Tampere University of Applied Sciences

Designing Circular Economy (CE) Model for After Sales Services in AWPs Industry

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ABSTRACT

Tampere University of Applied Sciences
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In this thesis, a literature review has been done to discuss the CE as new and general concept and the need to move the economy form linear old traditional economic to this new concept CE. Moreover, a general overview and some market share facts have been discussed related to the AWPs industry and linked the CE concept with future of this business specially in the after sales service.

In this thesis, a model design of four closed loops were implemented, maintenance and repair loop, re use loop, refurbishment loop and recycling loop. In each loop a feasibility study was taken place in term of technical difficulties and profitability to the business model. Published data, interviews, and internal data form Bronto Skylift were used to make the recommendation and the analysis.

At the end of the thesis, it has been found that AWPs are still new to the CE strategies not same as other industries or even same as small automobiles. However, it has been found that most of loops can be implemented and thus a huge and dramatical changes can be expected in the short and long run when it comes to the sustainability, environmental impact, CO2 emissions, draining natural resources and following the new regulations which will improve the quality of go green based concept and thus increase the customer satisfaction and loyalty.

CE is not only about the environment, at one day it will be about the dignity and feasibility of AWPs business to keep it sustainable, endurable, and profitable.

Key words: circular economy, AWP, after sales, maintenance, development

CONTENTS

GLOSSARY or ABBREVIATIONS AND TERMS (choose one or other)

CE	Circular Economy
AWPs	Aerial Working Platforms
HDOR	Heavy Duty and off Road
EOL	End of Life
SW	Software
EU	European Union
OEM	Original Equipment Manufacture
CIP	Continuous Improvement Process
PM	Preventative Maintenance
CM	Corrective Maintenance
MTBF	Mean Time Between Failure
S	Industrial aerial working platform
F	Fire & Rescue aerial working platform
TDI	Time Definite International
PW’s	Weight per Shipment
DHL	Daley Hillblom Lynn
WtW	Well-to-Wheel

1 INTRODUCTION

1.1 Background

Truck-mounted aerial work platforms (AWPs) are specialized equipment that used for working at heights. Truck-mounted AWPs offer a versatile, cost-efficient solution to access and complete projects that require workers to be lifted off the ground as well as fast and manoeuvre solution for firefighters in the emergency respond departments worldwide.

These vehicles are equipped with specialized booms and ladders to allow safe and efficient work at height. AWPs can be used for a variety of tasks, not limited to window washing, bridge inspections, wind turbines inspection & maintenance and building facade repairs. While if the AWP is a fire truck, then it is being used mainly for rescuing and firefighting missions. There are different heights of these platforms range from 22 m all the way to 112m with different kind of technical specification for chassis side or superstructure to fit the purpose that made for. (Bronto Skylift website).

Even though we have nowadays a tremendous jump of using smart technology in the truck-mounted aerial work platforms, which can improve productivity by completing jobs quickly and safely while reducing downtime and resources. As per figure 1, the global Aerial Work Platform (AWP) market size is estimated to be worth USD 9262.2 million in 2023 and is forecast to a readjusted size of USD 11860 million by 2031 with a CAGR of 4.2 Percent during the forecast period 2023-2031(Global Aerial Work Platform (AWP) Market Research Report 2024). This growth opens the door to discuss the negative impact of applying the linear economy in operating these units.

In figure 2, shows another research analysis report, where there are different numbers for the market share with expectation to touch 7.83 billion dollar with the key companies, the most important in this report showing the market distribution per region where North America has the biggest market share and Europe is the second (Aerial Work Platform Market (Global Distribution Global Industry Analysis and Forecast (2023-2029)).

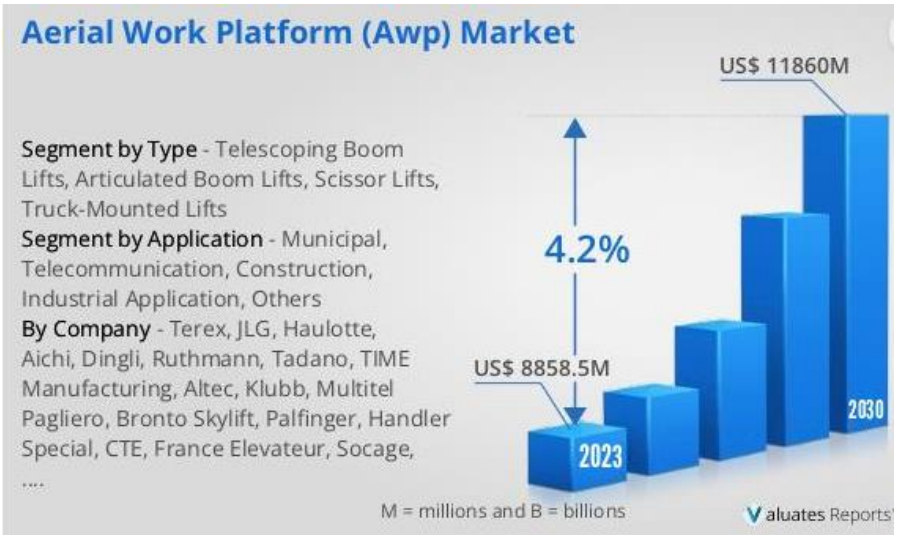

FIGURE 1. Aerial Work Platform Market (Global Aerial Work Platform (AWP) Market Research Report 2024).

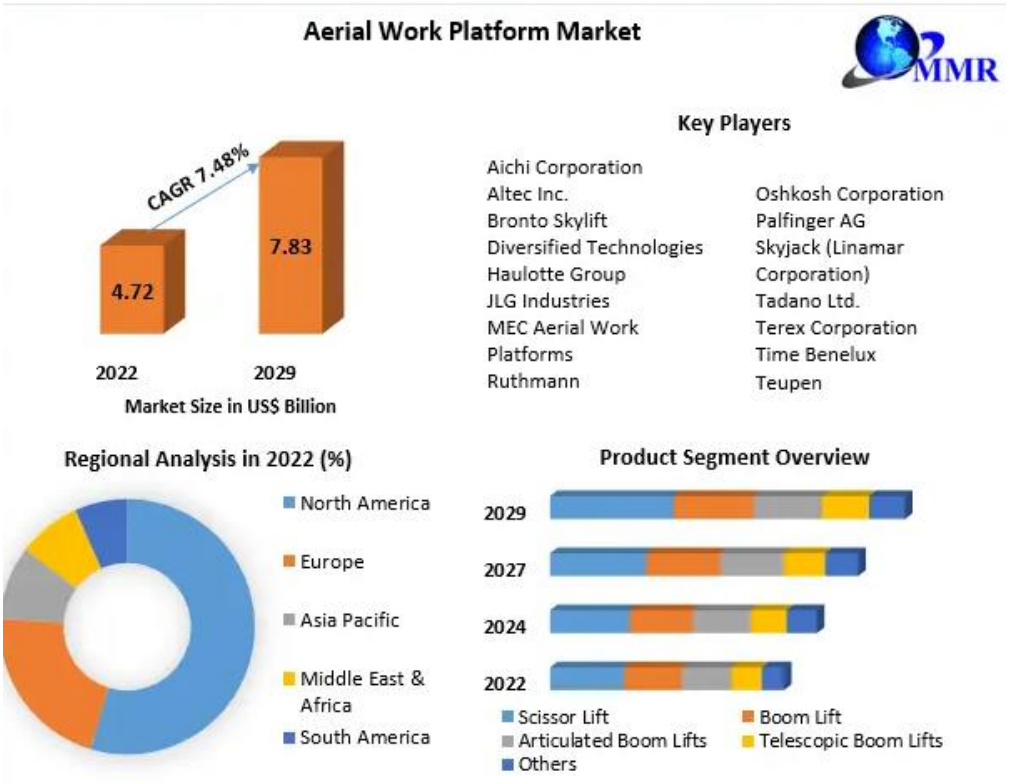

FIGURE 2. Aerial Work Platform Market (Global Distribution Global Industry Analysis and Forecast (2023-2029)).

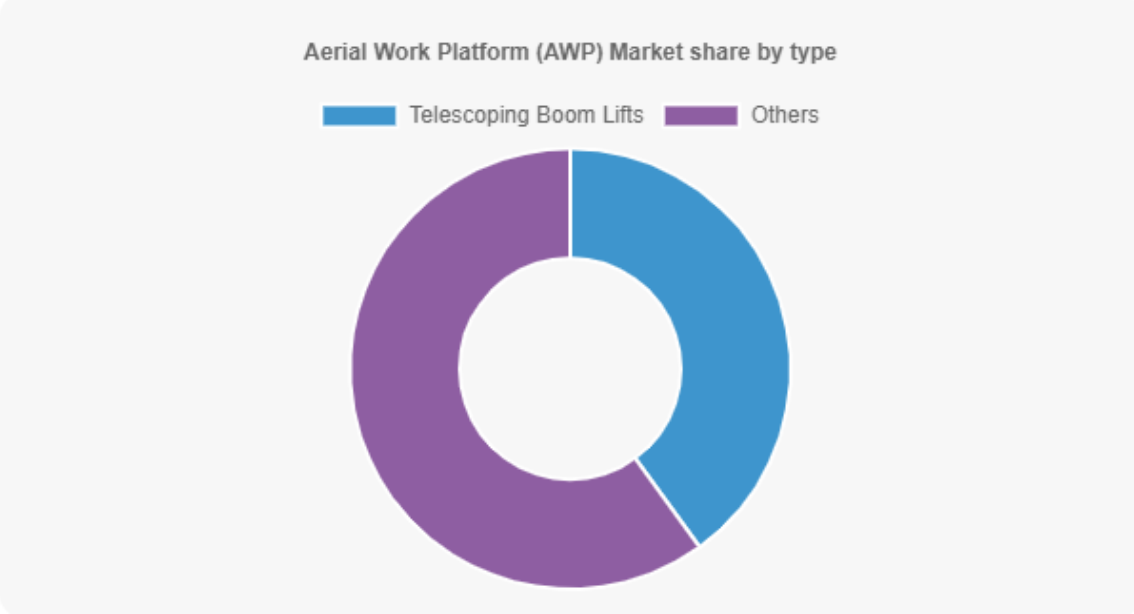

FIGURE 3. Aerial Work Platform Market (Global Aerial Work Platform (AWP) Market Research Report 2024).

In Figure 3, gives more static information about the share market for each type of the AWPs, we can notice that the Truck Mounted platform is not the first type, nor even the second, however the truck mounted aerial platform has the most important impact as it used directly in rescuing the people and the firefighting application either in municipality or used in the Industrial fire service applications such as oil and gas premises, chemical factories and power plants. The main four types are Telescoping Boom lifts, Articulated Boom Lifts, Scissor Lifts and the truck mounted aerial platforms.

