, fill up a specific part in the warehouse is also uncertain as it depends on having the same car in the inventory with specific parts undamaged. Because of this constraint, implementing pull, Kanban or conwip system will not have fruitful impact on the business.

6.2.3 Manufacturing Strategy

Overproduction is the most crucial waste as it impacts on generating extra inventory and causes extra works (Liker, 2004). In the dismantling companies, overproduction incurs because of lack of information of exact demand, like, when a part will be sold and which part will be sold. There is no certain answer of these two questions. On the other hand, some parts like-engine or gearbox usually have high profit margin and are preferable to sell more. Though having uncertainty, keeping these parts in stock is necessary to increase the chance of being sold. Another factor is that, the demand of the parts from new cars usually generates after two to three years and by this time the parts needs to be remained in the inventory. However, the cost of overproduction and inventory is not significant over the profit margin. Therefore, the ideal way of Lean production system becomes less preferable here.

6.3 Inventory Analysis

Though the inventory is required for this kind of business, however, as a part of continuous improvement, different tools should be applied to find out if there is any possibility to improve the system. Based on the ABC analysis, it has been found that, only few parts (A-class parts) contribute to most of their profit and working with those parts only will generate high profit margin. However, the main drawback of only picking A-class is that the car recyclers would get a limited range of parts that they could supply. This means that all of the customer requests would not be met and some customers would contact other car recyclers to get all the parts that they need. Another drawback of only extracting A-class parts is that the value of many high-quality B- and C-class parts in value cars (label 1 & 2) would be lost.

Another benefit of only picking A-class parts should be that they would have a faster throughput time of value cars, which would be beneficial if there was a surplus of them. Though in reality there is a limited amount of these cars, which might also result in more time being spent on non-value cars that isn't as profitable. It is likely for this scenario that the warehouse would be reduced in size, but the levels of the A-class would be increased. Having higher levels would result in longer storage time if they keep the same marketing model and customer basis.

The outliers that was removed from the dataset of the ABC analysis, made it easier to overview the data. If the ERP-developer or any of the car dismantling companies would like to make a new ABC analysis, it is advised to set some lower limits, similar to our analysis. It is not that they should stop extracting these parts, as they still might show up on the picklists or on make to order basis (customer requests). Though it would make a better basis for decisions if they were excluded from the dataset. If it is possible from the software to automatically generate such analysis it could be very beneficial for the companies.

The present data shows that, the service level for most of the parts are low for both companies. However, it was found that, there is an error in the present data provided by the companies which we assumed as the demand of the parts. If the companies could measure the amount of customer requests and compare it to inventory levels, they could justify having a high number of items stored for certain parts. Hence, it can be a good way to monitor the service level and formulate the business strategy accordingly.

As there is a high gap between the item sold and revenue comes from the insurance company and private person, therefore, it would be better to have separate ABC classification for different business segment and monitor the service level for crucial parts. To do so, the ERP system needs to be updated so that, they can be able to easily visualize and compare different parameters.

There are some limitations in this analysis. The standard deviation is a critical factor. The value of the part depends on its quality, reliability and performance. Therefore, for B- or C-class parts, it would not be wise to eliminate those, rather set the quality level as a decision parameter to extract that part.

6.4 Limitation of the Result

The case study was conducted within short time frame and the possibility of adoption of Lean was analyzed taking data from CDB. As the dismantling time of a car is very long (around 6 hours on average), only one sample was taken to perform task analysis to find out wastes involved with the operations in dismantling station. Also, to check the possibility of engaging multiple operators in one car dismantling station, only two experiments were conducted. Having a large sample could provide a better accurate result which would be statistically significant. Moreover, as the proposed possibilities of reducing wastes were not implemented which means that there is no further analysis of the actual improvement scenario. However, the study showed the possibility of utilizing the Lean manufacturing philosophy to improve the operational processes of dismantling companies which might be a doorway for other dismantling companies to gradually adopt the Lean philosophy to some extent.

Though the case studies are usually criticized in terms of generalization, however, according to (Eric, 2004) it identifies the disconfirming situations and provide valuable information about the boundary line of the theory. The study revealed some of the barriers of implementing Lean tools in car dismantling companies which might be in turn set a boundary limit of Lean theory too.

6.5 Future Research

The case-study was carried out incorporating with two car dismantling companies. A similar study can be conducted in larger scale to statistically prove the feasibility of adoption of Lean in car dismantling companies and the barriers associated with it.

