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A Multi-Actor-Perspective on Reverse Logistics and Enhanced Circularity of Car Bumper Covers: A Case Study at Volvo Cars

Master's thesis in Industrial Ecology

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DIVISION OF PRODUCTION SYSTEMS

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Cover: Stripped bumper covers at Volvo Car's facilities in Gothenburg.

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ABSTRACT

The automotive industry ranks as the third biggest plastic consumer, responsible for 8.8 % of the total plastic demand and 5 % of the post-consumer plastic waste. Today, close to1000 tons of high- quality material from bumper covers alone is discarded at Volvo certified repair shops globally, with Sweden being the biggest market. The vast majority of this material is incinerated with energy recovery. This master thesis project therefore aimed to identify critical factors and enablers for an effective bumper cover recycling and to demonstrate what such a value network can look like in terms of actors involved and material- and information flows. This was done through exploration of the value network and reverse logistics system from a multi actors' perspective. Interviews was the main source of data. Seven impact factor categories were identified: operational and logistics, technical and quality; economic; people and attitudes; policy and regulations; ownership and control; and information and communication, of which the most important factors are feasibility of material reuse; quality control; employee engagement and competencies; and material flow control. Important enablers to avoid or overcome barriers include active learning, focus on communication and education, and further testing of material tolerances to remove uncertainties relating to technical aspects of material reuse. Recommendations to project coordinators at Volvo include getting familiar with the identified impact factors, and to organize material and production testing to determine tolerances to eliminate existing and restraining uncertainties.

Keywords: Actor system mapping, automotive, circular economy, circular value network, ELV, plastic recycling, plastic waste, reverse logistics, value retention.

FOREWORD

When I started thinking of what I wanted to do in my master thesis work I soon knew I wanted to do something relating to circular economy strategies, preferably in the automotive industry. My supervisor's contact network and initiative, at Volvo Cars, opened up for the opportunity for me to work with a pilot project at a leading car manufacturer. Getting to observe and explore the aspects of the development of a new circularity project has been incredibly interesting and inspiring.

I want to give my thanks to my supervisor Erik Sundin and examiner Mélanie Despeisse for guidance throughout the project and to my contact persons at Volvo Cars, Christian Nilsson and Tom Engblom for involving me in the project and welcoming all my questions and inquiries. I also want to include a thanks to Victoria Thomas for support in the writing process. Finally, I want to extend a thank you to my parents for being available on the phone when I needed a sounding board or support.

Gothenburg, Sweden, June 17, 2022

Lea Myklebust

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Abbreviations

ASM	Actor System Mapping
CDC	Central Distribution Centre
EEA	European Economic Area
ELV	End of Life Vehicle
EoU	End of Use
EoL	End of Life
EU	European Union
IR	Infrared
LCA	Life Cycle Assessment
LDC	Local Distribution Centre
PP	Polypropylene
PP-EPDM	Polypropylene ethylene–propylene-diene-rubber
RL	Reverse Logistics
SO&T	Service, Operations & Technology

1 INTRODUCTION

Estimates suggested that there were 1.3 billion cars in use in the world in 2015, whereof 0.95 billion passenger cars (*Number of Vehicles in Use Worldwide 2015*, n.d.) and in 2021 alone, more than 79 million motor vehicles were produced world wide ('World Motor Vehicle Production', 2022). Cars have provided benefits to our societies and become a natural part of people's daily lives, especially in the wealthier demographic regions. However, the environmental impact of the automotive industry (globally) is indisputable, and the automotive industry, along with other industrial sectors, is under pressure to address this. To a large extent, the car manufacturing industry still operates in a linear economy. The European Parliamentary research service describes a linear economy as an economic model based on a *"take-make-consume-throw away' pattern"* (*Circular Economy | EPRS | European Parliament*, n.d.).

The effects of large production volumes in a linear economy are becoming more and more evident. Effects take the form of resource scarcity, large waste dump sites, pollution and more. For example, in EU+EEA, the automotive industry ranks as the third biggest plastic consumer, responsible for 8.8 % of the total plastic demand (*Plastics - the Facts 2021*, 2021) and 5 % of the post-consumer plastic waste (*The Circular Economy for Plastics-A European Overview*, 2020).

Increasingly governmental institutions, private organizations, and the public expect companies to transition towards sustainability. In response, companies are increasingly taking responsibility for what happens to their products after the products reach end of use (EoU) or end of life (EoL). In dealing with the enormous amounts of waste being produced all the available tools must be used. A circular economy has become a go-to framework for dealing with waste, EoL or EoU products. The European Commission's online resource page on circular economy, provides a simple definition of the concept: "*In a circular economy, the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimized*" (*Circular Economy*, n.d.). R-strategies or R-frameworks are often referred to when discussing strategies for circular economy. These are strategies or a collection of strategies starting with "re" which are to be helpful in practicing circular economy. Examples of these are *rethink, reuse, repair, remanufacture, recycle, etc.*

Many companies have responded to the societal attention on sustainability by setting concrete targets, including Volvo Cars AB (from here referred to as 'Volvo') who has their headquarters in Sweden. Volvo has stated that they strive to become a circular company by 2040. One of the intermediate goals they have set is that 25 % of the plastic used in the cars is recycled or biobased by year 2025 (*Hållbarhet: Cirkulär ekonomi*, n.d.). Today the average Volvo car contains, by weight, 17 % plastics, of which 12.6 % are thermoplastics and 4.5 % are other polymers (Volvo Car Group, 2021). Only 4 % of the plastics used in production of new cars are recycled or bio-based (Volvo Car Group, 2021). One component of cars which is predominantly made from plastics is the bumper cover. Bumper covers are damaged relatively often compared to other car parts, and thus the potential volumes to be collected are relatively large. Today, close to1000 tons of high- quality material from bumper covers alone is discarded at Volvo certified repair shops globally, with Sweden being the biggest market (*Closed Loop Recycling for Bumper covers at Volvo*, 2021), and the vast majority of this material is incinerated with energy recovery.

Volvo is looking to start recycling of bumper covers. In order to increase the recycling rate, a take-back system is needed to recover the bumper covers. Rogers & Tibben-Lembke (1998, p. 2) offer an elaborate definition of reverse logistics: "*The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal.*» and a simple definition: "*reverse logistics is the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal.*" Reverse logistics, or a take-back system is a crucial part of both closed- and of open loop supply chains. Closed loop supply chains are chains where the material that results from recycling a product are used to produce an equal or similar product again, while in open loop used to make other products. Volvo already has experience with reverse logistics (RL), but not with the product of bumper covers. By creating a closed loop recycling system with the bumper covers, the bumper cover recycling can contribute to Volvo reaching their plastic circularity goals.

Volvo has a pilot project for increased circularity of bumper cover plastics, which started in Spring 2021. Their pilot project is used as the case study for this thesis. Volvo's pilot project so far has included a pre-study with a plastic material producer to assess the recyclability of the collected material and quality assessments. In the pre-study, Volvo collaborated with the project SEkond2life at RISE. The pre-study suggested that recycling is a good strategy for the plastics in the bumper covers, which is in line with findings from previous studies on the topic (e.g. Makuta et al., 2000; Hongshen & Ming, 2012) and the goal is to reach a high recycling rate for these plastics and produce new bumper covers of the recycled material. Volvo's pilot project has also included workshops with different actors, and disassembly and collection of bumper covers from a selected few repair shops and dismantlers. Options for the circular bumper cover flows are still being developed and investigated. This serves as the foundation for this thesis.

Although recycling of bumper covers has been feasible for many years, and the fact that bumper covers hold a value retention potential is well known, recycling is not yet common practice. Reverse logistics and circular solutions are often seen as complex and coupled with uncertainty. Thus, a good understanding of a circular value network can facilitate enhanced effectiveness and so increase recycling and decrease the incineration and environmental impacts.

1.1 Aim

The aim of this master thesis project is to contribute with knowledge on how successful and effective car component recycling can be achieved. To address the aim two objectives were set: (I) To identify critical factors and potential challenges for an effective bumper cover recycling through the exploration of the value network and reverse logistics system from a multi actors' perspective, and to identify enablers to overcome or avoid challenging impact factors. (II) To demonstrate what such a value network can look like in terms of actors involved and material- and information flows.

These research questions (RQ) will be central in fulfilment of the aim and objectives:

RQ 1) What can the circular bumper cover flow look like in terms of material flow and involved actors?

RQ 2) What factors can impact a circular bumper cover flow and how do different actors in the value chain see the relevance of these factors?

RQ 3) What enablers can be implemented to avid or overcome challenging aspects of the bumper cover circularity?

Initially, a literature study was performed focusing on existing literature on circular economy and reverse logistics in the automotive industry, and on understanding the regulatory environment of the EU in which Volvo operates. The main findings of the literature study are presented in Chapter 2 along with a short introduction to circular economy. The methods adopted in the report are presented in Chapter 3 followed by results in Chapter 4. Thereafter the findings, relevance and reliability of the study are discussed in Chapter 5, and finally conclusions and recommendations are presented in Chapter 6.

1.2 Scope and limitations

As this study depends on an ongoing study at Volvo, the amount of information available is constrained. The study is focused alternative circular flows in the Swedish market, potential actors outside of Sweden are therefore not considered. Assessment with regards to environmental impacts, such as emissions from transport alternatives, energy use, etc. also falls outside of the scope of this thesis.

The number of interviews was limited to 12. Choices on who to include and not were based on reaching a broad representation. Technical aspects of recycling and chemical processes are discussed qualitatively, while quantitative descriptions fall outside of the scope. Furthermore, the car factory, car retailers and car owners are excluded from the scope.

The term *actor* will be used throughout the text to refer to the people, departments and organisations who take part in the bumper cover project in some way. This means that different departments and department representatives at Volvo, representatives from companies who perform services or produce products making use of bumper covers or bumper cover materials, or companies, company representatives or persons physically handling bumpers are all viewed as actors. This may be in contrast to Eden and Ackerman's (2013) distinction between stakeholders and actors used in the stakeholder analysis. Policy making institutions, which impact the system, but are not actively, or will not be actively involved in the project are not viewed as actors.

2 THEORETHICAL BACKGROUND

This chapter firstly provides a brief introduction to circular economy including the End-of-Life Vehicle directive and some policies and regulation on circular economy in the EU and in Sweden. Secondly, some of the drivers and barriers for Reverse logistics (RL) identified in current literature are presented. Thirdly, an overview of existing circular measures for bumper covers is given, and lastly, some of the benefits of bumper cover circularity identified through life cycle assessments (LCA) studies are presented.

2.1 Circular Economy

In economic theory, goods and products can flow linearly or circularly. A linear flow is one where products are treated as waste after one or a few use phases. As stated in the introduction, a circular economy is one where "*the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimized"* (*Circular Economy*, n.d.). Bocken et al. (2016) developed a categorization of circularity as a function of whether a flow is closed and/or slowed down as illustrated in Figure 1.

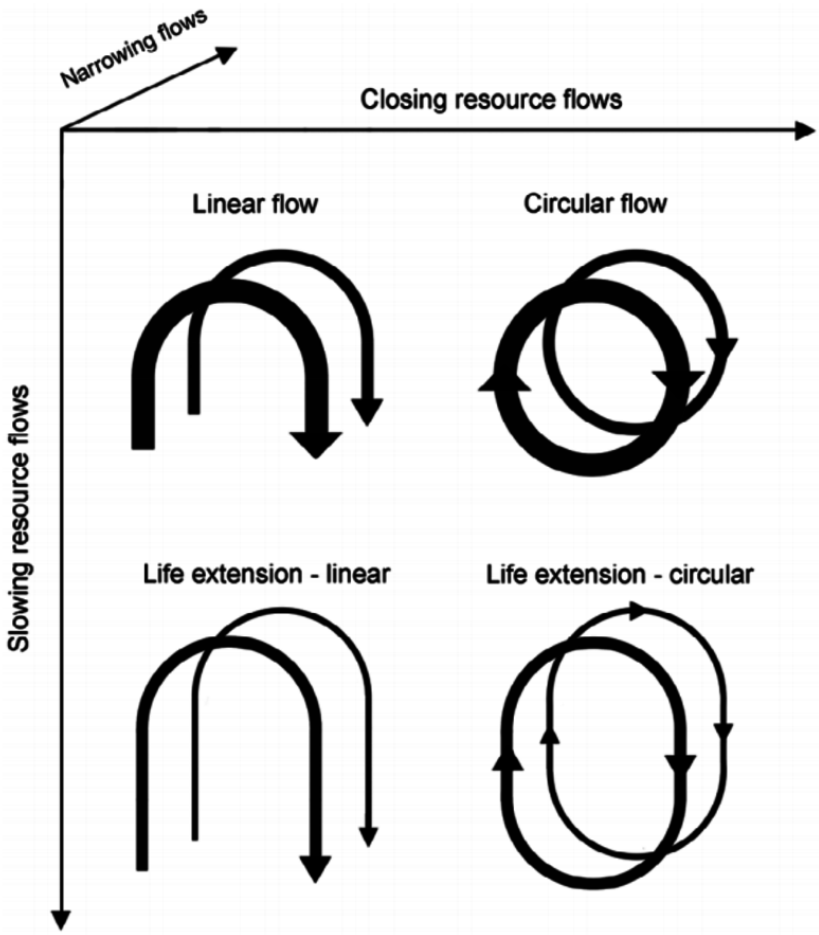

Figure 1: Closing and slowing of resource flows (Bocken et al., 2016).

Life extension or slowing of the loop can be achieved by strategies like reuse, repair, refurbish, remanufacturing and closing of the loop can be achieved by recycling (Bocken et al., 2016). In order to ensure a continuous loop rather than a single or a few circles solutions should be applied that allow for "true" recycling rather than downcycling, ensuring that the recycled materials have equal quality to the original materials. This can be done through use of "primary recycling" which is recycling where the quality remains equal, or "tertiary recycling", which is chemical recycling where the chemical constituents are recovered (Hopewell et al., 2009). Energy recovery can be referred to as quaternary recycling. Although the amount of waste being sent to landfill can be reduced through incineration, the need for new materials is not reduced, and there are emissions related to the incineration process (Hopewell et al., 2009).

2.1.1 Circular economy and the European Union

The European Union is actively working towards sustainability and circular economy, and this work includes, amongst others, the development of *A European Strategy for Plastics in a Circular Economy* and the EU taxonomy.

EU taxonomy. The EU-taxonomy was developed to make it easier for investors to know how to invest, and as a key to determine whether different industries are sustainable or not, based on their economic and industrial activities. The taxonomy is still new, and while some industries will notice the presence from day one, other industries are given time to adapt. This is the case for the plastic industry which is seen as a "transitional" technology or industry, meaning it supports the transition to a more sustainable society as long as it fulfils some criteria. (Chinda, 2017) (EU 2020/852). Three criteria which the activity, in this case production of plastic in its primary form, must meet are (1) the GHG emissions from the activity must meet practice in the sector or industry; (2) the activity must not interfere or make the development and spread of low-carbon alternatives more difficult; and (3) the activity must not contribute to lock-in of carbon-intensive assets (EU 2020/852 (p. 18) Article 10.2). Chapter 3.17 on manufacturing of plastic in primary form sets three additional criteria out of which one must be fulfilled in order for plastic to be considered as "*contributing significantly to climate change mitigation"* (EU 2020/852, (p. 69) Chp. 3.17). The criteria are as follows: (1) the plastic in primary form must use mechanically recycled (primary recycling) plastic as feedstock; (2) if mechanical/primary recycling is not an option, in regards of technology or economy, the chemical (tertiary) recycling must have lower GHG-emissions than primary plastic produced from fossil feedstock; or (3) all or parts of the feedstock is from renewable sources (C(2021) 2800 final- Annex 1, supplementing Regulation (EU) 2020/852, Chp. 3.17).