In figure 4, we can see an example of the Truck mounted aerial platform, these are heavier truck mounted units that can reach over 100m range. Workplaces varies from building assembly to Wind turbine and blade inspections and repairs. Operation is from ground level or from work cage. These platforms are intended for temporary working in changing working circumstances. They have been specifically designed in order to lift persons, working equipment and devices to the working place with regard to safety aspects. Working cages are often equipped to maintain telecommunication antennas, media broadcasting, window cleaning etc,

FIGURE 4. Truck Mounted Aerial Platform, Bronto Skylift, S 90 HLA. (Bronto Skylift Website)

There are several current challenges and drawbacks of following traditional methods in after-sales services and spare parts management. These outdated approaches, we might be missing out on valuable opportunities for improvement. That's why it's why transitioning to a Circular Economy (CE) model is a must at certain point in near future.

The resource consumption is one of the critical negative impact of keep using linear economy, and exhausting the natural resources because of the excessive waste during production stage or after sales stage, which we will cause also dramatic increase in the items prices and pressing on the waste management, this shortage in innovation and not paying attention in CE models, will have in near future bad hit on environment sustainability and thus on the firms stability. (Khan et al., 2022)

As per figure 5, There are four loops related to CE in after sales services in AWP business can be extracted. Maintenance & repair loop, Reuse loop, Refurbishment loop and recycling loop. These loops can be linked to each other, however in maintenance & repair loop, doing the periodic service will keep the unit in operational position and will reduce the down time and will eliminate the breakdown due to lack of service and maintenance, in addition also to the new smart services such as predictive maintenance that rely on IoT. While Reuse loop is taking care

of putting the good quality parts back into operation, to avoid the unwanted waste, a lot of components may contain different parts and not necessary all of them getting damaged or reaching end of life span. (Khan et al., 2022)

Refurbishment loop tend to be for big scale, and AWP is part of this scale, where big parts or even the aerial platform itself can be under refurbishment project which will bring the unit back into service and increase its expected life span, with minimum spare parts and with cost effective solution. Recycling loop is the oldest loops were innovated, and it is getting benefits of the materials as possible to put it back to its original as raw materials, however a bonus system will be implemented to encourage all end users to recycle their waste in order to control this loop as it does rely on users more than the factory itself. (Rönkkö et al., 2021).

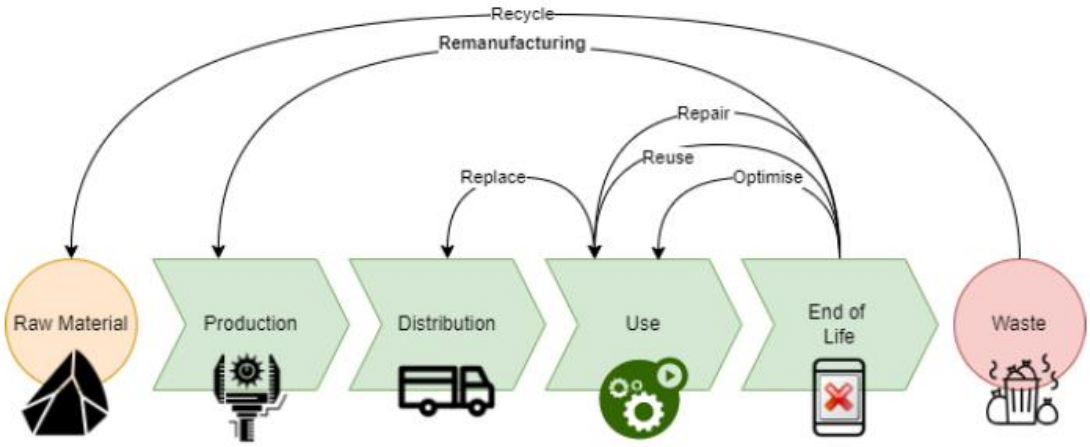

FIGURE 5. General Lay out of CE loops in manufacturing and after sales service (Khan et al., 2022)

End of life for the AWP is pressing on the economy, and circularity will not only solve the problems coming from dramatic increasing number of retired AWPs but also to find ways to improve the business and the customer experience, a qualitative method were used by having different interviews with managers in this field, discussing with them their opinion, vision and challenges to move forward with industry toward the CE. Moreover, a quantitative method was used to discuss the positive and negative impact of moving from linear to circular economy in after sales in AWP industry. (Denise et al., 2018)

The focus of the research is to recommend and create practical steps into a Circular Economy model for the after sales in the truck-mounted aerial platform industry. Ensuring that this model improve the operational quality, reduces downtime, and promotes sustainability. Additionally, will provide practical advice on how to implement this CE model effectively, making sure it's visible and reliable. Furthermore, the thesis will discuss how the CE model and suggested plan which can improve sustainability, cut costs, boost operational efficiency, enhance reputation, increase customer satisfaction, and even positively impact sales. To do so few recommendations to manufacturers on how they can transition to a CE model, including steps for changing mindsets, and aligning organizational vision with CE principles. Through this thesis we wish to contribute to a more sustainable and successful future for the truck-mounted aerial platform industry.

1.2 Research Questions

Narrowing the questions for such research study was one of the challenging points to move forward in this research, as studying and designing a model for after sales department in truck mounted aerial platform industry has a lot of connections to different aspects, such as the heavy truck itself, the superstructure, the electronic components, hydraulic components, and other components. In this study, the research questions will be integrated to each other to establish a rigid point of view to get a valuable understanding.

Circular economy had a very wide concepts and had multi and variant loops that can describe any model, in order to shift away from the linear economy. We will discuss in this study the main loops that can have core relationship with after sales service in AWP business, in each loop; the study will discuss two examples, one for positive example for transition process and has a feasible solution in the loop, and another example which presents the constraints and barriers to complete that loop. Based on a case study.

Another research question will discuss how to implement the positive solutions and how to overcome the constraints' examples in order to reduce the gap between the theory and practical when it comes to design a model can fit this industry.

And last research questions will be about the impact of applying the CE models to AWP's business specially in after sales department. By analysing few indicators such as the environment impact, sustainability, profitability, and customer satisfaction.

Research questions can be briefed as following:

1- What are the main Circular Economy loops can describe the AWP after sales department.
2- How can these loops be a positive transition into CE or how it can be a barrier, at the same time how to improve the positive ones and how to overcomes the negative side. Case Study.
3- What are the indicators can be used to analyse the impact of using the CE into the AWP after sales department and analysing them.

In addition to the research question, many related questions were asked to the interviewee to collect important information about their opinions and to have more data from their professional daily life related to this matter.

1.3 Thesis Structure

This thesis includes 6 chapters, an introduction which covers background discussing the history of AWPs and the market share of this business, as well as how the CE can be produced in this field specially in the after sales services, it also discuss the research questions, then the thesis structure.

Second chapter is the literature review, where three main points will be introduced, first one is an insight on the Circular Economy concept, second point is the positive impacts of moving towards Circular Economy and last point is about Circular economy in heavy machines and AWPs.

Chapter 3 discuss methodology and research design, which covers the framework introduction, research design and the interviews.

In chapter 4, the core of this thesis, where a case study will be introduced, the case study will discuss the main four points related to CE in the after sales services in the AWP's industry. First loop is the maintenance and repair loop, while second one is the re use loop, then the refurbishment loop, and finally the recycling loop.

Discussion and results are in chapter 5, where the data and information have been discussed in chapter 4 and 5 will be reviewed and discuses, while in chapter 6 a conclusion statement will be made, including an introduction of future implementation.

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2 LITERATURE REVIEW

2.1 Insight on the Circular Economy Concept

Recently, there is a serious change in the heavy vehicle industry, where manufactures trying to move from linear economy model to circular economy, sustainability became a demanding point to keep the growth possible, as this is adding to the environmental sustainable impact plus adding benefits to the economy throughout the lifecycle of the heavy vehicles; where reducing the raw material at the production stage, having ability to reuse the material if still applicable or at least recycling it to be reused as raw material. This circular model is substituting the linear model, which is using the material, making the product, and then dispose it at the end life cycle. (Fusco et al., 2019)

Recycling is one of the most popular and old elements in the circular economy, the majority of the manufactures recycling the material such as plastic components to put into the production phase once again, for instance; DAF trucks using recycled plastic in the interior and design parts, while in MAN truck focusing more on the reusing and remanufacturing used parts which can be part of the new engines, this will reduce the costs and the energy consumption. (Nasr et al., 2006).

CE is aligned with production stage as well as the after sales services, where each part should be designed in such a way to serve the after sales period, even the consumable parts, for instant, tires have been developed and made throughout retreading process, and still having new tires with similar performance, however this kind of post thinking of the after service of the tires, managed to reduce the economic impact such as carbon impact by extending the lifespan of this part and avoid draining the raw material and natural resources.

As per research study of (Michael Saidani), in 2017 we had almost 270 million of light vehicles operated around the world, and almost 20 million of heavy duty and off road (HDOR) only in the EU, and as per (Acea facts), there were more than 6,4 million heavy duty truck operating in the EU in 2022, and as per (Genevieve

et al., 2021) we have expectation that only the heavy duty truck will be increasing dramatically up to 64 million by 2050.

As per the facts, there are 1.2 million light vehicle going out of service every year, in addition to 1 million HDOR vehicles, as they reach the end of their lifespan, figures assume that the average age of the trucks around 14.2 years in EU, so with small calculations, we are expecting huge retirement of the operated trucks in near future, this is raising an urgent question about what will happen to these trucks and to what extend the classis economy will press on our natural resources if we know that only in EU in 2022, more than 503,155 trucks were manufactured. Here exactly the importance of the circular economy to reduce the negative effect of this huge disposal rate. Since we are discussing the truck mounted aerial platform as prototype among these trucks. It is also worth to mention that this thesis will not discuss the positive side of using electric vehicle, as this study is not meant for fuel emissions but for the after sales service till the end life span of the truck. (Michael et al., 2019)

2.2 Positive impacts of moving towards Circular Economy

The circular Economy (CE) is one of the most important opportunities recently to have more sustainable economy and having green impact on the environment side by side, while huge expanding is expected in the future. The main idea of CE is to change the old school of linear style of making, using, and dispose it. To circular style where we have close loop and the product stay in the loop as much as we can and different shapes; require huge change and evolution in every organisation and even beyond that, as to make the circular economy happen, we need to involve producers, customers, stakeholders, and the global governments as well who will impact the policy and make things happen. All these players should be having at least one vision and original point of view that the resource of this planet is limited, and the linear economy will not last for ever which means we (all), will face hard time at some point soon and things cannot be feasible any more with linear economy. (Supanut et al., 2024).