Another interesting area would be to form a mathematical model to predict and forecast the arrival rate and demand of the parts. Because of uncertainty of demand and customer order it is very difficult to apply fundamental principles of Lean and improve the system accordingly. Therefore, further research can be done to analyze the arrival of an ELV and the demand pattern along with forecasting. It can be done by analyzing the previous data and behavior of a particular car model using statistical and probabilistic model. By analyzing the behavior, a total demand can be set for a specific part (for example, 30% of the car parts are reused) and when the combined inventory level of all dismantlers reach this number, then that part will not be extracted unless it is of better quality than the parts currently kept in stock.

7 Conclusions

The case study revealed that, Lean tools can be fruitful for car dismantling companies to improve the operational processes. Analyzing the current state using value stream mapping (VSM) revealed that the inventory level of the finished goods is very high and the processes are unstable, specially the dismantling process, because of the operational time varies a lot, because of the high product variety. High inventory and overproduction are the most crucial wastes on which they have little control due to the high uncertainty in both supply of the incoming cars and the demand of the extracted parts. The task analysis showed that, the dismantling operation involved with the wastes so called-Motion, which is possible to reduce by designing the workplace which will eventually increase the output level. It is also possible to increase the flexibility and save space by engaging multiple operators in one workstation to disassemble a single car. However, because of the business nature and high uncertainty, which act as the barrier, some of Lean strategies like pull system, Kanban or Just in Time (JIT) might not be suitable for this sort of business.

As this type of business usually deals with a high level of inventory, therefore, ABC analysis could be useful tool to classify the products based on revenue, sold volume and customers. As the service level is the key factor to get success in this business segment, therefore, ABC analysis can be utilized to prioritize different parts and set their service level accordingly in order to control the inventory and formulate business strategy accordingly.

8 References

Almström, P., & Kinnander, A. (2011). The productivity potential assessment method: Assessing and benchmarking the improvement potential in manufacturing systems at shop-floor level. *International Journal of Productivity and Performance Management, 60*(7), 758-770. doi:10.1108/17410401111167825

Car Recycling Systems B.V. (n.d.). CAR DISMANTLING SYSTEM FOR SALE. Retrieved September 04, 2017, from http://www.fransvandenmosselaar.nl/carrecyclingsystems/en/car-dismantling-line-for-sale.html

Cossu, R., & Lai, T. (2015). Automotive shredder residue (ASR) management: An overview. Waste Management, 45, 143-151. doi: 10.1016/j.wasman.2015.07.042

Dora, Manoj, Maneesh Kumar, and Xavier Gellynck. (2016) 'Determinants and Barriers to Lean Implementation in Food-Processing SMEs - a Multiple Case Analysis', *Production Planning & Control*, vol. 27/no. 1, pp. 1-23.

Go, T. F., Wahab, D. A., Rahman, M. A., Ramli, R., & Hussain, A. (2012). Genetically optimised disassembly sequence for automotive component reuse. *Expert Systems with Applications*, *39*(5), 5409-5417.

Jonsson, P., & Mattsson, S. (2009). Manufacturing planning and control. London: McGraw-Hill Education.

Kazmierczak, K., Winkel, J., & Westgaard, R. H. (2004). Car disassembly and ergonomics in Sweden: current situation and future perspectives in light of new environmental legislation. *International Journal of Production Research*, *42*(7), 1305-1324.

Kosacka, M., & Golińska, P. (2014). Assesment Of Sustainability In Dismantling Station–Case Study. *Research in Logistics & Production*, *4*(2), 135-145.

Mishra, Avinash; Lsoni, M. (Dec 2012) ABC Analysis Technique of Material towards inventory management; International Journal of Management Research and Reviews; Meerut2.12: 2092-2097.

Mourtzis, D., & Doukas, M. (2014). The Evolution of Manufacturing Systems: From Craftsmanship to the. *Handbook of Research on Design and Management of Lean Production Systems*, 1.

Ravinder, Handanhal V., and Ram B. Misra. (2016), 'ABC Analysis for Inventory Management: Bridging the Gap between Research and Classroom', *American Journal of Business Education (Online)*, vol. 9/no. 1, pp. 1.