EU Circular Economy strategy. The strategy includes a long list of encouragements directed at authorities and private industry. As a means to improve the economics and quality of plastics recycling authorities are for example encouraged to "*make better use of taxation and other economic instruments to reward the uptake of recycled plastics and favour reuse and recycling over landfilling and incineration*" and industry is encouraged to "*take concrete steps to improve dialogue and cooperation across the value chain*" and to "*make voluntary commitments in support of the strategy's objectives, in particular as regards to the uptake of recycled plastics*". As means to urge investments and innovation for circular solutions authorities are amongst other encouraged to "*make better use of economic instruments, especially to raise the cost of landfilling and incineration"* and industry to *"increase infrastructure and R&D investment in areas of direct relevance to achieving the strategy's objectives".* (*European Strategy for Plastics in a Circular Economy, Annex 1-3*, 2018)

End of Life Vehicle directive. The end-of-life vehicle (ELV) directive (*Directive 2000/53/EC*) contains a number of guidelines on how cars and car parts should be handled when they reach end of life, and what responsibilities and actions car manufacturers and governments should take. The responsibility is put on the member states rather than directly on the vehicle producers, and the member states are asked to either encourage or to ensure certain actions.

Much attention is given to recycling. Article 4 (1.c.) in the ELV directive proclaims that "*Member States shall encourage […] vehicle manufacturers, in liaison with material and equipment manufacturers, to integrate an increasing quantity of recycled material in vehicles and other products"* so that the markets for recycled materials can develop(*Directive 2000/53/EC*). In article 6 (3) member states are asked to ensure that establishments who perform recovery, disposal, or preparations prior to this, fulfil a number of obligations, including obligation (c) under annex 1: "*Stripping operations and storage shall be carried out in such a way as to ensure the sustainability of vehicle components for reuse and recovery, and in particular for recycling*" (*Directive 2000/53/EC*). Furthermore, article 7 (2) asks the member states to *"take the necessary measures to ensure*" that targets regarding recycling and recovery are reached. The current target, which was to be reached by January 1st, 2015, is found in article 7 (2 b) and states that "*for all end-of life vehicles, the reuse and recovery shall be increased to a minimum of 95 % by an average weight per vehicle and year. Within the same time limit, the re-use and recycling shall be increased to a minimum of 85 % by an average weight per vehicle and year"* (*Directive 2000/53/EC article 7*).

An evaluation of the ELV directive and its effect was published in 2021 (*Evaluation of Directive 2000/53/EC*, 2021). The evaluation found that the ELV directive fails to properly address important areas, like waste prevention – linked to eco-design to facilitate repair, reuse, remanufacturing, and recycling. Furthermore, it is recognized how the targets of recovery and recycling in article 7 (2 b) described in the above paragraph are poorly adapted to current designs and market for cars. The target is set in percentage in relation to weight, and thus actors in the ELV handling sector focus their attention more on heavy materials, like metals, than on light-weight materials, like plastic(*Evaluation of Directive 2000/53/EC*, 2021). This is an important realisation, considering the immense increase in plastic content in cars. Today, the average car contains about 10 % plastic, if measured by weight, but 50 % plastic if measured by volume (*Automotive Plastics in Modern Cars*, n.d.). The plastic content is expected to increase even more, with some suggesting the plastic content might increase with 75 % (*Plastics Use in Vehicles to Grow 75% by 2020, Says Industry Watcher*, 2015).

2.1.2 Swedish environmental regulations

Swedish tax on incineration. A new tax on incineration for heat recovery was introduced in Sweden in 2020. This tax has been increasing steadily, and is set to reach a final 125 SEK per TON in 2025 (Andersson & Larsson, 2019). The Swedish Consumer Energy Markets Bureau discussed this tax in the article *Higher prices on district heating with new tac on waste incineration* (*Högre Fjärrvärmepriser Med Ny Skatt För Avfallsförbränning*, 2021) , and explained that since the incineration for heat-recovery capacity in Sweden is fairly large compared to the access to waste for incineration. Therefore, to stay competitive, the incineration companies cannot increase the price for incineration much, and the added cost is not expected to be noticeable for the waste-producing companies. The tax will rather impact the profits of the incinerating companies. Thus no added incentive to reduce the amount of

waste sent for heat recovery is given to the waste producing companies through this tax. (*Högre Fjärrvärmepriser Med Ny Skatt För Avfallsförbränning*, 2021)

The Swedish environmental code. *Miljöbalken (SFS 1998:808)* 10 § lays out a hierarchy of waste which is to advise which waste management practise to follow. This is the same guidelines as presented in the European commission's directive on waste treatment. The law commands that the entity responsible for waste management should see that the waste is (1) recycled through preparation for reuse; (2) recycled for material recovery; (3) recycled in another way; or (4) discharged. The strategy highest up on the list is to be preferred, and one can use strategies further down the list if that strategy is seen as "more convenient" than the strategy above (*Miljöbalk, SFS 1998:808*). Thus, the law provides a guideline, but it is not clear on what constitutes convenience.

2.2 Drivers and barriers relating to circularity of car components

The following section provides an overview of barriers and drivers related to the circularity of car components from current literature. The articles used include case studies, expert interviews, and literature reviews, and originate from different parts of the world, including Spain, China, and India (Gonzalez- Torre et al., 2010; Abdulrahman et al., 2012; Sharma et al., 2011). While a few of the articles were specifically focused on the automotive industry (Chan et al., 2012; Kaviani, 2020; Zailani et al., 2017), much of the reviewed literature takes a broader focus, investigating reverse logistics (RL) in different industries (Abdulrahman, 2014; Fawcett et al., 2008; Richnák & Gubová, 2021; Zailani et al., 2017). One article took a multi-actor perspective and listed the nature of business the interviewees worked in (Rameezdeen et al. (2016). The majority of articles only named the number of interviews or questionnaire respondents, without differentiating between barriers recognized by different types of respondents. These have been included because they contain valuable information for this overview. From these articles, external and internal reasons for having RL were found.

There are many reasons for organizing RL and many of the drivers are external. Firstly, companies often must deal with unavoidable returns. These can come as a result of faulty production and warranties. Secondly, increasing legislation and regulations for waste management drive increased RL. Thirdly, customer expectations of corporate citizenship have increased, and environmental performance can both improve competitiveness and improve customer satisfaction. A fourth, and internal reason is that returned parts often have value to recapture, -a value retention potential- and organizing RL is a necessary step if a company wants to retrieve product, component or material value. (Chan et al., 2012; Simões et al., 2017).

Barriers identified from the literature were categorized into six categories: *management, financial, infrastructure and operational, market/competition, policy,* and *people,* with several subcategories in each. In general, there is high variation regarding which barriers have been recognized as most important in the different studies.

Management. The major observations within the category of management are as follows. The number of parties involved in organizing reversed logistics makes the process complex, and coordination and integration becomes a challenge (Chan et al., 2012). Often there is a lack of shared understanding between the actors of what is the best practise (Abdulrahman, 2014) and

either a lack of effective information system or willingness to share information (Fawcett et al., 2008; González-Torre et al., 2010; Rameezdeen et al., 2016). Low or insufficient involvement and support from top management, and lack of attention given from top management to RL in strategic planning was identified as a main management barrier by Abdulrahmen et al. (2014), Kaviani et al. (2020), González-Torre et al. (2010) and Sharma et al., (2011). Finally, Chinda (2017) found "availability of managers with necessary RL experience", or the lack thereof to be an important factor for RL.

Financial. Regarding financial barriers there seems to be slightly more agreeance. Lack of initial capital was identified in five of the articles (Abdulrahman, 2014; González-Torre et al., 2010; Kaviani, 2020; Richnák & Gubová, 2021; Sharma et al., 2011). Such capital could be needed for human resources, training of personnel, system development and time (Sharma et al., 2011; Zailani et al., 2017). A second financial barrier is the risk of virgin materials being cheaper than recycled material, especially if added cost of the RL is included (Chan et al. 2012; Kaviani et al., 2020; Gonzalez-Torre et al., 2010). Kaviani et al. (2020) who investigated the situation in Iran also identified lack of economy of scale and the presence of economic sanctions as important barriers. The latter must be seen in relation to the country of study and the specific political situation.

Infrastructure and operations. Although many articles mention an increased need for personnel and trained personnel, only Chan et al. (2012) specifically mention operational barriers like physical and technical difficulties and that dismantling can be challenging. Abdulrahmen et al. (2014) and Kaviani et al. (2020) stated that difficulties in finding and coordinating with third party logistics providers was challenging, while Chinda (2017) concluded that "infrastructure to support the reverse logistics implementation" was among the least important factors.

Market and competition. Fawcett et al (2008) identified two market- and inter-firm competition barriers, namely that different actors and organizations might have inconsistent operating goals and that risks and rewards are not necessarily shared between the parties. Also relating to markets, Kaviani et al. (2020) identifies underdeveloped markets as a barrier.

Policy. Within the topic of policy and politics, Chinda (2017) identified "compliance to law and regulation" and "penalties" as important factrs for the implementation of RL. Furthermore, lack of governmental support can be a barrier for RL implementation (Richnak Gubova, 2021; Gonzalez-Torre et al., 2010). Gonzalz-Torre et al. (2010) point out that although the Spanish government shows little interest in environmental issues, this might be different in other European and developed countries. Kaviani et al. (2020) whose study of barriers for reverse logistics took place in Iran pointed out how lack of supportive laws also can be challenging. Kaviani et al (2020) also identified economic sanctions as a barrier and uses this as an example to underpin the following statement: "*The barriers to a successful implementation of RL in the automotive industry in developed countries do not apply to the Iranian automotive industry because the industry faces unique difficulties* (Kaviani, 2020, p. 7). These examples point towards that barriers for RL implementation must be seen it their geographical and geopolitical context.

People. The last barrier category is 'people'. An external people related factor is the risk of customers having doubts about quality of recycled goods (Chan et al., 2012, Kaviani et al., 2020; Gonzalez-Torre et al., 2010). However, Chan et al. (2012, p 1219) point out that "*people*

are now more concerned about environmental issues due to increasing awareness of environmental impacts and the legal requirements of disposing of vehicles", and that customer concern is becoming less of an issue. Fawcett et al. (2008) mention human nature as the main barrier and highlight the human tendency to be change averse. Chinda (217) found "workers concern about the environment" and "open-mindedness towards the use of recycled materials" to be of high importance, for the implementation of RL

2.3 Existing circular activities for bumper covers

Bumper cover recycling is not a new concept. An example of this is the car manufacturer Mazda who started bumper cover recycling in 1992. From 1992-2003 the bumper covers were recycled, or more correctly, downcycled to other car components, and in 2003 a technology which allowed for the quality demands for closed loop recycling was developed. Since 2005 they have practiced closed loop bumper cover recycling on a continuous basis (Nitta & Ito, 2013). Challenges they ran into in the early stages included, firstly, issues with the delay of return. In the time passing from production to EoL of the bumper covers, material choices had changed which challenged the quality. Secondly, the designs and construction of bumper covers made disassembly and collection of the bumper covers difficult and time consuming. Challenges were met by developing quality assurance systems and designing bumper covers for disassembly. Another strategy was to focus mainly on recycling bumper cover models that had more disassembly—friendly construction designs already. Winslow et al. (1997) published a set of design guidelines for easing bumper cover recycling already in 1997. These guidelines covered the topics like material selection, fasteners and adhesives, component design, plastic parts marking. Winslow's guidelines were developed to make bumper cover recycling economically feasible and to enable recycling, with the continually increasing use of plastic in cars in mind (Winslow et al., 1997). Zhang et al. (2016, p. 182) concluded that "*the performance of the bumper cover with 30% recycled material meets the requirements of production."* These examples show that bumper cover recycling is both technically and practically possible, however, bumper cover recycling is as of 2022 not common practice.

In addition to recycling, 'life-extending' activities are also practiced to some degree. Three life-extending practices are most common: direct reuse, cosmetic repair, and structural repair. Direct reuse is not offered as a service at car repair shops today, but at many car dismantlers cars are often available for people to come and pick up parts for free to reuse and install at their own initiative. This practice has, however, decreased steadily the last decades. One reason for this is that bumper covers have become a more technical part of the car, with sensors attached to it, making the task of replacing a bumper cover more difficult. Direct reuse is also possible as many cars that come into car dismantlers still have an undamaged front- or rear bumper cover. In these cases, the dismantlers can resell the bumper cover to car repair shops. This was common practice at the car dismantler visited and interviewed in this study.

Cosmetic repair is when minor scratches and marks from for example gravel are fixed by repainting. This is a service provided by many repair shops, and some repair shops also buy bumper covers with minor damages from car dismantlers and repair them for resale. Structural repair can be repair of larger cracks and marks. This can entail adding plastic or other material. Some car repair shops offer this as a service, but not all damages can be repaired like this,

partly due to severity of the damage, but often also due to guidelines. Within clearly defined radiuses around e.g. sensors, repair is not legal due to security reasons. This is further explained and illustrated in subchapter 4.7.1.

2.4 LCA-studies on bumper cover recycling.

In addition to reduced use of virgin material and economic benefits, using recycled plastic offers environmental benefits. Exactly how much GHG-emission reduction and water use reduction one can achieve varies from case to case with different technical solutions, energy mixes available, transport distances needed etc. According to an LCA study of bumper cover closed-loop recycling from year 2000 the environmental load from material production can be reduced significantly, with CO_2-emission reduction at almost 80 %, NOx-emissions reduced by 75 % and SOx-emissions reduced by more than 80 % (Makuta et al., 2000). The environmental load over the life cycle, however, cannot be reduced as much, since much of the emissions are related to the bumper cover production. This is much due to the energy needed for moulding bumper covers. The potential for environmental benefit is mostly restricted by the filling ratio – the percentage of recycled material versus the virgin material, the production technology used, and the energy mix where the production facility is located (Makuta et al., 2000). Hongshen & Ming (2013) also conducted an LCA study of producing new bumper covers with material from recycled bumper covers. They found that water consumption could be reduced by 20.8 %, energy consumption by 10.4 %, wastewater production by 26.8 % and gas- and solid pollutants from production decreased by 11.0 %.

3 METHOD

This project was conducted in an exploratory, qualitative approach and interview-based. The project case observed and investigated is new of its kind at Volvo, and the literature is scarce on the specific topic of plastic component circularity from a multi-actors perspective. Therefore, an exploratory approach was appropriate. Creswell (2009) states that it is appropriate to treat questions qualitatively when the topic is new and the variables unknown. Furthermore, interviewing is a successful method of inquiry when the aim is to identify the subjective understandings and views of the interviewees (Seidman, 2006, p. 11) .

Figure 2 shows which method steps address which research questions. Figure 3 provides an overview of the methodological process applied. Boxes in Figure 3 are colour coded to indicate whether the box represents a process or results. Numbers in the process boxes correlate with the numbers in Figure 2 and indicate which step in the process it was. Roman numbers represent steps in the method while regular numbers represent steps in the Actor system mapping (ASM) methodology. These numbers are also referred to in the continuation of the method description. The figure naturally simplifies the methodological process, in reality, many of the processes ran in parallel.