In the last ten years, CE gained a lot of attention from researches and from the academia sector in general, which allow us to have more inputs and data and real analysis about the CE which have been obviously affected the policy makers and the business men around the world, CE gained also a lot of attention in the official level where a lot of rules will be coming soon and will get into effect in Europe by 2025 and gradually will expand beyond that.

Some of the researches were focusing on the environmental impact, while others consider its implications for sustainability, including social and economic aspects. Moreover, it highlighted the potential for job creation and improvements in social life or on other side loosing old style jobs and what we should do to move with the wave and not against it., while others insight more into aspects like consumer behaviour change. Raising consumer awareness and interesting in the development of circular business models and supporting governmental policies. Figure 6 illustrates the positive impact of the CE. (Ghisellini et al., 2016)

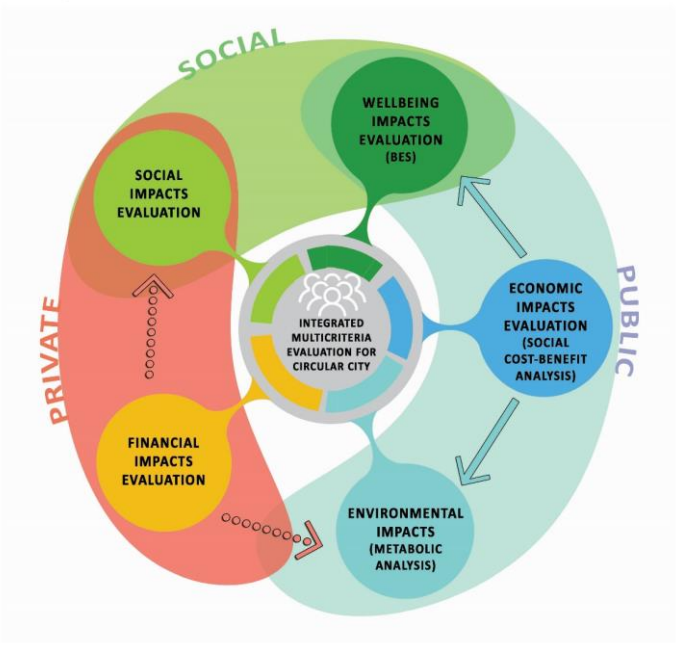


Figure 6. The integrated evaluation framework for the circular city. (Fusco et al., 2019)

Transitioning process to the circular economy brings positive impacts that improve environmental, social, and economic. The most important point is the resource efficiency, where Circular economy models prioritize minimizing waste

and maximizing resource use through strategies like recycling, remanufacturing, and refurbishment.

Second point is reduced environmental footprint; By pushing forward the lifespan of products and materials and recycling them at the end of their lifecycle, the circular economy is supporting to reduce the pollution, either by reduce the need to re manufacture the same material which can be reused, or even to avoid sending the shipments globally from producers to end users while the product can stay on the same place if we manage to reuse it, moreover by not add more waste into the environment which lead to pollution for sure.

Third point is about changing the job orientation and the demand of old job style, researcher illustrate that CE will improve a lot of sectors related to green energy like renewable or any industry involved in the recycling process, while any firm or model is relying on linear short model will struggle with maintain the jobs among it.

Supply chain and reducing cost are one of the key impacts by applying CE, as CE will provide a sustainable supply chain depend on the closed loop and will make the users have better solutions and more choices which will improve the chain and thus will reduce the cost in the long run.

CE will have a direct positive impact on the society as it will motivate them to be part of this process in the wide picture, starting from recycling their own material at home, at their garden, and at the work, this will increase the knowledge of the importance of having things with our hands and how to improve their attitude of consuming and change their mind set to keep what we need not we like, and even keep it as mush as we can and as long as it do the work, moreover the society will have the principle of donation and keep thing running between the people and stop just through them to the trash, by doing this and in the long run and for future generation, this mentality will be able to give us the chance to grow our economy multi X in linear with population growth and which will make at the end of the day our life easier and possible. Overall, transitioning to a circular economy can be one lifetime chance to survive in the future where our natural is limited and our population stressing very fast. (European Commission Plan)

2.3 Circular economy in heavy machines and AWPs

Analysing quality and compliance risks is essential to make the CE transition smooth and effective. Following the desired international standards, sharp standards of procedures should take place when repairing and reusing the return parts to maintain the safety of operation, quality of the product and follow the desired international standards. This will lead to customer satisfaction.

At present, it appears that the linear economy is no longer the smarter approach to developing the fundamental concepts of the entire manufacturing process, from the design stage in the factory to the provision of technical service and product support to end users. Hydraulic aerial working platforms industry is an example of this imperative natural forced transition to the circular economy to stay stronger in the market in the long term and to be part of having better environment and even social wellbeing. (Patrizia et al., 2016).

Variant engineering designs are a top priority to be changed. This does not mean terminating the wide range of products, not at all, but unifying the concept of design structure for each part of AWPs in each type of category as much as possible. This will lead to reduce the complexity of the design, supply chain, and service. The structural design harmonization of these units will lead to higher quality manufacturing processes and better functionality in the long term, in addition to smoother service and product support.

When it comes to after sales services, there are a lot of electronic equipment being sent as spare parts to all over the world. By applying the CE concept, we should get all of these parts back to us and re-use the components that are repairable. This will reduce the cost of sending new parts and reduce the pressure on the supply chain. Also, getting the failed parts will give very strong feedback on the reasons for failure. This will allow R & D to develop new components more reliably and have a longer lifetime.

Electronic components life span is often shorter than mechanical and hydraulic components thus obsolete management is crucial part of keeping the equipment in service when original control system computers and processors are no longer available in the market. Developing new software generations for all of the computers and electronic components will let these items be compatible with each other in terms of service. All of the additional service tools can be used now by all of the units regardless of the year of production. As an example, we don't have to send hundreds of electronic components, and other tools every year to the same customers, as we can recycle them. (Rönkkö, et al. 2021).

Using new technology to apply service conditional monitoring will improve failure detection and reduce wasted parts due to incorrect diagnosis. And will develop some sort of preventative maintenance by default even before the failure. At the end, there is less downtime and more customer satisfaction. (Aljohani et al ., 2023)

Having a CE structural will re shape the supply chain which will make the industry and the economy less sensitive to any financial risk, outstanding geopolitics, health crisis like corona pandemic and poor cash flow, ultimately affecting the profit and loss indications. Second, as a result of the previous point, this will lead to avoid as much as possible the forced layoffs for labour, or temporary closing of this organization, which will not affect only the employees of this organization, but at some point, other organizations that are related in the same supply chain with this organization. the Dynamo effects!!

One of the main and first skills to be gained before launch the CE concept is "shaping" mentality. Each organization's top management team should recognize and understand that CE, or at least a hybrid CE with traditional economy strategy, is required for the organization's long-term development. It should be recognized that a linear economy in the coming decades will be no more feasible with a high increase in customer demand and a high load of production than the negative effects on nature and the way of consuming resources and wasting products in the future.

In Bronto Skylift there are restrict policies to follow the environmental trends and requirements to reduce the environmental impact related to the productions and after sales services. In product design and in the manufacturing processes at early stages, there is an aim to increase the product life cycle by utilising energy-efficient and sustainable technologies and solutions.

Bronto Skylift is aiming to reduce the carbon footprint by investing in energy-efficient technologies, optimising transportation, and adopting renewable energy sources. Including improving the waste reduction strategies, recycling programs and sustainable packaging solutions, to minimise the impact on landfills and as result stated in Figure 10, the recycling ate has been increased by 60%, while the VOC waste was kept below 50 kg per unit.

3 METHODOLGY AND RESEARCH DESIGN

3.1 Framework Introduction

Although this thesis depends more on the qualitative research methodology, however, still can consider that mixed method is more reliable to express the methodology, as there are quantitative research data were collected either during the interviews or from the existing data available from company or even from the literature review.

The qualitative part of this research was derived from observations from the literature review, case studies and interviews with key mangers. This information was able to give better understanding to explain how CE can be expressed in different loops and how these loops can be closed and then making the After sales services part of the CE in this industry.

Two interviews were conducted, 6 questions were asked for each interview, valuable information were collected including facts, thoughts and quantitively data that can be used for data analysing, data was analysed by basic method using excel tables and charters to give insight on how the CE is going, is it a positive trend or numbers are negative!

There are some limitations, as there is not enough quantitative data to analyse which means less insight to study the case more precisely, however all information shown in the thesis is part of daily work where the reliability is high, and ethics were achieved in collecting all this information. By filtering the confidential information that can not be presented to public and by getting consent to publish the information available here.

3.2 Research Design

Research design is a clear approach on how possible to get the data and from which source and how data will use it.

This thesis depends mainly on the study case, and on the real data which can be extracted from the study case, qualitative data has core importance to give a ide understanding on the CE in after sales sector in the Aerial Hydraulic platform industry and heavy vehicles in general as well.

CE in Aerial Hydraulic Platform specifically still relatively new topic and when it comes to the after sales service then it become more and more new topic which still has not been studied intensively, so Qualitative approaches are more reliable and logical to be the heart of this thesis, as mainly most of the information and data are practical ones and derived from the daily work life.

Part of this research design. To make sure from applying the mix method, as having quantitative research aspects will make this thesis richer and more reliable when key persons read it and will hopefully change their mindset and try to go with the trend and change their business model to a CE one,

3.3 Interviews

These two interviews have been done in Bronto Skylift premises and it was hold with the spare parts manager and the service manager. The questions covered the actual situation right now in Bronto Skylift in term of how much the spare parts department and service department are complied with CE, what the prons and cons to do so, and what are the challenges that prevent these two departments to move totally to CE, and what are the actual CE practices that being implemented in the company right now.

3.3.1 Interview #1

The interview took place in Bronto Skylift in Tampere, Finland on February 28th with the spare parts manager Mr. Henri Kalteinen. The answers will be put as it is from the interviewee.

Q1. How many shipments you send every year? Do you have an idea from the couriers about the CO2 impact?
A1. We have new system, that will start in near future, called (DHL go green), reduction target based on bronze, platinum so on, we have picture for each, as per EU Taxonomy, all companies should control their activities environment impact, DHL offered this new system, Bronto Skylift sent 60 tons of parts in 2023 to all over the world.

Q2. How many shipments you receive as return/wrong parts/wrong address?
A2. Not much, we had only 24 shipment which have been sent to wrong address and came back to us here in Finland.

Q3. How many shipments you send for parts that require a return for an action in a year or so here in Finland, such, calibration keys to conduct the sensors calibration, USB dongles which required to do the remote connection through internet and for modems which used to do the remote connections?
A3. We have sent last year 272 calibration keys, (same amount will come back to us), while dongle 26 (and same amount will come back), while regarding modems we have sent 63 modems, while 20 modems came back here for repair or for testing and analysing.