Riksdagen. (2014, December 12). Regulation (2007:185) om producentansvar för bilar. Retrieved August 30, 2017, from http://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/forordning-2007185-om-producentansvar-for_sfs-2007-185

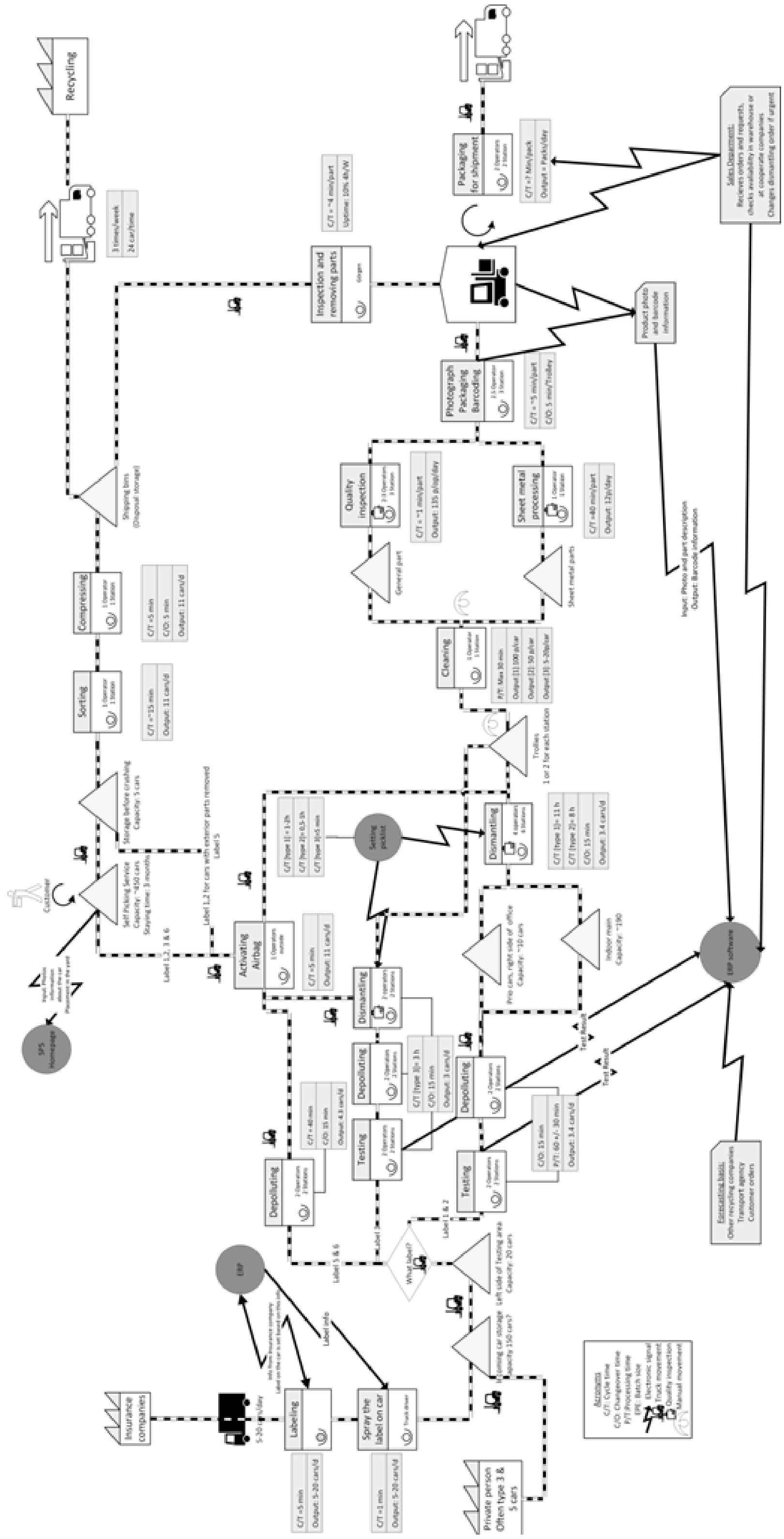
Rother, Mike; Shook, John (1999). *Learning to See: value-stream mapping to create value and eliminate muda*. Brookline, MA: Lean Enterprise Institute. ISBN 0-9667843-0-8.

Spearman, M. L., Woodruff, D. L., & Hopp, W. J. (1990). CONWIP: A pull alternative to kanban. *International Journal of Production Research, 28*(5), 879-894. doi:10.1080/00207549008942761

Wild, T. (2002;2007;). Best practice in inventory management (2nd;2; ed.). GB: Taylor & Francis Ltd. doi:10.4324/9780080494050

Yin, Robert. K. (2014). *Case study research: design and methods*. London: Sage Publication.

9 Appendix-A



Recycling
Sorting
Compressing
Inspection and removing parts
Packaging for shipment
Photograph Packaging Barcoding
Quality inspection
Sheet metal processing
Cleaning
Dismantling
Activating Airbag
Depolluting
Testing
Insurance companies
Labeling
Spray the label on car
Private person Often type 3 & 5 cars
ERP
ERP software
SPS Homepage