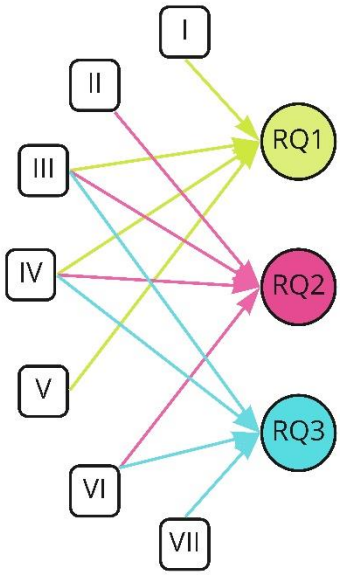

Figure 2: The links between the steps of the method and the research questions

ASM, as described by Desai et al. (2017), was used as a base framework and adapted to fit the project purposes. ASM is a method for visualizing an existing or a potential product-service system (PSS) with the actor networks, product- and material flows and information flows between the actors. Such visualization for developing or improving a PSS system helps identify important flows or the lack of such. Such knowledge about the flows of information and material between actors is, according to Desai et al. (2017), often missing or not sufficient, particularly in regards to a holistic understanding of the actors involved. As Volvo's bumper cover systems is still under development, the ASM tool is suitable for this project. One methodological adaption made was to exclude the focus on services, since the project of study is not service based. A stakeholder analysis was performed following methodology suggested by Reed et al. (2009) including a power- interest grid as described by Eden & Ackermann (2013). Finally, impact factors and categories thereof were identified and analysed, methodologically inspired by thematic analysis, and these findings were compared to the literature findings.

3.1 Step I: Obtaining a project overview

The first step of the project was to get a project overview. An overview of the project was obtained through video meetings with project initiators (A and B) and through the reading of documents describing the initiated bumper cover project. These conversations and readings

allowed for understanding the scope of Volvo's project, what work had been conducted so far and what work was planned in the next phases, and for mapping out initial contact persons and potential interviewees. Obtaining an overview also led the way for setting a direction in the literature search, forming the research questions, and determining the scope of the thesis. Obtaining a project overview and determining the thesis scope partly overlapped with ASM step 1. In ASM step 1 the system is identified, the focus and ambition level is determined, and how the analysis will be performed is decided.

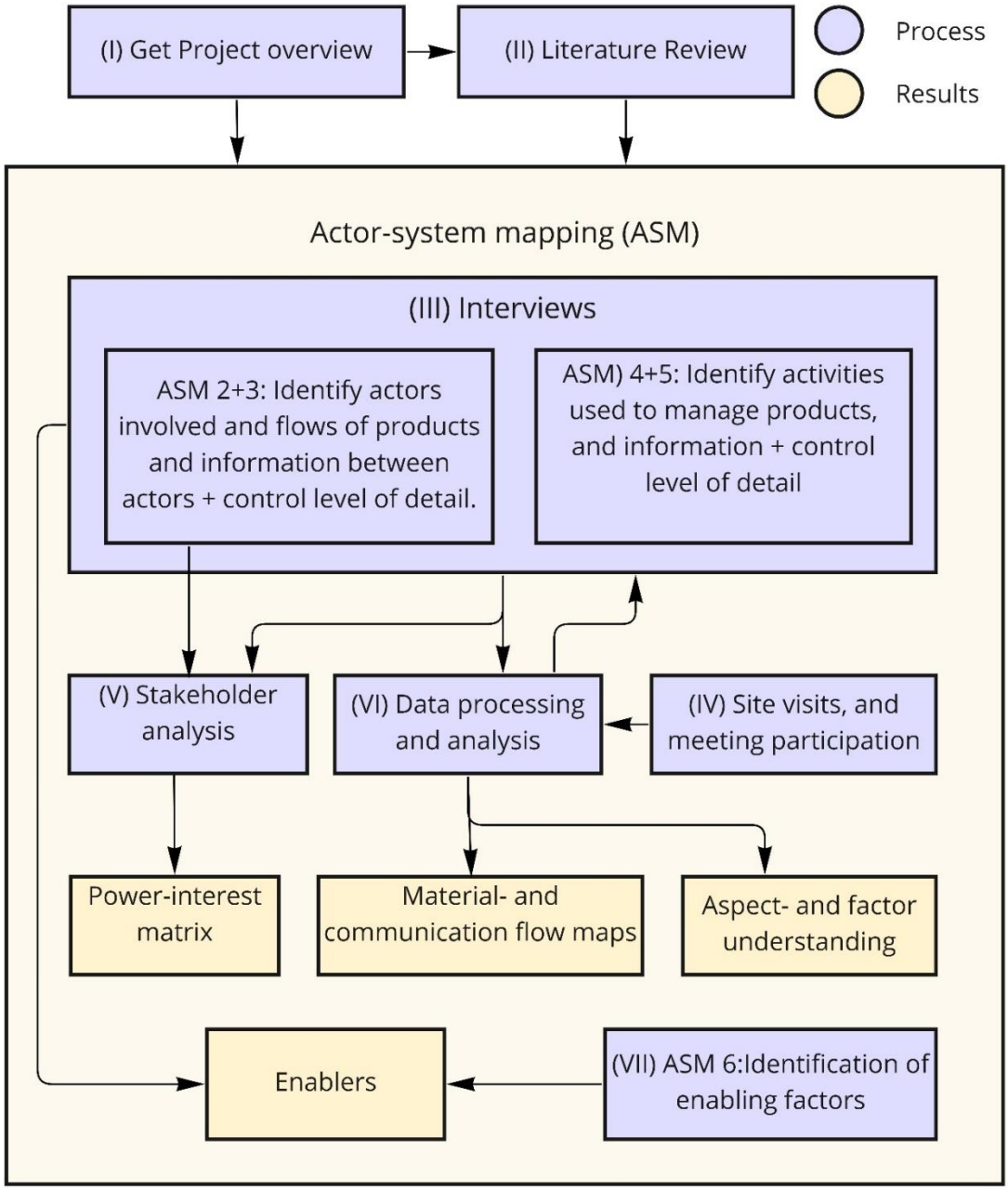

Figure 3: Illustration of the steps of the method used in this master thesis.

3.2 Step II: Literature review

A literature review was conducted to better understand what types of knowledge are currently available in the reverse logistics field and identify common challenges related to take-back systems. Scopus was used as the main search platform and key words such as *reverse logistics, barriers, challenges, factors, circular economy, automotive, bumper covers,* and combinations of these were used across multiple searches. In addition, reverse literature search both from research articles and review articles was done. Interesting findings were summarized in text, and barriers, enablers and critical factors relating to reverse logistics were catalogued in a table. The literature review focused on articles concerning the automotive industry, but additional articles on the construction industry or on multiple industries were added, as they contained relevant input on barriers and factors relevant in circular systems.

3.3 Step III: Interviews and Actor system mapping

Interviews were used as the main source of data and were conducted as a part of performing steps 2-5 of the actor system mapping (ASM) methodology. Desai et al.'s (2017) ASM methodology suggests using workshops or interviews. Rather than group interviews or workshops, individual interviews were chosen. While individual interviews are time-consuming, one-on-one interviews helped to ensure that people's perceptions remained uncoloured by a group discussion and other's perceptions. Furthermore, the ASM steps 2-5 were conducted in parallel rather than sequentially, as it was appropriate to gather all the necessary data in one interview with each actor. In addition to gathering data as prescribed in ASM 2-5, the interviews focused on factors which did or could impact the material- and information flows, and the activities performed in relation to these.

ASM step 2 is to identify actors involved in the project, the flows of products and material, and information flows between actors ASM step 4 is to identify the activities used to manage the products, product flows and information flows. ASM steps 3 and 5 are to control that the finding of ASM steps 2 and 4 are correct and at a sufficient level of detail. The method suggests arranging a workshop for ASM steps 3 and 5. However, analysing the available findings and consulting the project initiator, who was also an important actor with a good overview over the project and project actors, was chosen instead, as this required less organizing and was deemed sufficient.

One finding in the data analysis was some discrepancy between the opinions and facts presented regarding new component production and technical feasibility and challenges. It was therefore decided to consult with an outside materials expert. A plastics material expert was contacted and interviewed. The focus of this interview was narrower than in the other interviews, as she was not an actor in the bumper cover chain. The expert's opinions and statements were judged to be of high value due to her experience in the field. She has 26 years of working experience in the field, including 10 years of experience in plastic material science in the bumper cover producing company involved in the bumper cover project. She was employed at the Norway facility of the component producing company, but now works for a

different company. Employment titles include senior development engineer, R&D manager, research manager, etc.

3.3.1 Interviews

In total, 12 interviews were conducted. The interviewees were categorized in four groups: 1. Volvo department representatives and project initiators; 2. plastic recycling, material producers and component producers; 3. car repair shop and dismantlers; and 4. other. The interviewees and the interviewee categories are presented in Table 1. The colour coding is used throughout the report. Blue represents the Volvo department representatives, green represents the repair shop and dismantler, and orange represents the recycler, material and component producers. Other are shown in white. A letter is assigned to each interviewee, and the letter is used when referring to them in the results. The interviewees were chosen based on their active participation and relation to the project, and with the aim to have a representative from each link in the circular chain. Two of the project initiators were first interviewed, representing different departments at Volvo. These project initiators provided a list of potentially relevant people. In addition, they explained which parties they had contact with in the project, who their contact persons were in the involved organisations, and in what way these people and organisations were connected to the bumper cover project. This information was used to choose further interviewees, as described in step one of the stakeholder analysis. Seven of the interviews were conducted in person while four were conducted over video-call.

The interviews were semi structured to allow for an exploratory approach. The interviewees were all asked questions with a similar focus, but with some variation to adapt to the different roles of the interviewees and the activities of the organisations they represented. A list of interview questions can be viewed in Appendix I: Interview questions. Interviewees did not receive questions in advance. The interview conversations were accompanied by a figure showing some of the main actors in the value chain. This figure can be seen in Appendix II: Simple Flowchart used during interviews The figure was used to support questions concerning how the material- and information flows looked, or could look, and also as an aid in discussing factors which influence the flows, barriers and enablers. In the physical interviews, the figure was brought in A3 format along with markers in different colours, while in the online-interviews the figure was either shown through shared screen or shared by a direct-access link. Participants could choose to either draw on the figure themselves or to describe what should be drawn. All interviews were recorded and then transcribed.

Table 1: Overview of the interviewees, including information on what organization they represented, their position in the company or department and how many years they had held that position.

	Department/ company	**Position**	**Years in position**
	Volvo department representatives		
A	R&D sustainability centre	System architect, strategic enabler.	3
B	Service business, Commercial	Handling of after-market questions relating to plastics and EOL cars	24
C	R&D, construction plastic exterior	Project leader for new cars	4
D	Gothenburg Local Distribution Centre (LDC)	Runs the Gothenburg LDC	1, but many years in logistics at Volvo
	Material- and component producers and handlers		
E	Recycling company	Account manager for Volvo AB	20
F	Material production *	Responsible for recycled products for sale; Procurement of recycled sources for production	- ; 8

G	Component producer	Material specialist for plastic materials and granulates	1, and 15 in the field (phd)
	Repair and dismantling		
H	Car dismantler	Head of production and repair shop	19
I	Car repair shop **	Responsible for the damage department	4
J	Car-repair shop	Mechanic	
	Other		
K	Composite component manufacturer	Head of Research and sustainability. Previous experience in material engineering and as manager for research on plastics for car components (including bumper covers)	
L	Special parts repair and method development	Key account manager.	

* Two representatives took part in the interview, but they are treated as one case.

** The repair shop where the interviewee works is owned by Volvo, but categorized as Repair and dismantling since this indicates better their roles, and since they are thought to represent other repair shops, which are not owned by Volvo.

3.4 Step IV: Site visits and meeting participation

Five site visits were conducted as part of the data collection. Three repair shops were visited, whereof one was the one who's manager was interviewed. A tour of the interviewed dismantler's facilities was conducted, which also allowed for conversations with mechanics. Finally, one material recycler was visited. However, the recycler that was visited was not the same recycler who was interviewed. The site visits allowed for a better understanding of the activities and potential material flows, along with more input on impact factors and attitudes. Notes were taken during and after the visits. Notes were also available from site-visits conducted by project partners at Volvo.

In addition to site visits, Volvo allowed the author to participate in meetings concerning the bumper cover project. This included meetings between Volvo employees and meetings between Volvo representatives and representatives from other organisations.

3.5 Step V: Stakeholder Analysis

The general use of 'actor' in this thesis is separate from the description of this particular stakeholder analysis. The terminology used in Eden & Ackerman's (1998) framework is used throughout the stakeholder analysis sections.

A stakeholder analysis is a three-step process as suggested by Reed (2009). The three steps are as follows: 1) identifying stakeholders; 2) differentiation between and categorizing stakeholders; and 3) investigating the relationship between the stakeholders. Reed (2009) lists a variety of methods and frameworks which can be used for each step. The methods used in this project were chosen as they fit the purpose of the project and because they partially overlap with the methods of actor-system- mapping. The stakeholder analysis is coupled to ASM step 2 which is to identify actors, and thus provides additional data on the actors to provide the reader with context and insights.

First, stakeholders were identified. This was done through unstructured conversations with the main players/organizers at Volvo and through semi-structured interviews. Snowball-sampling was also embedded in those conversation and interviews. An example of this is that person A raised awareness of person C, who introduced persons F and G.

Secondly, stakeholders were differentiated and categorized. The author used an analytical top-down approach but consulted the main organizers to verify and clarify uncertainties. Other stakeholders were not included in the categorisation, but information collected in interviews with different stakeholders was used as a basis for the analysis. Eden and Ackermann's (1998) framework was used. In this framework, stakeholders are plotted in a matrix based on their level of interest in the organisation developing the strategy or project, and their level of power or influence on the realisation of the strategy or project. Based on this, the stakeholders can be divided into *players*, *subjects*, *context setters* and *crowd.* Since step one and two were conducted in an iterative manner, the differentiation was also used to determine who to interview. Only people with legitimate interest, meaning representatives in the categories *players* and *subjects,* were chosen for interviews.

Lastly, the relationships between stakeholders were investigated. The relationships were investigated as part of step two of the ASM, and visualized in figures over material- and product flows, and information flow between the actors, along with descriptions of activities relating to these flows.

3.6 Step VI: Data processing and analysis

The interviews were all transcribed and then analysed. Concepts and methodology from Lester et al. (2020) and Braun & Clarke (2006) articles on thematic analysis were used as a basis for the analysis. Analysis was done through first going through the transcriptions with colour coding to establish a rough sorting of the interview contents. Along with the colour coding, notes were scribbled along the sides of the pages to indicate topics or concepts, or the authors initial ideas or interpretations. On a second read through keywords from all the interviews were written down and categorized on different sheets of paper and again revisited and partly moved around. This resulted in the identification of seven main categories. The importance of different impact factors was determined based on the number of interviewees talking about them, how the factors were described by the interviewees, and the factors' relevance for the bumper cover flow.