Q4. Have you ever got hydraulic components back just to recycle them here?
A4. No, we don't get back any hydraulic components or so from the customers worldwide, however; we have a local company in Tampere; that recycling all hydraulic oil and hydraulic filters inside Finland, including also high tensile steel that might be recyclable, they do pay few euros per ton, then they send these materials to another factory who will melt it and put it back as raw material, also rubber and wires can be the same thing, However not all material in Bronto units can get

us money from these companies, however; the main idea to dismiss these material in such way can be a sustainable and not harm to the environment.

Q5. In your opinion, will be a problem for the department to get back all failed components (Especially the electronic ones) and then put them in repair process or recycling process? will this reduce the pressure on your supply chain?
what about your inventory capacity? Can you use outsource company to do this kind of Recycling?

A5. If we have resources such as persons to take over the importing of old/failed components, would be a great idea, however our spare part team have enough load and they can't get more work, so if we start to collect all these return parts and store them and put them inside a repair process then we might need to have new staff which means additional operation cost, process could be lean, so there should be systematic system take care of this and our existing team can be just as controller without going inside the process by themselves, and one more point it require more efforts from you guys in the product support, to be able to have enough time to filter and repair and test these staff, and if these components are hydraulic, then it require more sharp and deep process, I am not talking about profits so far. I am just discussing the feasibility and how to make it happen.

However, we did recently this kind of repair programme, but only for specific electronic devices, our internal computers and displays that being used directly with our units worldwide, can be sent back to Bronto for repair, however this programme has been done in collaboration with suppliers, so the load on us in spare parts or product support team can be in the acceptable range.

Q6. Would be there any economic benefits? will this reduce the pressure on your supply chain?

A6. Let's just take an approximate example where we can present right percentages; so if we bought a new sensor from our supplier that will cost X euros, we found the repair cost for the same sensor will be so much expensive maybe like 90% from the new price, and then we should sell them cheaper to the end user

as they are considered repaired parts and customers is not expecting to buy repaired component for just 10% discount, so the profit is not that high so it is not good business for us.

Yes, we faced a situation that we have issues with supply chain, so we need sometimes just to sell the old repair parts just to keep their units running, but these are limited cases, keep our promises and we should be able to deliver parts for 15 years.

3.3.2 Interview #2

The interview took place in Bronto Skylift in Tampere, Finland on March 8th with the service manager Mr. Juha Pietila. The answers will be put as it is from the interviewee.

Q1. Have you heard about CE, if yes what is your opinion about it?
A1. Yes, we need to preserve our natural resources, so we need to develop method of circulating parts of our production which they do not need to be banned or whatever, so yes, it is important.

Also, we have planned all new units that reached 15 or 20 years, we can buy them as second hand and then decide to re-sell the chassis or re use it, and then take all Bronto parts to be re used or refurbishment, but first we need to make sure that this process is profitable to us.

Q2. Have you considered CE to be part of the company/department vision?
A2. The working gloves we are sending to be washed or our service works, the issue when it is easy to be re used. We are thinking of the.

Q3. What is the percentage of disposing your electronic components after failures occur, what is the repair percentage? What are the obstacles that prevent you from doing the repair?
A3. Not more than 20-25%, no joysticks no sensors, only computers and displays.

Q4. Why don't you repair electronic failures such as sensors?

A4. We don't have resources, and some suppliers don't want to do it, we have done for cage load sensor which it was so expensive with no economic benefits. It is just electronic garbage for time being, maybe later when we have new version of Bronto units. In case we need to repair old sensors in old units; then we might need just to repair them as we have no option.

Q5. Hundreds of hydraulic filters, hundreds of mechanical parts, being changed every year around the world, do you have any influence on these parts, do you have plan to recycle them if you get them back here?

A5. Some local companies here in Tampere are recycling these parts with money reward, such as copper.

For now, we don't have go green plan to influence the end users and dealers, however we will have new designs to help this strategy, for example changing filter can be by just washing them instead of troughing them. The main problem that our unit design started 50 years ago, and sustainability was not part of our considerations like all other companies at that time, and this should and will be changed.

Q6. You are sending hundreds of calibration, service and operation keys, these shipments to go everywhere cross the world which will have CO2 impact, do you have alternative solution?

A6. RFID key by phone, by just using the phone, to avoid using the calibration key, the same concept will extend to other parts, we have life cycle knowledge for some parts, for example like ropes for 11 years, but nor for all, so maybe in future, we can make program to discover this for all service components. If we disassembled one unit here in the workshop, we take each movement for each part and then comparing the weakness of each parts VS movement to have better idea of changing process. We are more looking for mechanical parts more than the electronic parts.

4 CASE STUDY: FOUR LOOP MODEL IN AFTER SALES SERVICES IN AWPs INDUSTRY

4.1 Maintenance & Repair Loop

In AWPs, keeping the unit working all the time, is a key goal for all end users, these units either working in emergency services or in industrial sector where the unit is working heavily and in shifts almost all day. So down time is a very critical factor in term of economic wise and logistic wise side by side.

Maintenance and repair are including the normal maintenance schedules, routines check-up and inspections, and preventative maintenance schedules based on the factory recommendation, all issues come suddenly may classified it as a repair issues, while all corrective actions based on the time, can classified it under the maintenance umbrella.

In Bronto Skylift, the units should be inspected every daily, weekly, every 250 hours or three months, every 1000 hours or one year and every 2000 hours or 5 years. The real service inspection start on every 250 hours or three months, where there is need to lubricate the unit according to the manual's instructions and checking all sensors calibration, while in every 1000 hours or one year, it is a must change all filters and make sure from load test and stability test and other tests, however it is so important at this stage to make sure also from all electronic components such as computers and displays and potentiometers sensors. Appendix 2 illustrate more information about the Inspection list of points to be conducted as per the time interval.

Each Bronto's unit B3+ generation and newer, has at least three control stations, and each station has a computer and a display, all sensors and limit switches are connected to these computers and communicating all together by the can bus, if any of these components has a defect the whole unit will go out of service. Figure 7 shows the can bus layout of Bronto Skylift and how the electronic components are connected to each other.

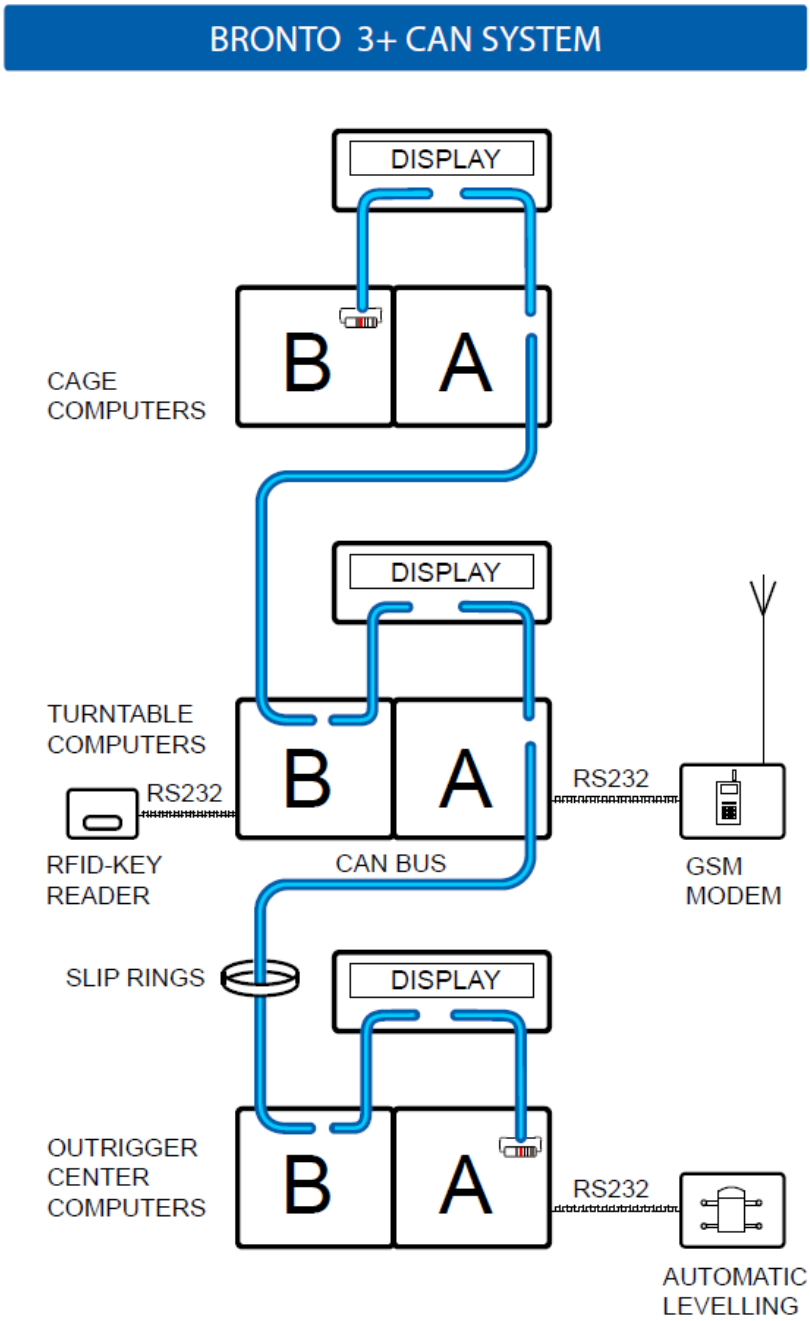


FIGURE 7. Can Bus layout in Bronto Skylift including the main electronic components. (Bronto Skylift Data)

Lacking information about the EOL product for these components is a challenging problem, as it is difficult to predict and monitor each component when and why it was out of service, to over come this, the periodic inspection and service are key factors to prevent any major repair, however this is not the major study case, the question is what to do with these failed components,

In Bronto, there is already a closed loop with computers and displays, all computers and displays when they are failed worldwide, they are coming back to our factory in Tampere, then the product support team filter the issues and categorized them, then they are getting shipped to the supplier of these components who will fix them and sent it back to Bronto once again, the main advantage of having these VO components, that the ability to send them with half price to the end user compare with new part, but it can be provided quickly and fast. Relying on used parts means achieving the CE goal, the no need to stress on the raw material, all what need is the knowledge to put back the component back to service.

However, Bronto are not able to put the sensors into this closed loop yet, even though the sensors are so many in each unit, around 20 sensors and they are essential elements in the operation, and they are small enough to have an advantage when it comes to re send them back for repair in the headquarter in Finland. Reason of this, the cost of repair the sensor is high to the limit make repairing the sensor almost 90% of cost of the new one, the only solution for this obstacle is changing the methodology of manufacturing these sensors, they must be able to be fixed by changing specific parts, these small parts can be changed by the product support team in Bronto without the need to send them to the supplier. This will save time and cost. Figure 8 shows the computer layout of Bronto Skylift, and how many sensors can be connected to each computer in the AIN.