In order to properly report on the findings, the impact factors within each impact factor category are presented along with an overview of which stakeholders spoke of or had opinions on each impact factor. Additionally, descriptions of what was reported on the impact factors, and selected quotes from the interviews are presented.

3.7 Step VII: Identification of enablers

The last step in the method is also the last step in the ASM methodology, namely, to identify improvement possibilities, or enablers. Initially, improvement possibilities which arose during the interviews and data collection were summarised. To explore the possibilities to overcome existing and potential challenges in the circular bumper cover system, a follow up conversation was arranged with two of the Volvo representatives, (A and B). The identified categories and impact factors were presented, and *A* and *B* were asked to reflect and talk freely around the importance of these and how they could be overcome. They could themselves impact which impact factors were given the most attention. Follow up questions and guiding questions were asked to encourage elaborations and reflections.

3.8 Method outputs

The results of the methodological process are presented in the results. Many of the results are visualized or summarized in tables and figures. Tables were made in Microsoft office and figures were made with Miro.

4 RESULTS

4.1 Alternative scenarios for material flows and involved actors

Volvo is using a selection of working hypotheses for how the bumper cover flow should be organized. There are still many decisions to be made. The impact factors which are investigated in relation to bumper cover-circularity-scenarios are in general very similar for each scenario but vary slightly. Below three main scenarios are be presented. These scenarios are based on Volvo's scenarios, but slightly simplified.

Volvo has existing, regular transport between the local distribution centres (LDCs) and the repair shops. These transports bring parts that will be used for repair to the repair shops and occasional parts Volvo or Volvo's suppliers want to investigate in relation to insurance- or quality questions back to the LDC. The existing transport lines are to be utilized since the transports currently bring more goods out to the repair shops than they have on the return drive. This also means that the return logistics will not add much extra cost. This transport is thought to be used in all the scenarios. Figure 4 shows an overview of all three main alternatives for material flow.

***Alternative 1*:** One alternative, as illustrated in figure 4, is that from the LDCs the material continues to the central distribution centre (CDC) where Volvo would have a process for quality control and shredding of the material. From here the material would either be transported to or picked up by the material producer located in Sweden, who can produce pellets, and then sell the material on to the component supplier.

***Alternative 2*:** Another alternative, as shown in figure 4, is that after the bumper covers have all been transported to the CDC via the LCDs, a recycling company will pick them up and perform the shredding process. The recycler would then sell the recycled material to the material supplier who later sells it to the component supplier.

***Alternative 3*:** A third alternative, see figure 4, is that the bumper covers will be transported from the CDC to the European distribution centre in Maastricht, Netherlands. From the Netherlands, the bumper covers would then be transported to material and component producers in Germany and Poland. This alternative is only an option after scale-up if several European markets are included in the project.

In addition to these main alternatives, variations of these are also being discussed. For example, it is not completely established what plastic processes can be conducted by the recycler, and which processing is needed for the plastic material to be ready for the component producer. Depending on what kind of plastic processing is needed and what kinds of processing (e.g. shredding) can be conducted by which company, the material producer, the recycler or both can potentially be removed from the chain.

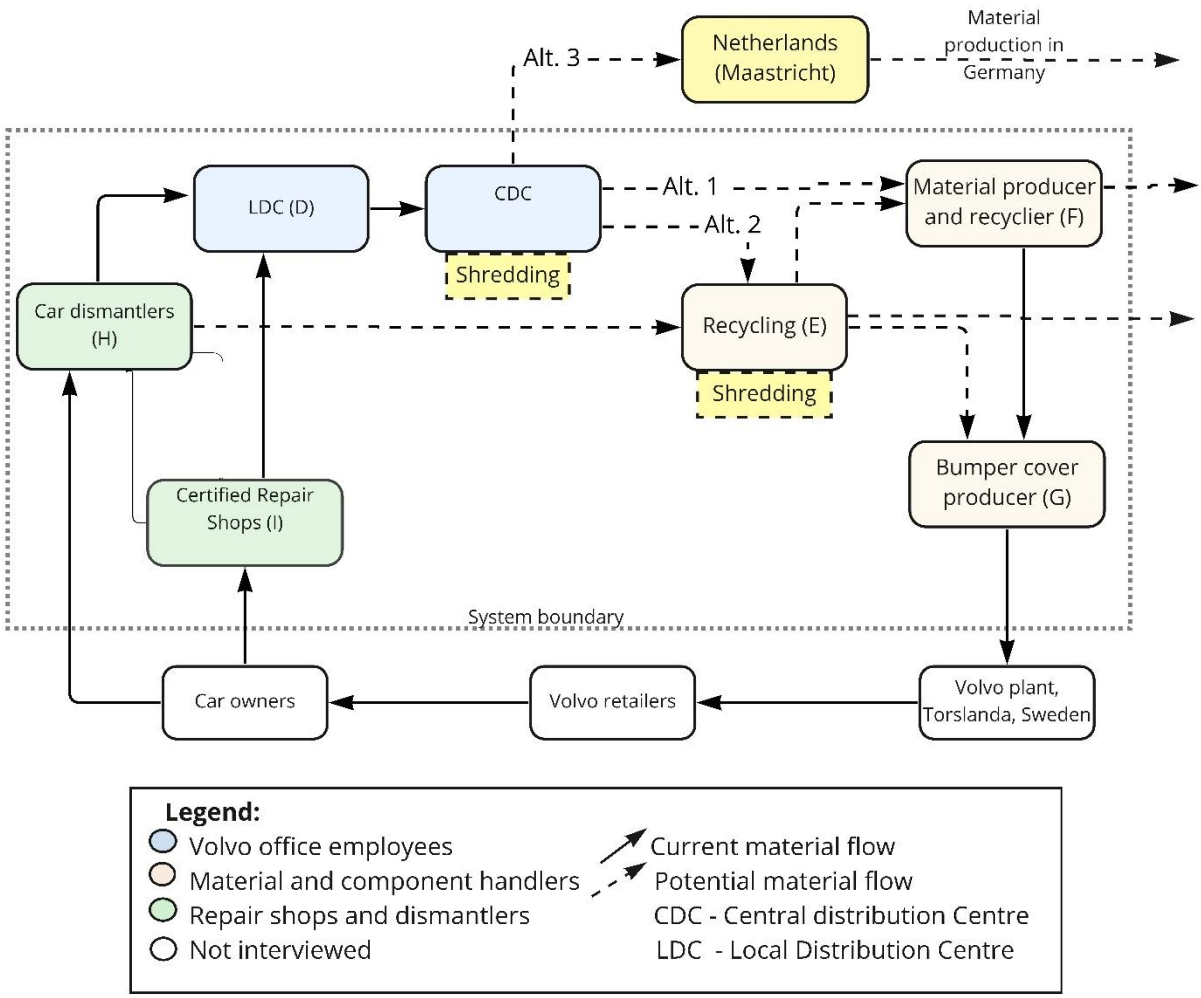

Figure 4: Alternative material flow scenarios. Solid arrows indicate certain material- or product flows, while dotted lines represent potential flows. Alternative 1 and 2 differs in whether the bumper covers will be shredded at the CDC or at an external recycling company. In alternative 3 the material would be handled abroad.

4.2 Stakeholder analysis: power-interest matrix

A stakeholder analysis was conducted. Step one of the stakeholder analysis was to identify stakeholders. This resulted in the list of interviewees presented in Table 1 in subchapter 3.3.1. The second step of the stakeholder analysis was to differentiate between and categorize the stakeholders. The interviewees are sorted based on at what kind of company they work at. Eden and Ackermann's (1998) framework for stakeholder analysis using a power-interest matrix was applied to further differentiate and categorize the interviewees based on their level of power to influence and interest in the bumper cover project. This chapter focuses on the second step of the stakeholder analysis and Table 2 and Figure 5 show the results of this step. The third step of the stakeholder analysis was investigating the relationships between the stakeholders. This resulted in a visualization (see Figure 4) and description of the actual and potential material flows presented in subchapter 4.1 and in visualisation (see Figure 6) and description of information flows in subchapter 4.4.2.

Table 2 lists the stakeholders and provides an overview over their employment and their power to impact and interest in the bumper cover project. Interviewee A-J are considered actors, while the interviewees K and L in the category "other interviewees" are not actors in the bumper cover project. By *interest*, a stakeholder's "stake" and interest in the organisation, or in this case, the project's strategic shape and future is meant. *Power* refers to a stakeholder's ability to impact the future and shaping of the project (Eden and Ackermann, 1998).

Table 2: Stakeholder description and analysis

	Department/ company	**position of interviewee**	**Power**	**Interest**
	Volvo department representatives			
A	R&D sustainability centre	System architect, strategic enabler.	High	High
B	Service business, Commercial	Handling of after-market questions relating to plastics and EOL cars	Medium	High
C	R&D, engineering design, plastic exterior,	Project leader for new cars	Medium	High
D	Gothenburg Local Distribution Centre (LDC),	Runs the Gothenburg LDC	Medium-high	High
	Material- and component producers and handlers			
E	Recycling company.	Account manager for Volvo AB	Low	High
F	Material production	Responsible for recycled products for sale; Procurement of recycled sources for production	Low	High
G	Component producer	Material specialist for plastic materials and granulates	Low	High
	Repair and dismantling			
H	Car dismantler	Head of production and repair shop	Low	Low-medium
I	Car repair shop	Responsible for the damage department	Low	Low-medium
J	Car repair shop	Mechanic	Low	Low-medium
	Other interviewees			
K	Composite component manufacturer. Head of Research and sustainability. Previous experience in material engineering and as manager for research on plastics for car components (including bumper covers)		Low	Low
L	Special parts repair and method development. Key account manager,		Low	Low

The sustainability centre at the research and development department at Volvo (R&D) has the most power among the interviewees in shaping what the circular system can, and potentially will, look like. However, this department is not in a position to take the decision to run the project full scale or not. This decision belongs to a leader group at a different department several levels up in the hierarchy. This group and department are the ones who can decide if money will be allocated to the project or not. The power of the sustainability centre at R&D has still been categorized as high since the sustainability centre has the most power among the identified stakeholders. Among the people active in the project, the sustainability centre at R&D are designing the project, and thus can be said to have more power than the decision makers, in some respects.

The interest of the Volvo department representatives is judged to be high. The sustainability department is highly interested since the project directly relates to sustainability, which is in the mandate of this department. The construction department has high interest because this project entails new guidelines and impacts the freedom of design of the employees of this department. In addition, the aftermarket (commercial) department is judged to have high interest because EoL treatment of products is in their mandate. The interest of the material and component producers- and handlers has also been rated to be high because of the economic interest of the relevant companies. The interest of the car repair shops and dismantlers is rated as low-medium. The added work of handling the bumper covers for recycling makes little change on work procedures and economy of the businesses, and the representatives have expressed that doing the added work is fine. When evaluating interest, the focus has been on the interest of the organisations. Several of the interviewed representatives expressed strong personal interest in and enthusiasm for the project, much motivated by environmental values. This has been disregarded in the power-interest-evaluation.

Figure 5 shows the stakeholders placed in a power/interest matrix. The placement left-right indicates the degree of power, or influence they have on the project and the placement down-up indicates the actors' interest in the project and how it is shaped. For a more detailed indication of the actors' interest and power see Table 2 and the description in the text above. While a matrix of four boxes is a major simplification of reality, the matrix illustrates the impact and interest of the interviewees and organisations. A majority of the actors have been identified to belong both to the box of players and to the box of subjects. However, most actors fall more heavily into the 'subjects' box, as their power is lower than that of the "real players".

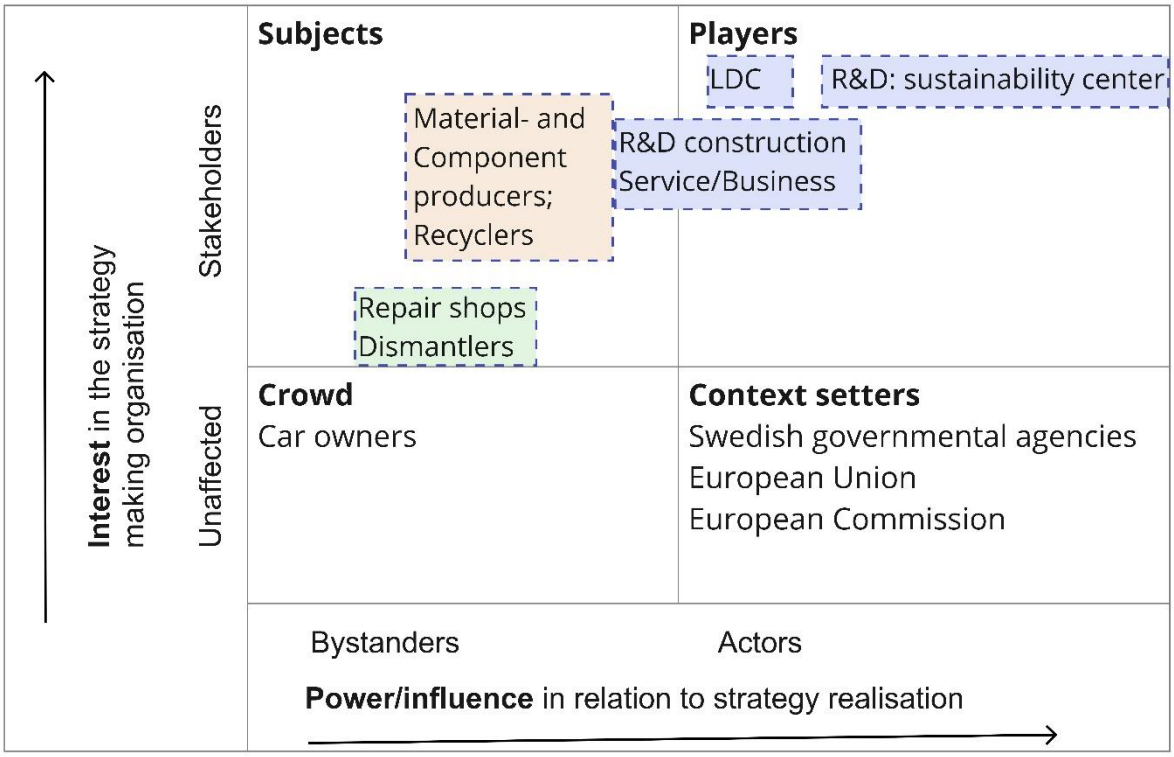

Figure 5: Power-interest matrix, in accordance with methodology developed by Eden and Ackermann, 1998

4.3 Information flows /communication channels

Figure 6 shows the possible flows of bumper covers and bumper cover material and the communication flows between the involved actors. There are more material flows, like flows from the spare-part factory to the repair shops, but these are not included as they are not relevant for this project. Some communication channels are active and regular, while others are used more sporadically, if something special comes up. An example of sporadic information is the reporting of labels not being compatible with the polypropylene (PP)-plastic recycling. The material producer *F* experienced that labels attached to the bumper cover could impact the quality of the new material, and that these labels were difficult to remove. This was communicated to the engineering design group to encourage the development of a solution. Some communication channels are also expected to become less active as the project goes on. This is for example the case for the communication out to the repair shops. As the repair shop employees learn the new routines further instructions will not be needed. Occasional "check ins" might still happen though, or updates for alteration in the routines. Figure 6 makes it clear that many interactions are needed for a circular flow of the bumper covers to work well. Some information flows have been added for this project, while some information can be transmitted through information flows that have been in place for a while. The difference between these is not indicated in Figure 6. Furthermore, the departments at Volvo cars also share information with each other. These information flows are, however, excluded from the figure for figure readability.

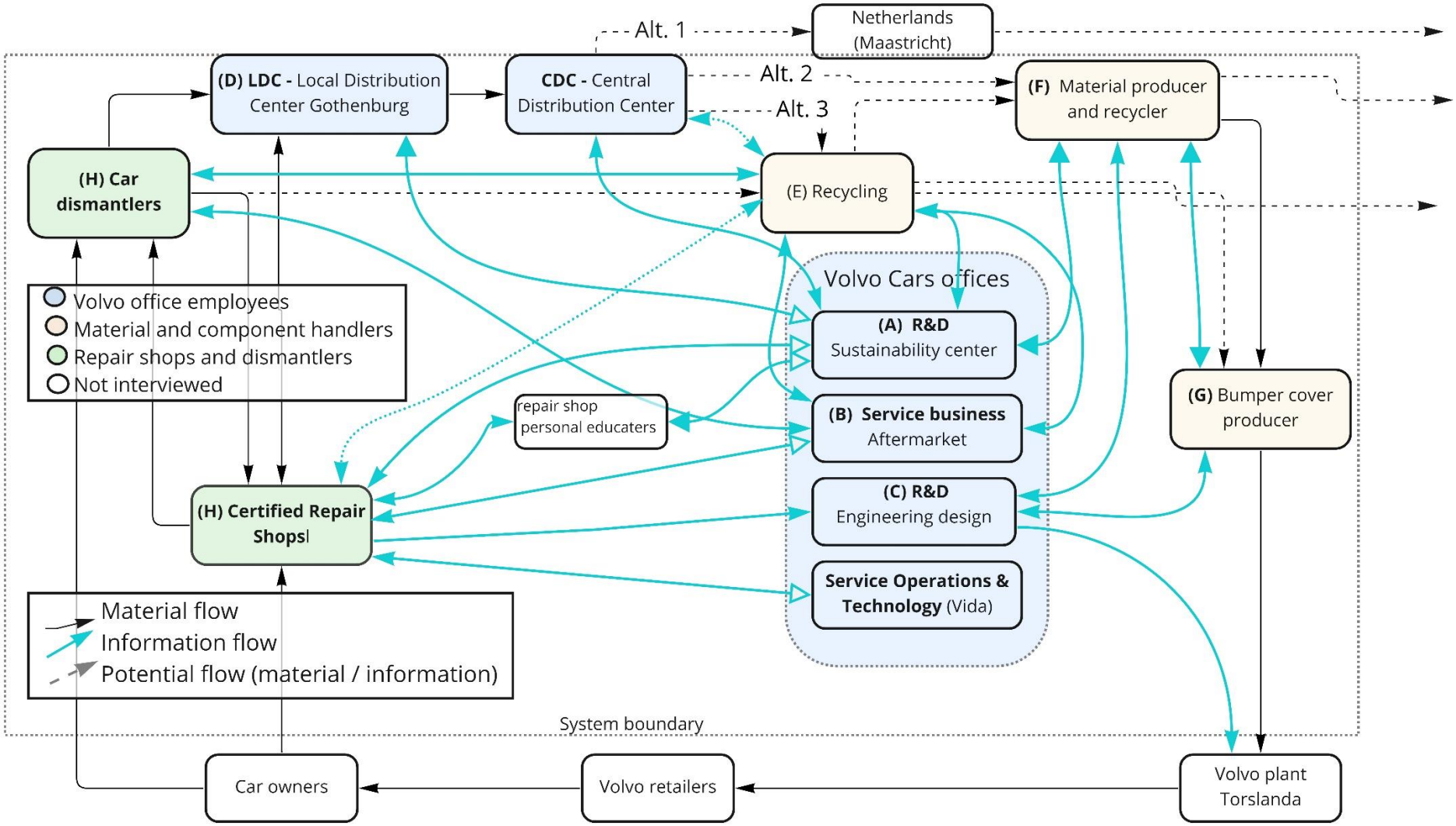

Figure 6: Material and information flows. Black arrows indicate flow of bumper covers or bumper cover material, blue arrows indicate information exchange. Open arrow tips indicate that only a little information goes this direction compared to the flows indicated by filled arrow tips.

4.4 Activities

A variety of activities are involved to manage the bumper covers and bumper cover material. This includes physical activities in handling the bumper covers or the bumper cover material and activities for communication and organization. The following subchapters presents the different activities conducted by the different actor groups.

4.4.1 Activities to handle the bumper covers

Volvo Departments. At the engineering design department bumper covers are designed in such a way to facilitate dismantling and recycling. This includes for example avoiding parts in non-PP plastic and metal being moulded into the bumper cover. When external suppliers are used, either for materials of for component construction, an 'engineering statement of work' is sent, and specific demands regarding recyclability and disassembly are stated. One issue that arose in the recycling process is that labels with information on the component and material, which is attached to the bumper cover are made in paper, and thus not ideal in the recycling process. To deal with this, solutions for producing PP-compatible labels are being developed. Bumper covers collected at different repair shops are collected at the LDC. Here they will be restacked to pallets or containers, and a quality control will potentially be conducted. Quality control is performed to control that the bumper covers are properly stripped from non-PP parts like clips and screws. With the current volumes this work can be manages by the current employees at the CSC and LCS, but when the bumper cover project is scaled up, extra personnel might be allocated to the tasks of restacking and quality control. Additionally, space must be allocated for storage of the bumper covers before they are moved to the CDC or collected by the recycler. The sustainability centre, *A*, and commercial/aftermarket, *B*, are active in planning and development of the program, and are active in collecting, analysing and sharing information for getting the flow up and running. The department for service, operations and technology (SO&T) is responsible for developing a new product group for EOU products to facilitate handling these in the information system Vida.

Material and component producers. Depending on which scenarios are chosen and how costs are allocated, the recycling company and the material- and component producers will get bumper covers or material delivered to their facilities or pick it up themselves. They will potentially also perform quality control to oversee that no incompatible parts are present on the bumper covers, like non-PP plastic clips or metal parts. The recycler will potentially shred the material into flakes, the material producer makes pellets and improve the material quality through performing material analysis and adding additives. The component producer will choose a suitable material mix, produce components and, depending on type of component, potentially also do a paint job.

Repair shops and dismantlers. Repair shops receive damaged bumper covers and judge whether to repair or change a bumper cover. If the bumper cover is to be exchanged for a new one, the mechanics must transfer many of the parts attached to the previous bumper cover to the new bumper cover, since things like clips and cables do not follow with the new bumper cover. A picture of the inside of a bumper cover with cables and clips can be seen in

Appendix III: Pictures of bumper covers In addition to removing these parts some labels and the lid covering the tow hooks must be removed. When a bumper cover is fully stripped for non-PP-EPDM-parts it is cut in two and stacked on a trolley. A picture of bumper covers stacked on a trolley can be seen in

Appendix III: Pictures of bumper covers The cutting serves the purpose of fitting the bumper cover on the trolley.

4.4.2 Activities of communication and system management

Three main purposes for communication were identified through the interviews: informing about procedures and demands; collecting information on feasibility; and shaping attitudes. Additionally, information is exchanged for the purpose of planning collection of bumper covers or material, reporting experiences, planning and executing the pilot project, and collecting feedback on the project. There are many activities for information sharing, as described in the following paragraphs.

The Volvo department representatives reported sharing or receiving information through meetings, workshops, site visits, e-mails, and informative documents. Informative documents could include reports, cost estimates and project descriptions, or making 'Engineering statements of work', which are documents containing specifications on quality demands, which are given to suppliers. Additionally, the department 'systems, operations and technology' (SO&T) adds information to the system 'Vida' which contains method descriptions for disassembly and repair, prices, and other information which can be of value for repair shops. Volvo representatives *A*, *B* and *C* are most active in information sharing and site visits, while *D* is less involved. *B* mentioned that they have very few workshops, and that having more workshops could be beneficial. B also said that the site visits are an important arena for working on attitudes and motivating the actors.

The recyclers, material producers and component producer also take part in meetings and e-mail exchanges, host site visits and receive engineering statements of work. The information sharing can be about results of process and quality tests relating to the PP-EPDM material, needs and preferences concerning transport, packaging, and about what they can offer or demand relating to payments and contracts.

The repair shops and dismantlers mainly receive information and have relatively few interactions compared to the other actors. They receive information on what and how to disassemble, and on the purpose of the project, and give feedback on experiences relating to taking part in the project. They have also hosted site visits, but this is an activity which will be less frequent in the continuation of the project.

4.5 Factors impacting the circular flow of bumper covers

Through the data analysis seven impact factor categories were identified. These are *operational and logistics, technical and quality, economics, people and attitudes, policy and regulations, ownership and control,* and *information and communication.* In addition, a last category, *other,* was added. A total of 28 impact factors were identified and between three and six factors, were found within each category. There is a natural overlap between some of the categories. For example, issues relating to packaging and handling of the bumper covers impacts economics, and information flow aspects relate much to attitudes. In the following subchapters each category and the impact factors are presented. The "x"-markings in the tables indicate if the actor had input on the topic

The repair shop and dismantling representatives, *H* and *I* had the least input and opinions with input on three categories and on four and six factors, respectively. The material handlers and the Volvo representatives all had input on each category. On average the actors had input on 12.5 impact factors each. The number of factors each actor had input on can be seen in Table 3.

Table 3: Overview of how many factors each actor had input on.

Actor	A	B	C	D	E	F	G	H	I
Number of factors they had input on (N = 28)	17	12	11	9	20	12	6	4	6

4.5.1 Operational and logistics

The category 'operational and logistics' concerns aspects relating to physical handling of the bumper covers, including the stripping, transport, storage, shredding and similar. Table 4 shows an overview over which interviewees had input on the different aspects concerning operations and logistics. Six impact factors were identified:

- time needed for stripping the bumper cover at the dismantler vs at the repair shop
- bumper-to-air ratio
- storge and space
- material security
- need for a process
- added workload for Volvo.

The time needed for stripping the bumper covers at the dismantlers vs at the repair shops and the bumper to air ratio were identified as the most important impact actors, and potential barriers in the operational and logistics category.

Table 4: Overview of which interviewees had input on which topics. The interviewees represent the following departments or company types: A-sustainability centre; B- aftermarket; C- engineering design; D – LDC; E- recycler; F- material producer; G – component producer; H – dismantler; I – repair shop.

Category: operational & logistics / stakeholder	A	B	C	D	E	F	G	H	I
Time needed for stripping at dismantlers vs at repair shops		x			x			x	x
Bumper-to-air ratio		x		x	x				
Storage and space	x	x			x	x		x	x
Material security	x			x		x	x		
Need for process				x					
Added workload for Volvo		x							

Handling of the bumper cover. The representatives of the repair shops and of the dismantler employee all agree that the stripping job itself is easy and involves no challenging tasks. The time for stripping, cutting, and stacking the bumper covers has been measured to 30-120 seconds by the repair shop workers. Variations in handling time can be explained by two main reasons. Firstly, some bumper covers are more damaged than others, and the stripping job thus

becomes more impractical. In cases where bumper covers are too broken, some also choose to discard the bumper covers as combustible instead of returning them. Secondly, one repair shop reported that the mechanics share one cutting tool, while at another repair shop all mechanics have their own cutter. Not having to go and get the common cutter seems to save much time on the job. The repair shop where the cutter is shared also reported having invested in a new blade better suited for cutting plastic, while none of the other repair shops had done this. At the car dismantler they agreed that the handling of the bumper cover was easy, but the handling time was measured to take 5-10 minutes. This matches what was pointed out by the aftermarket representative *B* and by *E*. At a repair shop most of the stripping is already included in regular bumper cover handling, while at the car dismantler the job is changed from not removing any parts (except maybe cables and electric components) to removing all parts. The measured time included stripping, stacking and handling the pallets the bumper covers were stacked in. Since time is a cost, handling time can impact both profitability and the dismantlers need for compensation.

***Storage, space, and bumper-to-air ratio*.** There is a general agreeance that transport and storage presents no larger issues. The sustainability centre representative has not received any critical feedback on this. The repair shops and dismantler all report that transport and storage work fine. The repair shops, who in general have less space available than the dismantler, point out that the steady and regular pick up of the bumper covers is what makes it work. Pick up happens automatically, and they never end up having many trolleys stored. The issues of storage, packaging and transport are rather of an economic manner. Bumper covers are bulky, as stated by many of the interviewees. Due to the large size and bent shape of bumper covers it is not possible to stack them tightly and there will be much air between the bumpers – a low bumper cover-to-air ratio. Low bumper cover-to-air ratio means that the volume of bumper covers that can be transported in one container or in one truck is relatively low which maters for economic and emission related reasons. Neat stacking of the bumper covers can increase the ratio to some extent, but only through shredding the bumper covers a high bumper cover-to-air ratio can be achieved. When the bumper covers go from the repair shop to the LDC they go in existing transport. If separate transport is to be arranged for the bumper covers, the degree to which the transport containers are filled matters more. The recycling company representative, *E*, said that the packaging structure worsened much after the bumper covers were restacked from pallets/trolleys to containers, and that this was an issue, as they do not want to transport air. He further suggested maybe cutting the bumper covers twice – into three pieces could help this issue. The LDC representative, *C*, suggested that the bumper covers ought to be shredded as early as possible in the chain to increase the transport efficiency. *A* explained how the restacking of the bumper covers from trolleys/pallets to pallets/containers is necessary since the trolleys should be kept in the internal flow, and also the material handling -and producing companies have preferences on which containers they prefer to handle. The recycler, *E*, mostly uses containers and have transport arrangements adapted for this. The material producer needs to receive the bumper covers on pallets, since they do not have equipment or logistics to handle containers.

At some point the bumper covers will need to be shredded. This can take place at the LDC or CDC, at the recycler's facilities or at the material producer's facilities. The decision will impact transport, stacking and handling for transport and costs of storage and transport. There is no consensus on what the best option is. Having a shredder at the LDC or CDC will imply added

investment costs for Volvo. *D* suggest that in the future Volvo should find a way to have the bumper cover recycling run with as few third-party handlers as possible. The investment and installation of a shredder at Volvo's own facilities need planning though, since shredders not only need space allocation, but also because they make much noise. Therefore, not all areas are suitable locations. What considerations need be taken to facilitate transport will also depend on how the transport and collection is organized.

A last point regarding storage of bumper covers- and material was added in the additional interview with *K*. Respondent *K* pointed out how the lean management philosophy might not be fully adapted to the work with recycled material. Extra storage might be needed when saving up for big enough batches before transporting and at the component producers facilities, as they might want to hold back on material to spread it out evenly in the production.

Material security, steady flow. A practical issue particularly important for the material- and component producers is that of material security and steady material flow. The LDC representative pointed out how being able to deliver a steady flow of bumper covers or bumper cover material is important if Volvo wants to be an attractive material supplier for the material producer. Both the material and the component producer representatives said that having a continuous flow is important. The material producer further said that limiting the mix-in ratio could be a way to secure continuity in the mix-in ratio, by creating a little buffer at their own facilities. The component producers suggested that having a back-up material would be a strategy to make up for the risk of an unsteady bumper cover material supply. Further the reliability of bumper covers as a material supply was discussed by the LDC representative and the component producer. They pointed out that one needs to rely on cars being damaged, and that cars are becoming more secure through the addition aids like sensors and automatic breaks. Further it was discussed how external events like fuel prices and the corona pandemic impacted the number of bumper cover damages. The pandemic and increased fuel prices both led to people driving less, and increased fuel and electricity prices could also make people drive less or with more care.