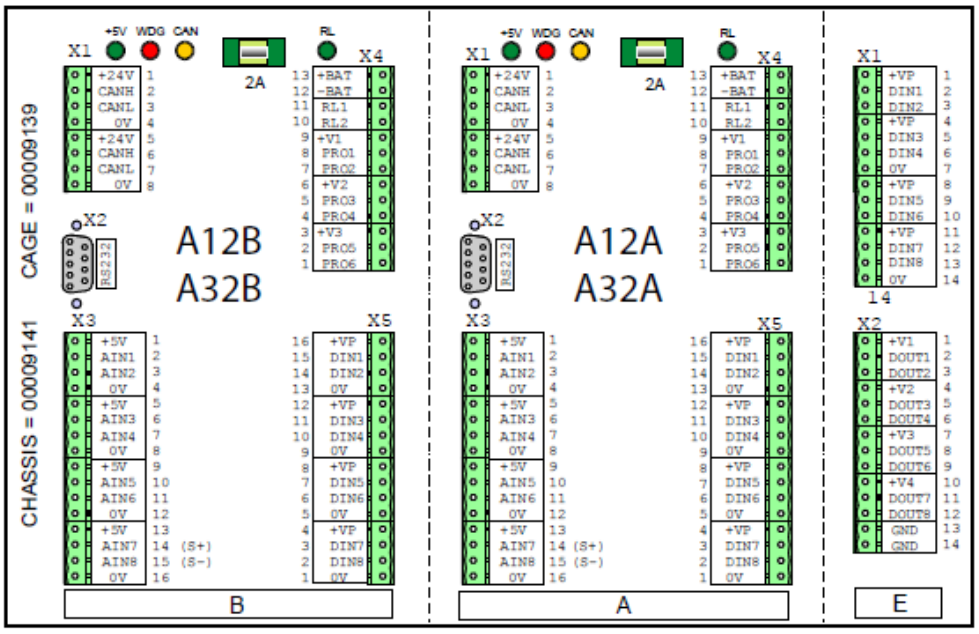


FIGURE 8. Bronto's computer. As an example of electronic components. (Bronto Skylift Data)

The maintenance and repair extend to other parts in the units such as hydraulic components, however these are very difficult to control their repair from the head-quarter in Finland, the best is scenario is to convince the end user and service providers to fix them and this is not possible or there is a safety consideration about the integrity of their operation, then replace them with new parts will be always priority, which is not the case with electronic components which they can be shipped easy and installed quickly.

4.2 Reuse Loop

Reuse loop one of the most important loops in the AWPs industry, reuse loop can be looked at it as small loop and independently, or be part of big scale like refur-bishment, in this section will discuss the small scale of re using some parts in Bronto's unit. (Payman et al., 2013)

The main idea of the reuse concept is to extend the EOL for parts and avoid bring new element inside the units, this will save money, Raw material, supply chain and a lot of sustainable benefits, and in this section, two main example of reuse

parts will be introduced, and will be discussed the best practice of achieving the best practice.

The concept of reuse in Bronto is occurred but limited, to reuse the calibration key and USB dongles being used for remote connection, although Bronto achieving the reuse concept with these two items, however it is not the optimum practice as still these items need to keep coming and going from to Finland for re validation, however with small SW and logistic communication all of these items should be supported and updated password to avoid sending these shipments, according to spare parts manager there around 300 parts from these types comes and go every year from to different locations and in different times, so if there are 600 shipments per year to send and receive parts which can be easily replaced by new design and new SW and with a password/license there is possibility of renewing the credentials without having any CO2 impact by shipping them all over.

During, the major inspection, and within the service contracts, a lot of customers asking to replace all parts for contingency and making sure to refresh all the fleet, some of the electronic components like computer, displays and sensors can be returned to Bronto to be re used with special price to support the units being operated in development countries.

In this section there are two kinds of loops, the first one is the perfect scenario loop, where parts can be used without even the need to re send them anywhere, so this scenario is 100% sustainable, fast and smart. And the second solution is to extend the EOL for specific parts and avoid exiting it form the operation cycle otherwise new material and new raw material should compensated for doing so.

Reuse require to have an updated SW and new smart technology to replace the traditional way of moving the parts between Tampere and the whole world, as well as reuse require to have mindset to receive the parts which they are still working and re sell them as used parts, instead of disposing them without serious problem.

Reuse can be extended to the meaning of re using the micro parts inside the main parts, example in extension sensors, even though the sensor itself is not

working, however to solve this kind of issues some times changing only the potentiometer will be enough and in this case keeping the whole sensor body can be re used again and again, changing sensor body might does not require to change the sensor connectors and cable, reuse concepts extend to major meaning where keeping all parts inside the operation cycle unless the specific parts is failed, trying to divide the parts into small pieces and trying to keep using all parts but the failed one.

Another popular example of reuse which is old enough that all companies and individuals do It these days. When hydraulic part is changed, re using the same the hydraulic valves and main hydraulic parts, this will reduce the pressure on the supply chain and moreover give availably to the service people at the site to have more options to fix problem with minimum parts replacement.

4.3 Refurbishment Loop

Refurbishment is the core of the circular economy and the biggest and most effective loop and considered to be the primary activity in this perspective, significant energy saving, and material consuming can be targeted with loop. The percentage of the saving can be up to 50% in the heavy truck industry. (Rönkkö, et al,. 2021).

As in Figure 4, The refurbishment loop is the wider loop that contains both previous loops, the re use loop and the repair loop. In Bronto Skylift, there is 10 years major inspection that will decide if the unit needs to have midlife refurbishment. In this inspection, all major parts will be inspected like energy chain, steel ropes, sliding pieces, booms assembly, chassis, hydraulic cylinders and frame structure.

This major inspection is the very first step in the refurbishment loop, where some others call it also remanufacturing loop. Other steps are considered to be the actions steps, starts from disassembling, repairing, replacing failed parts, testing, and re assembling. Refurbishment projects is a powerful tool to extend the EOL

components in AWPs industry, by applying circular strategy and the sustainable approach of keeping the AWPs into operation cycle as long as possible with only necessary change. (Sandvall et al., 2006)

These Necessary changes are not possible without this complicated process in the refurbishment. Where each part will be examined and most important will be decided separately if to be replaced, repaired, or even re use it in different process or for different role, or just decide to take out of operation. This process adding big advantage to the customer, in Refurbishment project, customer can have a new shape of their unit with minimum time required to complete compare with manufacturing new unit. The Remanufacturing Industries (Council ,2018) highlights several benefits of refurbishment and remanufacturing, such as cost savings for manufacture and higher profit margins, which will lead also to lower prices for end users, and this will improve customer satisfaction, and in the environment impact, refurbishment will reduce the raw materials and energy consumption compare to new units manducating, moreover will reduce CO2 emissions, reduce the solid waste, which will consider this process a sustainable project. However, on the side this CE loop require special skills which means new jobs and new opportunities. (Michael el at., 2020)

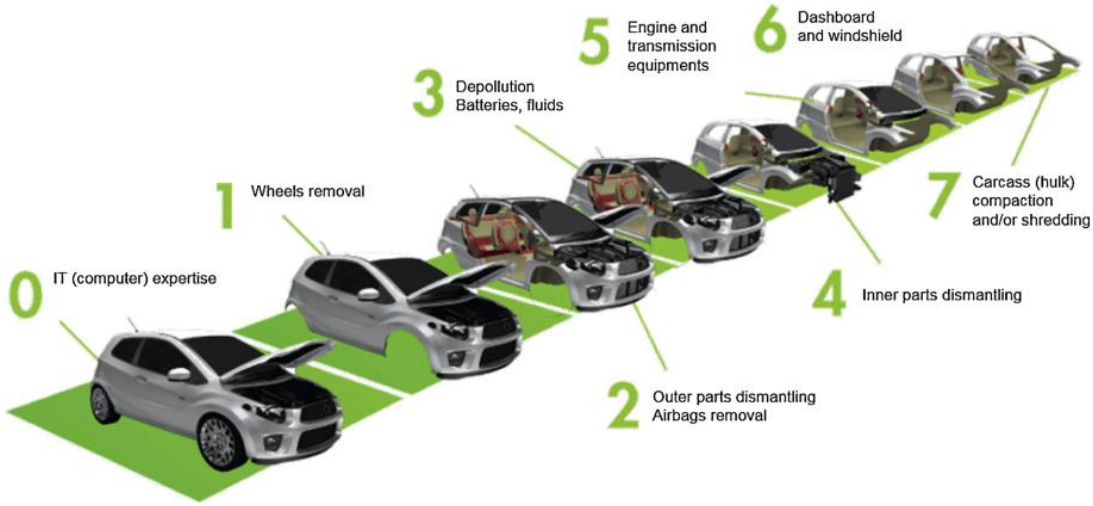


Figure 9. (Michael el at., 2020) (source: INDRA Automobile Recycling, 2016)

In Figure 9, a clear stage of dismantling the automobile sector like cars in order to start the refurbishment process, many steps from 0 to 7 where there is only the chassis without any additional equipment. AWPs industrial same as all heavy vehicles industry, still lacking of regulation which force the manufactures to have kind of specific rates of recycling and remanufacturing, which is not same as in the light automotive industry (Saidani et al., 2018a), Refurbishment loop will not only add a good reputation to the manufacture but also will lead to have more new customers who know by the fact the their unit can have longer life span, plus the manufacture with this loop can have more information about all parts being used and in different climate and conditions, which will lead to have bank of information about EOL and this can be used as valuable inputs for R&D rather than using these parts in loop 1, loop 2 and finally to loop 3 if it is just total failed.

However, achieving profitability in refurbishment by the OEM is complex and impacted by different factors, such as delivering the unit to the head quarter or at least the central workshop around the world, what is the condition of the returned platform and all of its internal components, all operation costs for this project based on the inspection result which might be really high in case the unit is too old or a lot of major items are non-repairable . More extended Challenges in automotive industry in general, can include the need for CIP for the workers, efficient dynamic management, accurate costing to make end price reasonable, and manage the supply chain for the required parts during the project. (Casper et al. 2018).

Appendix 1. shows that most of the parts required to be replaced/checked/repaired/calibrated under the refurbishment project are that kind of parts which is impossible to reach them in AWPs without dismantling the whole booms, which means the customer is not able to do this job everyday and just working on this scale require putting the unit in long downtime period and keep the unit out of service for few months, and this will lead to great idea that Bronto Skylift may even decide the time of midlife refurbishment at early stage and at sales order, so the all large scale repair can be done during the midlife refurbishment and then all parts can be used to the maximum benefits.

4.4 Recycling Loop

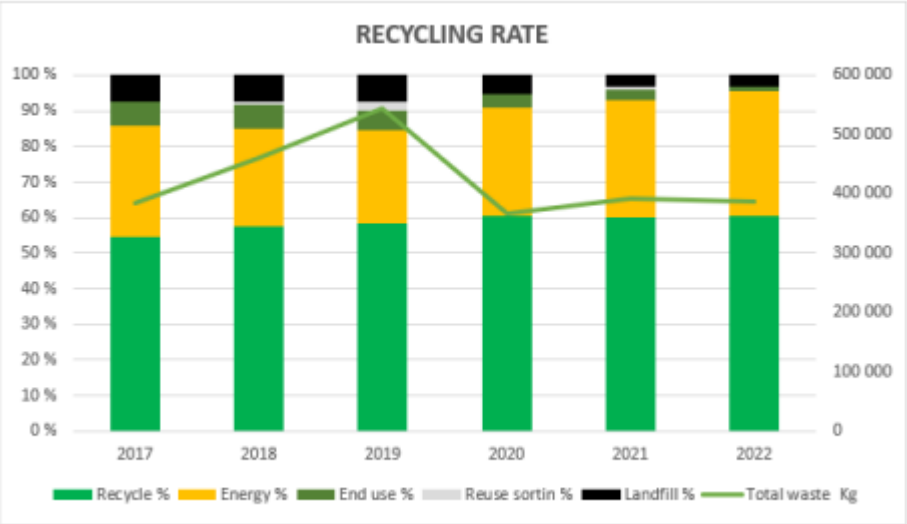
When a part is reaching its end of life, this part is not anymore adding nay benefits to the OEM or even to the customers, it cannot be repaired or even re used, then it is basically this part is just a waist that has to go somewhere, the main issues in these items when they are at the EOL, not only harming the environment and adding more CO2 to the surrounding, but also there is natural issue where there is need to product more raw material and which will lead to consume more and more form the natural resources that it is already limited. (Ilgin el at. 2009)

In Bronto Skylift, there are serious steps that have been taken forward with recycling process, as per the interview with Mr. Juha Pietila, that all metal like copper is being recycled with one company partner in Tampere-Finland, and while form the interview with Mr. Henri Kalteinen, there is another local company also here in Finland, taking care of all of the hydraulic oil and hydraulic filter and all of this kind of part to recycle them.

However, Bronto Skylift has more than 7000 units operating around the world, some of them very old and some of them brand new, however all of them have fixed rate of consumable parts to be changed, like changing filter every 1000 operation hours or ever year, whoever is first, and even though Bronto has no control om these units operated around the world, Bronto can have initiative to establish a rewarding system to the service providers around the world and thus the end users. That every time the service providers change filters and hydraulic oil. Etc and send them for local recycling company, they will get points from us, same as in the airline, these points can be transferred to have more benefits from Bronto, plus having green logo from Bronto to end users or service provides, in this way Bronto will lead the recycling process and will control it and most important to have more data about it.

The same idea can be extended to all other electronic parts that are not repairable, these parts should be sent to recycling company where they will do the filtering process and divide it to small pieces and then do the recycling accordingly.

In figure 10, Bronto Skylift is growing slightly their recycling percentage, which has led to reduce the total waste in Kg, in 2022 the total waste in Kg was around 360 thousand kg compare with 550 thousands kg in 2019, while in same chart there is more information about the Volatile organic compounds, VOC in Tampere factory doing better than Pori factory, however the numbers goes up and down.



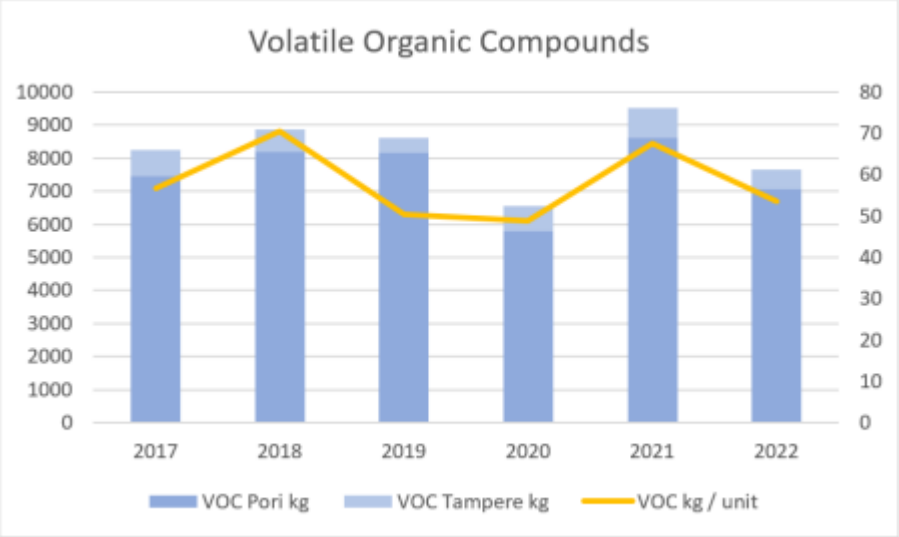


Figure 10, Bronto Skylift recycling process and VOC (Bronto Skylift Website)

In Europe, there are more rules and regulations about CE and recycling in particular, for example the Europe 2020 strategy that has been launched in 2010, by the European commission (Hagelüken et al. 2016), this strategy discuss the road map and long term policy to help reducing the natural resources consumption by focusing on the CE concepts and on the recycling, as this will control the waste generation especially those metal who have high quality for multi recycling loops

such as steel, aluminium and copper, and Bronto Skylift in its after sales department can have a big role to play on these items world wide with cooperation with its service providers. Figure 11 shows the zero programme for Europe where all CE strategies are linked to each other from raw material to recycling.

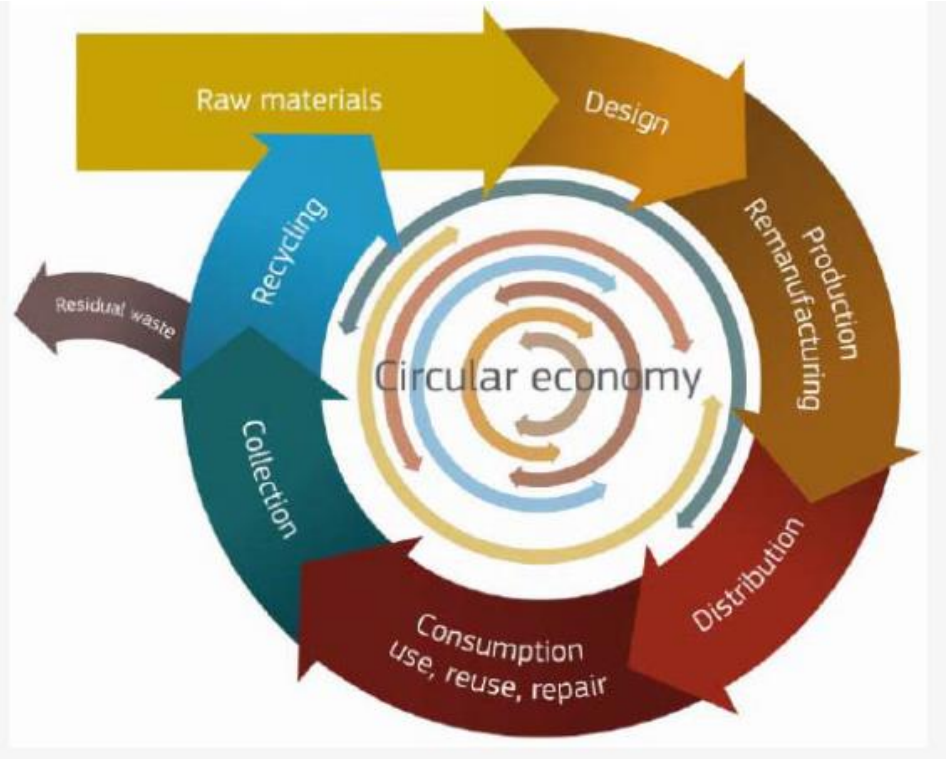


Figure 11. “Towards a circular economy: A zero waste programme for Europe”, (Hagelüken et al. 2016),

5 DISCUSSION AND RESULTS

5.1 Extend the equipment lifespan and reduce the down time.

Having a closed loop in the maintenance and repair tasks, will lead to have long life span in the aerial platform units. Following the maintenance programs and keeping the units in very good shape will get the maximum operation benefits from all parts, and thus reduce the probability to change these parts before its end life cycle.

Mean Time Between Failure (MTBF) is one of the most important indications for the availability of the AWPs. Where it can tell us for how long the unit can stay in operation phase before a failure occurs. (Galatia et al., 2020)

Formula is (MTBF = # of Operation Hours / # of failures), As mentioned in the introduction, there are two types of AWPs in Bronto Skylift, Industrial ones and Firefighting and rescue ones, MTBF in industrial units (S) should be pushed to the minimum, maintaining the unit will reduce the failures and with high operation hours per year which can go from 4000 to 6000 hours, the maintenance and repair loop will play a very critical factor.

An example of a unit where the filters have not been replaced as per manual (once per year or every 1000 hours) and if no inspections have been conducted (every day, weekly, every 250 hours or three months, and every 1000 hours or yearly), thus the failures will increase and the acceleration of having more failures will also increase by the time. Appendix 2 gives more idea about the general inspection points that should be covered on eat time interval.

In Figure 12, in s unit, where the expected operation hours to be 4000 hours per year, there as different scale of service interval, starting from the very first 250 hours, till last one which is for 4000 hours and still if no service actions had been conducted, it is very obvious that the failures will increase exponentially at some certain time and MTBF will dramatically increase. MTBF=4000 (total operation hours) / 25 (Total Failures) = 160 Hours.

4000 operation hours can be easy achieved if the unit working in a country where there is different kind of missions and different climate, so the unit can be moved between the cites all through the year. With 11 hours per day as an average and with shifts working style, 4000 hours can be achieved, there are a lot of record examples of Bronto Skylift units that work the same way around the world.

If the MTBF is 14 days, this mean every 14 days, the unit should be taken away from the site, and a service visit should be conducted, the loss in this can vary based on the natural of the failure and how long should need to solve it.

While if there is a reasonable service actions in every service interval like in Figure 13, then the MTBF can be reduced as figure to (MTBF = 4000/10 =400 hours), which means only every 36 days the unit might have failure compare only with 14 days with no service actions, and it is important to mention, the natural of the failure would be more known in case of solid organised service schedules.