Added workload. Organizing and running the reverse logistics, securing material quality, developing agreements with third parties and dealing with adaptions to use the recycled material entail added work and administrative burden for Volvo. The question was raised whether the ease of letting third party actors take care of a larger portion of the flow can be worth the loss of material flow control, since the bumper covers need much handling.

The need for a clear process. The need for a clearly defined process was addressed by *D*. The interviewee presented hypothetical questions like "*If [something] doesn't work, who do I contact, who do I talk to, or if we need to expand, who do I talk to*". Such a process description should contain guidelines for these questions. Since the reverse logistics of bumper covers differentiate from other material and component flows at Volvo, existing processes cannot be directly transferred.

4.5.2 Technical and quality

Technical aspects concern what is technically possible or challenging, and includes matters concerning material processing, component production and treatment. Aspects of quality include the demands set by Volvo, both for mechanical and safety matters and esthetical

matters. Bumper covers have developed from being purely an aesthetic component of the car to now, being the location for many of the sensors and electronic components increasing the safety of a car. In parallel with this the standards for aesthetics have also developed, for instance in that the gap between exterior components now is to be as narrow as possible. These changes add to some of the technical and quality related factors. *K* explained the increased aesthetical standards for bumper covers and included this statement:

> "*A bumper [cover], it is the jewelry of the car, kind of. And it does not have a lifesaving function anymore, right, but it has a function which is, you know, you want to show quality.*"

There are many aspects and factors impacting the feasibility of bumper cover recycling and material reuse. This section is more elaborate than others to provide a full picture of the challenges and factors brought up by the interviewees. The majority of information on this topic came from the current materials specialist in the component producing company, *G*, and the materials expert, *K*, who worked in the same company, at the location in Raufoss, Norway, for many years. On some aspects they differed in their opinion and impression of challenges and possibilities, as explained below.

Three impact factors were identified in this category:

- feasibility of material reuse
- inadequate quality control
- technical and esthetic quality demands

All three impact factors were identified as important and potential barriers. Table 5 shows an overview over which interviewees had input on the different impact factors.

Table 5: Overview of which interviewees had input on which topics. The interviewees represent the following departments or company types: A-sustainability centre; B- aftermarket; C- engineering design; D – LDC; E- recycler; F- material producer; G – component producer; H – dismantler; I – repair shop.

Category: Technical and quality / stakeholder	A	B	C	D	E	F	G	H	I	K
Feasibility of material reuse			x		x	x	x			x
Inadequate quality control	x				x	x				x
Technical and aesthetic quality demands			x		x	x	x			x

Technical feasibility of material reuse. Meeting the aesthetical demands is a challenge. Both the material producer, *F*, and the component producer, *G*, said that it is impossible to achieve a painted plastic surface which meets Volvo's requirements, if recycled plastic from bumper covers includes old paint which has not been removed. Paint removal is possible, but the technology is not available in Sweden and the process is expensive. They explained how achieving a good paint surface on PP plastic can be challenging in itself, and that the recycled material brings too much structural disturbance. Alternative methods for colouring the bumper cover exist, but then the bumper cover surface would not look similar to the surface of the metal exterior parts.

The material producer performed tests with the bumper cover material and concluded, in agreeance with Volvo, that the mechanical quality was okay, and that the material thus can be

used for other, less visible components that do not need to be painted. *G* agreed that it should be possible to produce parts which have the required mechanical properties, but pointed out additional challenges. *G* informed that when recycled material is mixed in it becomes challenging to meet the geometrical requirements – requirements for the size and structure of the components, with millimetre precision of +/- 0.5-1.5 millimetres.

G explained the reason for why meeting the geometrical demands is so challenging. Volvo uses many different suppliers for their bumper covers. Different suppliers can use several different material suppliers. Although all the material used is PP-EPDM the material can vary in structure and composition – material suppliers have different recipes. Variations can include the amount of chalk, the molecular weight of plastic used, how the plastic is mixed, and the number and amounts of different additives. Recipes and bumper cover production details are matched for each model. When material from bumper covers from different car models are mixed, the properties of the plastic material become unpredictable. Therefore, since the material quality details of the collected bumper covers will vary with which car models, they come from it is not possible to adapt to the material mix for new component production. Variation in the plastic properties makes it very difficult, and maybe impossible to produce new bumper covers with the precision needed for thickness and geometry. Currently, the spare part producer operates with 40-50 different PP-EPDM variations to produce spare bumper covers for different Volvo models. When material expert *K* was asked about the issue of bumper cover models containing different variations of PP-EPDM, she was more optimistic than *G*. She said that by analysing each batch of incoming material and estimating the right additive mix for the batch, one could make a material that would meet requirements. She built on this with more enabling strategies which are presented in subchapter 4.6 'Enabling factors'.

Use of structure as a design trait. An option being discussed at the R&D department among the design and engineering design teams is the use of 'structure' as a design trait. This entails adding larger pieces of used plastic to the plastic blend so that it becomes visible that the plastic is recycled. When the component producer, *G*, was confronted with this idea, he presented some challenges. Firstly, it is difficult to use both pellets and flakes in the machines they use, as the machines are specialized for the use of pellets. Further, if one wants a visible pattern the plastic will not be coated in paint. The paint is not only a decorative asset but also protects the plastic from UV-damage. To tackle UV exposure, additives must be added to the plastic material upon moulding. The plastic from the recycled bumper covers would not be made to handle the UV exposure and the quality of these parts will thus suffer. When plastics without the additives to withstand UV exposure are exposed to UV radiation, they become brittle and might break before the desired lifetime of the component. Again, *K* expressed less concern than *G*. *K* explained how adding a master batch (a concentrated additives mix adapted for a specific production) with high UV protection levels could secure sufficient quality of the material. *K* further added that the plastic flakes also would be remelted in the process, (and have the same melting point as the other plastic), and that UV-protective additives normally are added to all components, even those which are painted afterwards.

Using flakes or making pellets. On the question of whether flakes (ground plastic) could be used directly in the moulding process or if the plastic must be remelted and made in to pellets the two material experts *G* and *K* had different impressions. *G* stated that mixing flakes and pellets would be challenging in the production. He stated that getting the flakes to mix well with the pellets could be challenging, and that the flakes could get stuck in the machinery. *K*,

on the other hand, informed that flakes and pellets regularly were used in the same production at the spare part manufacturer in Norway. She further shared that she had met scepticism about using flakes directly at her current workplace too (where they work with plastic composites). She had told her colleagues that they should try it, since she thought it would not cause any troubles, and now they did it without problems.

Quality control and material handling.. The majority of recycled material used in production today is called "new scrap" – material which has never been in use but is left over from production. This can, for example, be material that is cut in a moulding process or material from components that did not meet the quality standards. Using "old scrap" – material which has been in use - presents different challenges. Both the recycling company and the material producer, *E* and *F*, says they will still have some form of quality control of the bumper covers/material that comes in and try to avoid metal parts or non-PP plastic parts entering the process. *G* said they have no way of controlling the material at their facilities, and therefore needs the material supply to be fault free at arrival. One risk is that metal parts enter machinery. The consequences of this depends on the type of machinery. Metal can be avoided by sorting the material magnetically and mechanically. It is more challenging to avoid non-PP plastic entering the process. As has been pointed out by several of the interviewees, human error will always be present and there is no guarantee that a clip will not be overlooked. *F* said that an entire batch can be compromised by non-PP plastic entering the plastic blend. Neither the material producer *E*, nor the component producer *G* were able to give any concrete answer on how much non-PP plastic could be accepted, but they emphasized the importance of avoiding the blend of polymer types. Bumper cover plastic has a melting point of 220-230 ˚C. *K* explained that if a contaminating plastic's melting point is higher than that of PP-EPDM plastic pieces can end up as pieces in the bumper cover. This can lead to reduced impact properties of the bumper cover as the contaminant can become a "notch point". However, *K* also added that it might be possible to remove such pieces during the process if they are few. If a contaminant has melting point below 230 ˚C it will blend into the polymer mix. Similar to *E* and *G*, *K* could not say how much of polymer contamination was acceptable before the quality would be too reduced to use in production.

A further contamination risk is the entrance of dirt. Rocks and gravel can have an impact on machinery and on plastic quality. The material producer, *F*, did some tests and concluded that dirt and dust were not an issue. However, they mentioned it as something to be aware of. At the recycler's facilities the shredder is coupled with a cleaning drum, while the material producer does not have such equipment. *K* particularly emphasized the importance of cleaning and drying the bumper cover material.

Quality standards. Volvo has high quality standards. The component producer reported that Volvos high demands for both technical and aesthetical quality is a challenge today, even when no recycled material from old scrap is included. With current material and methods, these demands result in that up to 10 % of the components they make are rejected by Volvo due to small surface imperfections (e.g. dust in the paint). Also, *C* and *F* talked of the strict quality standards. The aesthetical demands have been discussed at and among some Volvo departments, according to *A*, but changes will not happen immediately. *K* talked of how the quality standards have changed and developed over time. Over the last decades the focus has shifted more towards aesthetics, in that having smooth transitions and small gaps between components, and painted bumpers has become the norm, and the attention to impact properties

has, although not neglected, been reduced. Aesthetic demands are also connected to mindsets and people's attitudes.

The material producers, *F*, pointed out that following the present quality standards might be needed for 80 % of the components, but that in the case of some other components it might be "overkill", and these components would do just fine with lower standards.

> Reconsidering some standards – "[I]*t is kind of help for self-help. One has one's standard, but maybe one needs to go into certain details and say, but here one can [be less strict]. I don't know what it is called in their [Volvo people] language, but sometimes it is necessary to write a small, separate document which makes it OK – approves that kind of differences*".

Both the component producer and the material producer report having told Volvo that their quality demands are high, and in some cases maybe too high. While the component producer experienced that Volvo still seemed unwilling to reconsider these standards the material producer said.

> "*5-10 years ago Volvo wouldn't let go of any demands regarding the visual judgements […] but they have also been on a journey internally. If one is to reach our goal there are details which are not as critical visually, which enables reuse [of material] in a considerably better way. Those at Volvo have thought of some detail positioned under the car, which are not visible.*"

The use of recycled material in general. In addition to the impact factors relating to technical aspects and quality that are presented above, an additional aspect of the use of recycled material were brought up by *K*. For a product to be sustainable, it should have a quality which allows for the wanted lifetime, and if the use of recycled material diminishes the products quality, it might not be the most sustainable path of action after all. *K* stated the following:

> "*Lifetime trumps most other things. When it comes to sustainability, long lifetime is if high importance. It is of utmost importance that no choices are made so that, spare part wise, you will need to change parts more often, and then you actually just end up with more waste that must be handled and recycled.*"

To stay on the safe side when using recycled material, *K* proposed this rule of thumb:

> *"Add as little as you can, as little recycled material as you can, but make sure that we use all of it. Disperse it as well as possible. So that you do as little harm as possible. You make sure to have as stable a production as possible. Because, right, if we start producing wrecks, or if Volvo's suppliers start producing wrecks, then that is not sustainable. That is just nonsense. So, add as little as we can, but an amount that ensures that we can reuse all [the material] again."*

4.5.3 Economics

Starting a new project brings along new costs. Choices about how to organize transports, which actors to involve, which processes to perform inhouse and which to pay for all impact costs and profitability. The category of economics concerns these potential added costs and economic justifications relating to the bumper cover project. Six impact factors were identified:

- profitability
- volumes and transport
- cost of virgin material vs recycled material
- payment for material
- cost allocation
- third party involvement

Although impact factors relating to costs were identified as important, none were identified as barriers for the bumper cover project. Table 6 shows an overview over which interviewees had input on the different impact factors.

Table 6: Overview of which interviewees had input on which topics. The interviewees represent the following departments or company types: A-sustainability centre; B- aftermarket; C- engineering design; D – LDC; E- recycler; F- material producer; G – component producer; H – dismantler; I – repair shop.

Category: Economics / stakeholder	A	B	C	D	E	F	G	H	I	K
Profitability	x		x		x					
Volumes and transports		x		x	x					
Cost of virgin materials vs recycled material			x		x	x	x			x
Payment for material			x		x			x	x	
Cost allocation	x					x				
Third party involvement	x			x	x	x				

Profitability. Project profitability is highly important. As one Volvo representative put it:

> *"One can have the best intentions, regarding reductions in CO_2, absolutely, that's great, and one should strive for that. But if there isn't any money in it, then it's not interesting".*

Seeing that the project is still early on, no certain data for costs and incomes are available. The Volvo office representatives are working on collecting data and making estimates as this report is being written. The project leader and sustainability centre representative, however, pointed out that in the early phase, making the project float is in focus, and the goals of profitability comes later. The more activities (e.g. collection, handling, shredding) Volvo handles themselves, the more profit is potentially available. All outsourcing entails profit for the third-party actors. When the alternatives for third party actor involvement were discussed the Volvo representatives were good at recognizing which activities these actors were competent and skilled with, but parallelly seemed very aware of the third party actors' economic interests. This was evident in statements like "*They [recycler] are not stupid, they want to earn money*".

Profitability is not only important for Volvo, but for every business. The material- and component handlers all expressed flexibility and openness to adapt in order to make the flows work. This was partly motivated by the awareness that this project is new of its kind, and that existing processes might not be adapted to this kind of flow, but also that adaptability is important to be an attractive bumper cover customer or supplier.

Volumes and transport. The main sources of cost are transport, machinery, personnel and space. The costs are highly dependent on which alternative flow and process is chosen. In

accordance with what was reported about practical aspects, the transport and storage of the bumper covers and bumper cover material itself is okay but there is cost to it. Costs also depend much on the volumes. The LDC representative put great emphasis on how achieving high volumes is crucial for project success, and that expanding on markets can be a clever way to make this happen. The bulkiness of bumper covers, and bumper cover-to-air ratio is one of the factors limiting the volumes per transport before the shredding process. Expanding to the European market would also be a way to drastically increase the volumes. However, this is difficult to achieve short term.

Cost of virgin vs recycled material. One factor that limits the economic incentives for closed loop recycling of bumper covers is the low price of virgin material. The profits from recycling can, however, come not only from recycled procurement from virgin material, but from sales of the bumper covers or bumper cover material. *E* shared his thoughts on potential market development. Respondent *E* believes that as more and more businesses are taking part of the green transitions, and are pleading to increase their use of recycled material, the competition for material will make recycled material more attractive, and thus also increase willingness to pay for the recycled material. Relating to this he also pointed out how the cost of combusting plastic in Sweden is very low compared to many other European countries, but that he expected increasing CO_2 taxes and reduced number of emissions permits to help push the market into increased recycling. *K* presented the possibility that the price of recycled material reaches double that of virgin material. This leads to questions regarding the profitability of the bumper cover project versus the alternative of selling out the material. But since Volvo strives for using 25 % recycled or biobased material, price will not be the only factor steering choices.