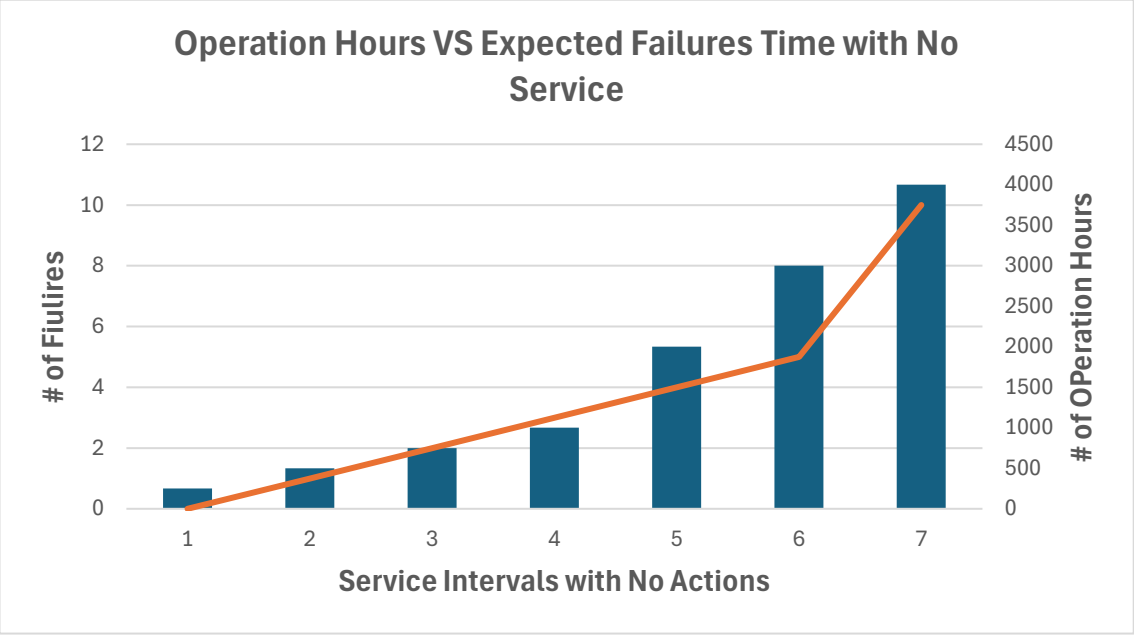


Figure 12. Bronto Skylift data for one of the units, Operation Hours VS expected failures time with no service actions.

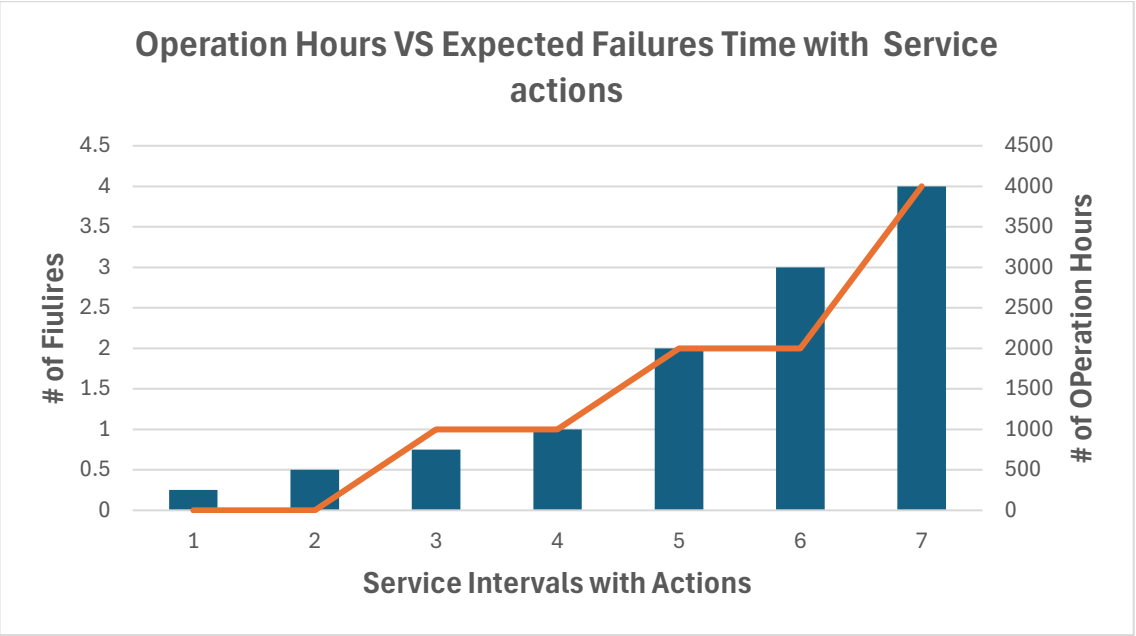


Figure 13. Bronto Skylift data for one of the units, Operation Hours VS expected failures time with service actions.

In Table 1, full break down for all of the expected cost of operation, direct and in direct for the end users for the whole period of the 4 days as one piece, while in table 2, there are more information how the cost of the break down will grow up by time for each day, this will how much important to act fast and even in advanced, In figure 14, it shows that both units had a solid linear increase of the failure cost with time, however it is clear form figure 12 that with bigger unit the cost of break down is more than other units and even the acceleration of the cost increases more with time. More sharp linear linearity relationship. Thus, bigger unit tends to have more attention and the service plans and maintenance loops will make big difference.

	S 70 XR	S 104 HLA
Cost of the down time period for four days	5312	12608
Cost of troubleshooting	157	157
Cost of shipping	100	100
Spare part cost	300	400
Crane Cost. *Due to break down	300	500
Operator Salary per day *due to break down	640	800
Interrupted service team plans for other scheduled work due to emergency	800	1000
Other Costs due to unexpected work	500	500
Total	**8109 €**	**16065 €**

Table 1. Breakdown of Cost of failure per day for unit S 70 XR, and S 104 HLA. Bronto Skylift Data.

	S 70 XR	S 104 HLA
1st day	3645	6009
2nd day	5133	9361
3rd day	6621	12713
4th day	8109	16065

Table 2. Summary of Cost of failure per day for unit S 70 XR, and S 104 HLA. Bronto Skylift Data.

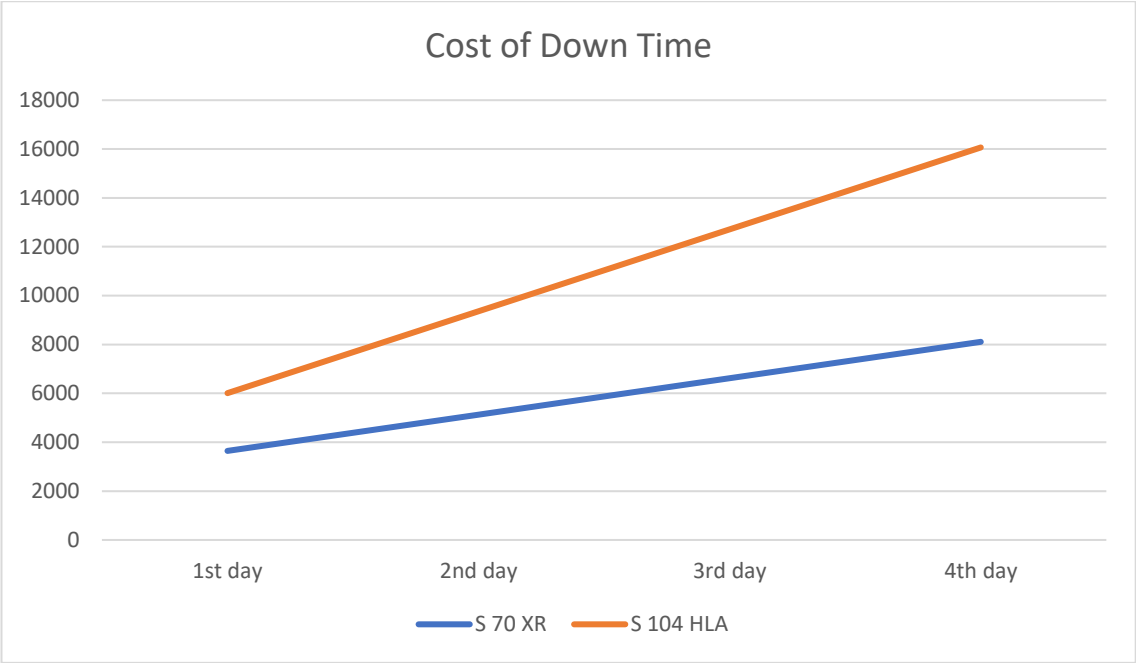


Figure 14. Visual distribution and growing up of the cost of failures for two different unit types for the whole 4 days.

In Fire units (F), MTBF it is not important compared to S unit, as idea of keeping the unit all the time in operation phase is essential.

In these closed lope cycles, it can get the maximum benefits from the used spare parts, and in refurbishment project it can put the unit into another 10 years operation phase with less than 50% from its original price. So, it is a triple wannish case, OEM, End User and the Environment.

5.2 CO2 footprint and Natural resources

In the rescue loops, sending unnecessary parts to all over the world was one of the challenging points in this business, in addition to keep sending new spare parts without having attention if the re use concept can take place on the site.

Keep sending new parts require new material, new material requires a raw material, and raw material means stressing on the natural limited resources, and on

each failure, more stress is applied on the natural resources at the end of the cycle effect.

While CO2 footprint, does not come only from the manufacturing process and preparing the material as a ready spare part, but also extending the issue to sending the spare parts to all over the world with shipping companies, where different kind of transportation are being used, buses, trains, cargo vans and cargo airplanes. All this transportation used fuels which has a direct impact on environment with every tone and every shipment as well.

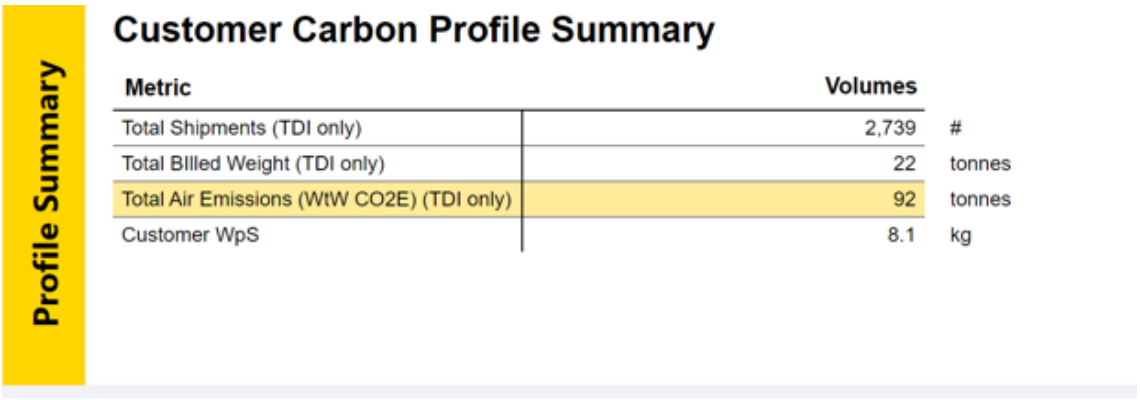


Table 3. Summary of Bronto Shipping data in 2023 (DHL Data for Bronto Skylift Profile).