Payments for the material. Repair shop managers and the dismantler all mention that it would be nice to get some form of payment for the added workload of handling the bumper covers. Volvo has made some estimates based on cost of delivering combustible waste, and time spent on bumper cover handling, and found that the repair shops save money on returning the bumper covers instead of sending them for combustion/energy recovery. These calculations however are not done for the dismantlers, who, as explained in subchapter 4.4.1, have a considerably larger added workload than the repair shops. Another aspect worth noting here is that the cost savings benefit the repair shops, but this might not return to the mechanics, who get paid per repair. How much this impacts the mechanics also differs between repair shops since some work on piece rates.

Third party involvement. The choice of involving external parties to handle the bumper covers- and material has a high impact on the costs and investments. *A* said that although outsourcing such work, or selling the bumper covers or bumper material to external companies is the easier strategy, doing more inhouse and investing more themselves can potentially lead to higher profits and *D* came with statements in agreeance with this. He pointed out how the external companies of course want the bumper cover material, since they want to earn money, and that although this could be a nice solution for Volvo in the initial years, outsourcing is not a lucrative long-term solution. *D* also added that reducing the number of external partners was not only a question of profit, but also of environmental impact, since more partners lead to more transport and thus can entail higher emissions. *E* and *F* also mentioned that leaving out some links, and doing more themselves could be attractive, but were less direct in their statements.

4.5.4 People and attitudes

The category 'People and attitudes' concerns the attitudes, motivation, and knowledge of those whose work connects to the bumper cover project in some way. Table 7 shows an overview over the impact factors in this category and of which interviewees had input on the different impact factors. Six impact factors were identified in this category:

- employee engagement and competencies - holistic understanding
- personal drive, colleague- and management commitment and zeal
- customer attitudes and public relations
- result assurance
- unease with change
- human factor

The engagement and competencies of employees and them having a holistic understanding of the project along with personal drive and the commitment and zeal of colleagues and management were seen as the most important impact factors in this category. Neither of them were, however, seen as barriers for successful implementation of the bumper cover project.

Table 7: Overview of which interviewees had input on which topics. The interviewees represent the following departments or company types: A-sustainability centre; B- aftermarket; C- engineering design; D – LDC; E- recycler; F- material producer; G – component producer; H – dismantler; I – repair shop.

Category: People and attitudes / stakeholder	A	B	C	D	E	F	G	H	I
Employee engagement and competencies - holistic understanding	x	x	x	x	x	x	x		
Personal drive, colleague- and management commitment and zeal	x	x	x						
Customer attitudes and public relations	x	x	x	x	x				
Result assurance					x			x	x
Unease with change									x
Human factor	x	x			x	x			x

Employee engagement and competencies. Engagement and a holistic understanding of the project and its purpose has been pointed out as an important factor for success. The initial stripping of the bumper cover is manual and requires orientation to details. *A* makes the point that since placement of clips and screws can vary, and since there is a possibility that foreign parts have been added in repair or by the car owners, mechanics might need to show initiative to ensure the removal of all parts not made of PP-EPDM from the bumper covers. *E* elaborates on this by adding that those performing the stripping should understand the purpose of the task. *E* explained that if they know about the following processes of recycling and using the material in new products and understand the negative impact metal or non-PP-EPDB parts could have in these processes, they are more likely to do a proper job. As an illustration *E* made a comparison of the project process to a Gantt chart:

> *"It is a bit like a Gantt chart. If it is so that the first person doesn't understand that the tenth will be affected, then it doesn't matter if the [process]chain is broken [in a later link], as it already is broken."*

However, when it comes to the attitudes and motivation of the employees at the recycler and the component production, both *E* and *G* agree that the employees' attitudes are of minor importance. They both declared that handling the bumper covers and- material was just another job, and that the company had to make money.

Both *I* and the employees at the repair shops visited during site visits agree that the general attitudes of the mechanics are good. Repair shop managers recognized that there maybe was some scepticism among mechanics right away, but when they realized how quick the job was everyone had been okay with it. *I* and *F* further pointed out how the generations they employ now have grown up with waste sorting as a natural thing to do, and thus also understand that recycling of PP-EPDM is a good thing. This is in line with the observations expressed by other interviewees. Both *E* and *F* noticed a large change in attitudes towards environment and sustainability among colleagues and in society. *C*, who is younger than *E* and *F* could not report the same, but spoke of differences in the attitudes of some older colleagues compared to younger colleagues.

D voiced another aspect of employee attitudes and knowledge. Respondent *D's* point was not only focused on those directly working in relation to the bumper cover recycling project, but rather on all the employees at Volvo. According to *K*, many bad decisions are made due to lack of knowledge, and that with increased knowledge, not only can these decisions be avoided, but good initiatives and ideas can be born. Furthermore, *D* pointed out that if one gets all employees on board, including "floor workers", there will be an increased pressure to the organisation's leadership, which will force change to happen faster and in greater range. Although *D* confirmed that management attitudes were very supportive and positive towards sustainability initiatives, he observed a lack of action.

Personal drive, colleague- and management commitment and zeal. The three people who took part in initiating the project, *A*, *B* and *C* all spoke of personal drive as a major motivator. As *C* put it

> *"One has to take action, for otherwise nothing will happen!"*

And as *A* reflected on his mandate as organizer of the project he said

> "*It is really this that matters – that this [project] should exist. If no one takes it [the organizing job], then I take it*".

Both *B* and *C* also expressed that they would have appreciated seeing more personal drive and interest in sustainability among their colleagues, while also asserting that they experienced support from the management and those in higher positions. *A* expressed it like this:

> "*We get good support even from above. Three is certainly an interest, but there is also still a bit of a grass root feeling over it – that it comes from below and bubbles up. But we get lots of support"*

Both *C* and *D* emphasized the importance of Håkan Samuelsson, former CEO of Volvo (2012 – 2022), who has been clear in expressing the environmental ambitions of Volvo.

Customer attitudes and public relations (PR). Customers attitudes towards a company and its products is naturally important. *A* does not fear that customers will be worried that material from old bumper covers is used in production of new components. On the contrary he thinks

this can be good for sales. *D* affirms this by stating that performing and succeeding in green initiatives is important not only for the sake of the environment, but to meet the expectations of the next generation of Volvo buyers, "*the Thunberg-generation*", as he labelled it. And *C*, who put much emphasis on the importance of the environment, also stated that:

> *"We want this as PR (...) we have the total offer which makes the overall feeling with environment and sustainability and such, there we are the best*".

C and *E* both mentioned how making the use of recycled material visible could also work as a sales momentum, and how having such details can be seen as cool and thus attracts customers. Such visibility can be obtained by making plastic with structures of different colours and not painting over the component.

Result assurance. Both the dismantler, *H*, repair shop representative *I*, and people at other repair shops visited said that it would have been nice to get to see some examples of products made out of the plastic they prepared, and that this would be a great motivator and assurance for the mechanics to see that the work they put in was worth it. *E* expressed attitudes in line with this, in saying that of course the price offered for the material they prepared mattered, but also knowing that the material would actually be used in making new components.

4.5.5 Policy and regulations

Policies and regulations can have large impact on a company's operations and can function both as drivers and as barriers. Four impact factors were identified:

- regulations and incentives of plastic and bumper cover handling
- variations in international policies
- insurance and warranty
- internal Volvo policies

None of the impact factors in this category were identified as important potential barriers for the bumper cover project. Table 8 shows an overview over which interviewees had input on the different impact factors.

Table 8: Overview of which interviewees had input on which topics. The interviewees represent the following departments or company types: A-sustainability centre; B- aftermarket; C- engineering design; D – LDC; E- recycler; F- material producer; G – component producer; H – dismantler; I – repair shop.

Category: policy / stakeholder	A	B	C	D	E	F	G	H	I
Regulations and incentives of plastic and bumper cover handling	x				x				
Variations in international policies	x		x						
Insurance and warranty		x							
Internal Volvo policies		x							

Regulations and incentives of plastic and bumper cover handling. In general bumper covers and plastics are not heavily regulated according to *A* and *E*. Therefore, policies do not hinder reverse logistics of bumper covers, and Volvo is not forced to collect and ensure recycling. Despite the recommendations and encouragements in the ELV directive and in Sweden's

Environmental Code, no legal papers force Volvo to ensure recycling. Energy recovery is listed as the third best alternative (after waste avoidance, and recycling) and is the standard treatment today. *E* also pointed out that combustion (with energy recovery) is too cheap in Sweden to incentivise alternative plastic handling, and that it is cheap compared to many other European countries. *A* reflected on the impacts of forcing regulations, and that not having such regulations allows Volvo to take the time to find profitable solutions, in contrast to if they were forced and they would have to perform the collection and recycling no matter the cost.

Variations in international policies. In order to increase volumes of returned bumpers one option is to escalate the project to include international markets. However, different countries have different policies regulating what can be transported, how goods can be transported, how goods must be treated and similar aspects. This does not hinder a project expansion, but entails more work, and potentially the need for several logistics systems instead of only expanding on one system.

Insurance and warranty. Whether a bumper is repaired or changed for a new one depends on the age of the car and the warranty agreement, and on the estimates and judgements done by the insurance company. Changing internal policies at the insurance companies or altering warranty agreements could thus impact how many bumpers are repaired, and how many cars get used bumper covers instead of new bumper covers when repair is not possible.

4.5.6 Ownership and control

The category 'Ownership and control' concerns Volvo's ownership of the bumper covers and control over the material flows. Three impact factors were identified in this category:

- material flow control
- material traceability
- relations to repair shops vs dismantlers

Control over the material flow was seen as the most important impact factor in this category. Table 9 shows an overview over which interviewees had input on the different impact factors.

Table 9: Overview of which interviewees had input on which topics. The interviewees represent the following departments or company types: A-sustainability centre; B- aftermarket; C- engineering design; D – LDC; E- recycler; F- material producer; G – component producer; H – dismantler; I – repair shop.

Category: Ownership & control / stakeholder	A	B	C	D	E	F	G	H	I
Material flow control	x		x		x				
Material traceability	x				x				
Relations to repair shops vs dismantlers	x			x					

Material flow control. The fact that Volvo wants to use the recycled material again themselves in their cars combined with the fact that the material will be sold to third party actors, like the material and the component producers presents a dilemma. Both *A* and *C* mentioned an uncertainty regarding this lack of guarantee of material return. They mentioned that some types of agreements could be possible, but how these would be set up still must be resolved. This might, however, not be as difficult as they fear. The representative at the recycling company,

E, affirmed that third party collaboration agreements, or fourth party agreements are possible solutions, and that this already is common practice. Respondent *E* reported they already take part in these kinds of collaboration agreements with other partners, and that he expects this to become more common practice as increased interest for recycled materials can lead to competition for the resources. *E* also stated it like this:

> "*It will become more and more common in the future [with third- and fourth party collaboration agreements]. In order to get the circular flow, one might need top control over certain flows.*"

Material origination traceability. In case large discrepancies in the bumper cover stripping are noticed, it is desirable to know which repair shop these bumper covers came from in order to give feedback. Perhaps the case is that only one or two repair shops need this feedback. Keeping an overview on the flows from the separate repair shops also allows to control the amounts. Based on general statistics and on data on sales and procurement on spare parts estimates can be made for how many bumpers should be returned from the repair shops. If the flows from each repair shop is kept separate, discrepancies in amounts from specific collection points can be noticed and investigated.

Dismantlers versus repair shops. The plan of the project is to involve Volvo-certified repair shops for collection of bumper covers. When cooperating with these repair shops Volvo can simply command that all Volvo-certified repair shops must take part in the return system of bumpers. Many bumpers end up at dismantlers when cars reach EoL and involving dismantlers is therefore of high interest too. This can however be challenging as Volvo cannot practice the same control over dismantlers. Other incentives might therefore be needed, like for example offering payment for bumper covers. Payment can also be motivated by the fact that the stripping job entails more work for dismantlers than for repair shops, as explained in subchapter 4.4.1.

4.5.7 Information and communication

As seen in Figure 6, a lot of information must be shared in relation to the bumper cover project. The category 'Information and communication' pertains to the sharing of information and information and knowledge's connection to attitudes. Three impact factors were identified in this category:

- information sharing
- information sufficiency
- information as a means

Information related impact factors were seen as important, but sufficiently well-functioning to not need much extra attention. Table 10 shows an overview over which actors had input on the impact factors.

Table 10: Overview of which interviewees had input on which topics. The interviewees represent the following departments or company types: A-sustainability centre; B- aftermarket; C- engineering design; D – LDC; E- recycler; F- material producer; G – component producer; H – dismantler; I – repair shop.

Category: Information / stakeholder	A	B	C	D	E	F	G	H	I
Information sharing	x	x							
Information sufficiency	x				x	x			
Information as a means				x	x				

Information sharing. Respondent *A* pointed out how information sharing and having a smooth information flow becomes more challenging as more stakeholders are involved. This was especially emphasized in relation to the information that should follow the bumper material from the repair shops to the recycler, or the material producer. As the bumper covers change owners, and enters different data systems, information can easily get lost. *B* reflected on other information related issues. He mentioned that different ways of working could hinder the information flow and shared the following example. The people at SO&T who develop the information for the Vida system work agile, while the team at commercial (aftermarket) do not work agile. Further, the SO&T team only work on a car model and components for a car model until it enters production and maybe for a shorter period after, while the aftermarket team are interested in components of cars that have entered the market. When requesting information from the SO&T team the case can be that all their employees are working on a different project with specific work packages, and no one really has time or wants to prioritize looking into parts of older models.

Information sufficiency. In order to make good decisions a lot of information is needed. Getting a full overview of options, costs, possibilities, and potential consequences is challenging, both due to the number of variables and the newness of the project. This impacts *A* and the decision makers at Volvo. *E* and *F* also reported lacking information. For example, they had not received confirmation on whether the material they produced met the demands of the component producer (*G*) or what types of material they demanded, like flakes or granulates. This again impacted what kind of information these could feed back to the Volvo representatives.

Information and knowledge as a means. Information and knowledge sharing is an efficient means for shaping attitudes, increasing employees "whole-picture" understanding and thus improve results of the work. Equally, lack of information and knowledge can be a major barrier for good results. *E* stated that he believes a lot of information campaigning is needed to get all the repair shops on board on the project. He emphasized how he believed making the mechanics understand the purpose of the bumper cover stripping would help ensure that they did a proper job, which in turn would secure clean PP material in the recycling and material production processes. *D* talked about how knowledge is key for building up employee engagement, and that the intranet could be used much more actively to inform about current projects, success stories, and to educate employees about the purposes of sustainability initiatives. The topic of information and knowledge as a means tightly connects to the category *attitudes*.

4.5.8 Other impact factors

One impact factor was identified which did not fit in with the categories and is therefore put in the category 'Other'. Table 11 shows which of the actors spoke of this impact factor. There is one impact factor in this category:

- International politics and unforeseeable events

Table 11: Overview over which actors spoke of the impact factor 'International politics and unforeseeable events'.

Category: other / stakeholder	A	B	C	D	E	F	G	H	I
International politics and unforeseeable events				x	x		x		

A last factor that was mentioned by the interviewees is how unforeseeable events can impact the project. Throughout the interviews international politics (the Ukraine war), the Covid-19 pandemic, and changes in oil prices were mentioned. These events could impact access to resources, fuel prices, and the habits and driving patterns of people. Resource access could impact the prices of or availability of both recycled and of raw material, and affect the market. Prices of fuels could lead to people driving less or driving at lower speeds, and thus reduce the number of accidents and then the number of bumper covers collected at the repair shops. Equally the Covid-19 pandemic reduced the movements of people and thus the number of broken bumper covers coming in.