From Table 3. Bronto Skylift sent and received almost 2739 shipment in 2023, the total weight for these shipments where 22 tonnes. While the weight per shipment were approx 8.1 kg, this gives a very important indication that there are a lot of shipments being sent with very low weight, same what have been discussed in the re use cycle, where a lot of modems, calibration keys, and dongle USB sent all the time (WpS). While total air emission is an indication and calculated by tonnes, and it is equal to total distance in km * the fuel consumption per km in litters * emissions factor Kg CO2/litter/1000

DHL express is launching a new delivery style where sustainability is essential factor to deliver all shipments, to do so DHL is taking few factors part of their innovation solution.

As in figure 15, using sustainable aviation fuel, where DHL target to have 30% of their fuel by 2030 with SAF. When DHL buy new aircrafts will buy only the latest

fuel-efficient aircrafts with SAF solutions. And Fuel optimization where plane weight and balance optimization with improve the over whole design and emission can be kept to the minimum.

While in figure 16. DHL will take lead the innovation by buying almost 12 fully electric eCargo planes which will be delivered in 2024.

And regarding the ground handling, DHL aiming to decarbonized it by using the electrification and the hydrogen technology and by using the green product for customers.

However, if Bronto Skylift would like to participate in the Go Green concept then Bronto should pay a fees per tonne, the new regulation in EU forcing the companies to take the sustainability part of their activities, so this will not be an option but a mandatory action at some certain point, DHL indicate that if Bronto Skylift would like to reduce the CO2 emission by 10% then the cost will be 2.99K Euros, and exactly adding 1.09 euros per shipment. This means Bronto can reduce the total air emissions by 9 tonnes with only 10% plan. (Source: DHL report to Bronto Skylift)

As per interview #1, it can be stated that there is approximate 400 shipments can be withdrawn with Bronto internal SW innovation. Which means reducing the total shipments and reduce the total air emissions at no cost, not only this, it will save a lot of money cost related to these shipments, this saving money can be used to fund the go green policy by DHL, and if the re use concept has been extended, then spare parts will be sent in narrow range in term of number of these shipments and in term of total weight. So Bronto can start to go green just by applying the CE concepts and again at no cost.

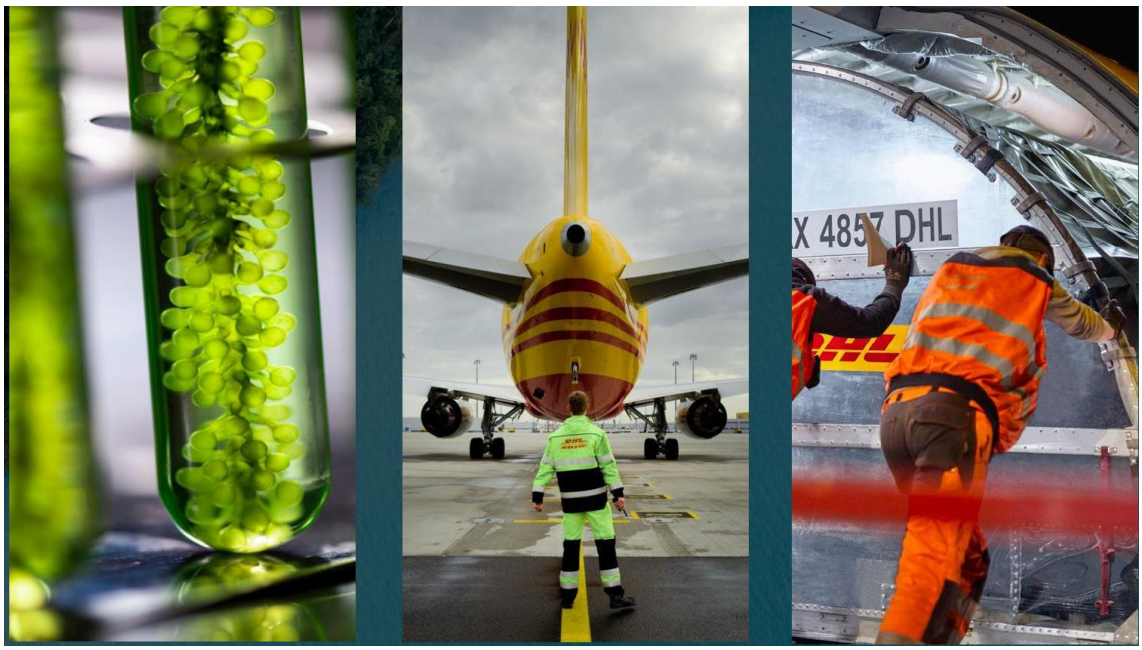


Figure 15. DHL sustainability Strategy Innovation Map. (DHL website)

Figure 16. DHL sustainability Strategy in Transportation. (DHL website)

5.3 Customer satisfaction

Customer satisfaction can be a mixed point with different results, some customers might not like the idea of increasing a bit the price of shipping the parts and the services, might not like the idea if the repaired parts is almost the same price of the new part, however the customer will appreciate to have an option of re using the parts that can be repaired quickly and easy and mainly at the site, and

also some customers are concerned to support the sustainable solutions. In fact, DHL did survey with Bronto potential Customers. 50% form the buyers were very interested in an environmentally friendly delivery method, 38% of consumers feel that retailers for example, are doing a good job of using sustainable delivery practices, and 20% of buyers indicate they would pay more for a delivery from an environmentally friendly company. This will lead customers to be loyal to the companies who support the sustainability and will be more willing to deal with them and thus will affect the buying decision. (DHL website)

Bronto can launch Loyalty programme which can boost the sustainable activities and can share the cost of the sustainable efforts to the customers and give them priority service and awarding them in other sectors and other services if they become part of the sustainable plan. And thus, a triple win case will happen, Bronto, customers and Environment, and this will increase at the end the day the customer satisfaction.

6 CONCLUSION

As per the studies in this thesis, it is very clear with numbers and facts, that applying the CE in after sales services in AWPs will have a direct impact of improving the business in the short and long run. Repair loops require commitment to conduct all actions as per plan and be effective in doing the maintenance. Refurbishment loop requires clear strategy on how to get the maximum benefits of all parts of the unit, in one hand the unit life cycle can be extended for another 10 years, and on other hand the spare parts will be used to the maximum benefits and no waste will be generated for no reason. While re use loop will reduce the need of using new parts and be more independent on the existing parts by innovation, this will extend the benefits to reduce number of the shipments being sent all over the world with all its direct an in direct carbon impact and draining the natural resources. While recycling loop is the oldest classis cycle to keep the raw material production to the minimum and get the maximum benefits of the parts material when it reached its EOL

Applying CE comes with risks and challenges, and one of the most important challenges is the human factor, the employees who should do the actions and take steps into the CE, good understanding and analysing the CE risks & challenges from the employers at early stage will lead to a better vision and plan of which skills are more required for the new rules within the new strategy and which rules are slightly minimized. This will require early actions from management to give specific training and education to reposition the team in their new places where they can be much more efficient and critical players in the new vision. This will reduce the risks of applying CE in general in terms of the organization's success and profit and loss point of view and will also reduce the moral level of risk and employee motivation when they think that their jobs are at replacement risk. With all of the challenges that might face in population rapid growth inequality and environmental challenges ranging from pollution to climate change and waste resources, CE should be a chance for better future. However, while planning for this and during the transition period, all what have been said; should be strictly aligned with making employees' conditions much better and growing the business, otherwise CE will be a negative approach and will face huge resistance from all levels.

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APPENDICES

Appendix 1. The main Refurbishment parts in Bronto Skylift

Full overhaul for all 4 outriggers including signal lights
Replacement of hydraulic pump shaft gaskets and cross joint
Replacement of clinometers
Reparation of electric and hydraulic center post
Replacement of battery driven pump
Replacement of telescope cylinder sealing
Replacement of slewing bearing bolts
Replacement of Oil filters & full oil change
Replacement of all water hoses
Replacement for first boom lifting cylinders sealing
Replacement of boom cables
Replacement of boom hydraulic hoses
Replacement of suction hoses
Replacement of sliding pieces for booms
Replacement of 2nd boom pivot bearings and pins
Replacement cage boom cylinder sealing
Replacement of cage levelling cylinder sealing
Replacement of all water monitor hoses and couplings
Reparation of all limit switches
Replacement of Lock- and Emergency valves
Replacement of telescope chains
Replacement of levelling chains
Change of telescopic waterpipe seals
Necessary paint jobs for booms
Necessary paint jobs for mainframe
Breathing air hose
Water hoses
Changing the reservoir and cooling system hoses
Working cage control station assembly
Telescope cylinder
Cage slewing mechanism
Cage load mechanism

Appendix 2. The General Inspection for Bronto Units per time

BRONTO SKYLIFT®

PERIODICAL SERVICE SCHEDULE

GENERAL INSPECTION	daily or before operation	50 hours or weekly	250 hours or quarterly	1000 hours or yearly
Main frame fastening to vehicle			x	x
Hydraulic pump drive shaft			x	x
Outriggers			x	x
Rotation gearbox				x
Fastening of rotation gearbox	x	x	x	x
Fastening of rotation ring	x	x	x	x
Retightening of rotation ring screws			x	x
Booms				x
Joints, bearings and locking devices	x	x	x	x
Levelling system			x	x
Cable chains inside of booms			x	x
Fastening of working cage	x	x	x	x
Doors, hinges, locks, foot plates and turning handrails of the working cage	x	x	x	x
Sliding surfaces of the extendable working cage (cleaning and lubrication)			x	x
Steps of working cage		x	x	x
Insulation test of working cage			x	x
Protective covers and bags			x	x
Instruction and warning stickers and labels	x	x	x	x
Oil leaks	x	x	x	x
Fuel level of vehicle	x	x	x	x
Batteries and fluid levels	x	x	x	x
Charging voltage	x	x	x	x
Electric centres			x	x
Connection boxes				x
Cables	x	x	x	x
Current rings of centre post			x	x
Outreach limiting system (if fitted)	x	x	x	x
Possible accident damage to bodywork	x	x	x	x
Lubrication of the unit	every 50 hours or quarterly			