4.5.9 Impact factors and barriers in current literature versus in the bumper cover project

Several studies have been dedicated to investigating barriers for reverse logistics and circularity. Eleven articles on this topic were reviewed. A focus on articles investigating the automotive industry was sought, but as the number of articles available was limited, other articles were included, which were considered to add value. Three of these took a more general approach and two looked at the construction industry. Generally, the articles did not specify whether the reverse logistics were for the purpose of recycling, remanufacturing, reuse or other R-strategies, but rather held broad foci on reverse logistics for circular purposes. Table 12 offers an overview of these articles including main methodology used, industry and country in focus. Table 13 presents barriers identified in these studies in parallel to the impact factors identified in the bumper cover project. In Table 12 these impact factors and barriers are listed so that it is visible which factors and barriers were identified in the bumper cover project or the literature, or in both, how many of the bumper cover project interviewees who talked of the factor, and in which article(s) the barriers were identified. Only the barriers rated as important in the literature are included. Following these tables some of the differences between the literature and the bumper cover project findings will be highlighted, and some excerpts from the literature are provided to give an insight to the literature's barrier descriptions.

Table 12: Overview over articles on barriers for reverse logistics and circularity

Article	Method	Industry	Country
Abdulrahman *et al.*, (2012)	Questionnaire survey, 239 companies	Automotive and other sectors	China
Chan *et al.* (2012)	Framework + literature study	Automotive industry	-
Kaviani *et al. (*2020)	Literature review + expert opinions	Automotive	Iran
Richnak Gubova (2021)	Questionnaire survey, 165 companies	Automotive and other sectors	Slovakia
Fawcett *et al.,* (2008)	Literature review, mail survey and 51 in-depth analyses	-	USA
Gonzalez- Torre *et al.,* (2010)	Interviews, 69 companies	Automotive	Spain
Zailani *et al.,* (2017)	Questionnaire survey, 228 companies	Automotive manufacturing firms,	Malaysia
Simões et al., (2017)	Questionnaire survey, 225 companies	Food, automotive, consumers electronics and manufacturing (metallurgical, energy, textile, paper and wood)	Portugal
Sharma, Sahu & Panda, (2011)	Literature study and modelling	-	India
Rameezdeen et al. (2016)	Semi-structured interviews	Construction sector	Australia
Chinda (2017)	Questionnaire, 6 construction companies	Construction	Germany and Thailand

Table 13: Identified impact factors and barriers from interviews and from existing literature. Column two, named [#], indicates how many interviewees spoke of the impact factor mentioned in column one.

Factors from interviews	#	Factors from literature	Article
Operational/logistics			
Time needed for stripping at repair shops vs at dismantlers	*4*	Dismantling, handling	Chan et al. (2012)
Bumper-to-air ratio, stacking and packaging (/cost)	*3*		
Storage and space	*6*	Storage	Abdulrahman et al. (2014)
Material security	*4*		
Need for process	*1*		
Added workload for Volvo	*1*	Administrative burden	Richnak & Gubova (2021)
		Lack of coordination with 3.pl providers	Abdulrahman et al. (2012),
		Uncertainty	Chan et al. (2012), Sharma (2011)
		Number of parties involved, complexity	Chan et al. (2012)
Technical /quality			
Feasibility of material reuse: Paint, Variations in plastic formulas, quality control, PP sensitivity	4	Physical/technical difficulties	Chan et al. (2012);

Table 13 continued

Factors from interviews	#	Factors from literature	Article
Inadequate quality control	3		
Technical and aesthetic quality demands	4		
Economic			
Profitability	*3*	Costs, general	Simões et al., (2017); Sharma, Sahu & Panda, (2011); Rameezdeen et al. (2016)
Volumes and transports	*3*		
Cost of virgin materials vs recycled material	*4*	Cost of virgin material/recycled material, economic justification	Chan et al. (2012); Kaviani et al. (2020); Gonzalez- Torre et al., (2010)
Payment for material	*4*		
Cost allocation	*2*		
Third party involvement	*4*		
		Initial capital	Abdulrahman et al., (2012); Kaviani et al. (2020); Richnak Gubova (2021); Gonzalez- Torre et al., (2010) ; Sharma, Sahu & Panda, (2011);
		Economy of scale	Kaviani et al. (2020)
		Lack of shared risks and rewards	Fawcett et al., (2008)
		Economic sanctions	Kaviani et al. (2020)
People and attitudes			
Employee engagement and competencies - holistic understanding + relations	*7*		
Personal drive, colleague and leadership engagement	*3*	Involvement and support top management and attention to RL in strategic planning	Kaviani et al. (2020); Gonzalez- Torre et al., (2010) ; Simões et al., (2017); Sharma, Sahu & Panda, (2011);
PR in use of recycled	*3*		
Result assurance	*3*		
Unease with change	*1*		
Human factor	*5*		
		Different perspectives when weighing trade-offs	Abdulrahman et al., (2012); Chan et al. (2012); Simões et al., (2017)
		Public awareness	Abdulrahman et al., (2012); Sharma, Sahu & Panda, (2011); Abdulrahman (2014); Rameezdeen et al., (2016)
		Customer reluctance	Chan et al. (2012); Chan et al. (2012); Gonzalez- Torre et al., (2010)
		Management competencies	Chinda (2017)

Table 13 continued

Factors from interviews	#	Factors from literature	Article
		Competencies	Gonzalez- Torre et al., (2010); Simões et al., (2017); Sharma, Sahu & Panda, (2011)
Policy			
Regulations and incentives of plastic and bumper cover handling	*2*	Regulatory environment; lack of governmental support; lack of supportive laws; lack of penalties	regulatory environment: Sharma, Sahu & Panda, (2011); Rameezdeen et al (2016); Chinda (2017), lack of governmental support and supportive laws: Kaviani et al. (2020); Richnak Gubova (2021); Gonzalez-Torre et al., (2010); Abdulrahman (2014), lack of penalties: Chinda (2017)
Variations in international policies	*2*		
Insurance and warranty	*1*		
Internal Volvo policies	*1*	company policies	Sharma, Sahu & Panda, (2011)
Ownership and control		**Market and inter-firm relations**	
Material flow control	*3*		
Material traceability	*2*		
Repair shops / dismantlers	2		
		Inconsistent operating goals	Fawcett et al., (2008)
		Cooperative behaviour of chain members	Simões et al., (2017); Sharma, Sahu & Panda, (2011)
		Contractual obligations	Rameezdeen et al (2016)
		Underdeveloped markets	Kaviani et al. (2020)
Information, information flow			
Information sharing	*2*	Information systems, info-sharing	Fawcett et al., (2008); Gonzalez-Torre et al., (2010); Rameezdeen et al (2016)
Information sufficiency	*3*		
Information as a means	*2*	Open mindedness to recycled material use (CF)	Chinda (2017)
		Systems for return monitoring	Abdulrahman (2014), Sharma, Sahu & Panda, (2011)
Other			
International politics and unforeseeable events	*3*		
		Lack of attention to design for RL	Rameezdeen et al (2016)
		Increased work, health and safety risks	Rameezdeen et al (2016)

The importance of different impact factors and barriers was determined based on the number of interviewees talking of them or articles mentioning them and how the factors were described

by the interviewees, and in the articles. The most important impact factors and barriers are summarized in Table 14.

Table 14: Important impact factors and barriers in the bumper cover project and in the literature.

Bumper cover project	**Literature**
Feasibility of material reuse	Costs and financial constraints
Quality control	Lack of management and governmental support
Employee engagement and competencies	Public awareness, customer reluctance
Material flow control	Policy and regulations

The literature barriers are to a large extent concerned with management support, governmental support, economic and resource aspects, policies and regulations, and customer attitudes.

The economic factor is one of the major barriers listed in the literature. Zailani et al (2017) found that attitudes and technical aspects were of less importance, while economy and resource access was the major barrier.

> *"At the very least, the study results found that the major barriers that impede the automotive manufacturers in Malaysia from adopting the product return management are related, extremely, to the availability of resources to support the product return activities. The result reflects that automotive manufacturers have a lack of resources to fund the product return implementation; as a matter of fact, a high initial investment in terms of finance, human resources, and time is required for such adoption,"* (Zailani et al., 2017, p. 37)

Several articles, including Abdulrahman et al. (2012) talked of the lack of initial capital as a major barrier.

> *"As indicated by the results on the six manufacturing industries investigated, the biggest financial barrier to RL implementation in Chinese manufacturing is the lack of initial capital" (*Abdulrahman et al., 2012, p. 468).

Abdulrahman et al. (2012) was also among those emphasizing management attention and competence:

> "*The general results show that the key management barriers to RL implementation in Chinese manufacturing sector are the low commitment to RL practices and the lack of RL experts at the management level in the manufacturing firms investigated. These management barriers are common to whole sector surveyed, with a low management commitment being the most influential barrier for the whole industry"* (Abdulrahman et al., 2012, p. 468).

Gonzalez- Torre et al., (2010) gave less attention to management support. Their focus was rather on governmental and public support. They included this formulation:

> *"As a final conclusion, it should be pointed out that greater support would be needed both from government as well as social actors on a broader level to foster the development of EORLP [environmentally oriented reverse logistics practices] firms belonging to the automotive sector, since these firms perceive reluctance on*

the part of government and of social actors as the greatest barriers." (Gonzalez-Torre et al., 2010, p. 900).

The aspects of ownership and control were not present in the literature. In Table 13 the category '*market and inter-firm relations'* from the literature is listed instead and was not mentioned by the bumper cover project interviewees. The topic of market and inter-firm relations includes issues of underdeveloped markets, cooperation between actors and the lack of common goals with other actors in the value network.

Technical challenges were heavily emphasized in the bumper cover project, while barely mentioned in the literature. Chan et al. (2012) mentions the lack of recycling technology and the many components of a car as challenging. Chan's et al. (2012) article also includes a paragraph dedicated to bumpers, but the focus is rather on the disassembly work and transport challenges (operational), and not on technical issues. Abdulrahman et al. (2012) points out the lack of technical knowledge but does also not mention technical feasibility. Both Abdulrahman et al. (2012) and Sharma et al. (2011) mention the lack of technical systems for monitoring return flows, while Simões et al. (2017) reports on increasing investment in information systems for reverse logistics in Portugal. Furthermore, Simões et al. (2017), along with Zailani et al. (2017) point out how the technical parts are among the less challenging aspects.

4.6 Enabling factors

Enabling factors were identified in literature, during interviews and through a follow up workshop with the two most involved Volvo representatives: The representative from the sustainability centre (*A*) and the representative from service- and business, aftermarket (*B*). Enabling factors are actions which can be taken to enable the RL and circular flow through reducing barriers or avoid challenges before they occur. Barriers and impact factors should be seen in relation to each other. Kaivani et al. (2020) and Sharma et al. (2011) both investigated how different barriers can impact each other. Understanding these interrelations can give impactful insights for desertions on where to put the attention when initiating enabling measures.

Kaivani et al. (2020) identified economic-related barriers and competitors- and market-related barriers as the strongest barriers in terms of how much they impact and have the potential to enhance (negatively) or relieve other barriers, in particular technology- and infrastructure related issues, knowledge related issues and governance- and supply chain process issues. Furthermore, knowledge-related and management related barriers have the largest number of impact-relations to other barriers (Kaivani et al. 2020). Sharma et al. (2011) analysed the dependence and driving power (a barrier's ability to enhance the strength of other factors) of different impact factors and barriers. They found that product quality, inadequate information and technological systems, uncertainty and limited cooperation are factors of weak driving power – low impact on other factors, but are highly impacted by other factors. Lack of management support, and management systems, personal resources, company policies and administrative and financial burdens were found to have both a strong driving power and to be highly impacted by other factors (Sharma et al., 2011). Additionally, insufficient awareness of reverse logistics, financial constraints and legal issues were identified as key barriers in that

they are quite independent from other barriers, but have strong impact power (Sharma et al., 2011).

The barriers listed above, except maybe the awareness barrier, are not seen as present and threatening barriers in the bumper cover system. Below enabling factors within each impact factor category are presented, followed by remarks and enablers directed at the bumper cover circularity project as a whole.

4.6.1 Operational and logistics

The extra time needed for stripping the bumpers at the car dismantlers is closely linked to the repair shop and dismantlers' wish for payments for the work and to the fact that Volvo does not own or have any control over car dismantlers. *A* and *B* recognize that giving dismantlers a monetary incentive to take part in the bumper collection would be necessary. This payment could potentially come from the recycler which would later sell this material in the bumper cover flow. *A* and *B* further expressed hope that "the market" would fix the issue, creating willingness to pay for stripped bumpers through increased prices and willingness to pay for recycled and recyclable material. Further design improvements could be made to reduce the number of steps in the stripping process, but the gain from this is estimated to be of minimal importance.

Regarding the bumper-to-air ratio, *A* and *B* recognized that the impacts this has on transports and costs are suboptimal, but stated that this was acceptable in the early phases to avoid high investments. The focus is on gathering experiences, establishing the bumper cover flow and familiarizing the actors with the project. When this is in place, the hope is that investments in smarter systems can be made without the risk of investing in the "wrong" solutions. One action which can reduce the bumper-to-air ratio is shredding the bumper covers early. The downside of this, however, is that monitoring the material and material quality control become more difficult. *A* and *B* concluded that even though the high bumper-to air ratio was fairly low and a barrier in some regards, the added benefits of it could be more worth, and that a system perspective must be taken when evaluating barriers.

Space limitations were mainly a topic for the repair shops. In order to avoid that repair shops experience challenges relating to gathering and storing bumper covers a regular pick up should be ensured.

Below is a synopsis of enabling factors related to the category operational and logistics:

- Pay for stripped bumper covers that come from dismantlers
- Shred the bumper covers early in the flow.
- Low bumper-to-air ratio can be accepted since it allows for increased control over material flows and facilitates additional material quality control
- Organize regular collection of bumper covers

4.6.2 Technical and quality

Bumper cover material reuse is feasible, but not without challenges. The number and severity of these challenges, however, must still be further investigated as the interviewees' impressions varied on this topic. One important enabler will therefore be to perform more testing to remove uncertainties on what is possible and what outcomes to expect, to avoid working around

challenges that are not really challenges. Establishing the details concerning feasibility and challenges with material and component production can further open up for research and development to overcome the technical barriers. Areas to investigate include how much and what kind of material contamination is acceptable; how flakes behave in the component production process versus pellets; and how easy and with how much added work additives can be prepared for each batch of bumper cover material to correct for the variations in model recipes.

One of the issues raised by several actors was that it is difficult, or even impossible to get a smooth painted surface of new bumper covers if recycled material is used. This fact should be controlled as post-industrial bumper covers (new scrap) with paint currently are used in new bumper production. If it is the case that a painted surface meeting Volvo's demands cannot be obtained, alternative strategies are to implement a paint removal process in the bumper cover flow, or to produce other components which are not visible on the car. Volvo's plan is to initially produce undershields as these are not painted and not visible.

The issues of feasibility are closely related to the strict quality demands Volvo operates with. Some demands are related to safety, or to ensure bumper longevity. Other demands are related to esthetical standards. Both *K* and several actors pointed out easing on the geometrical and esthetical demands as important enablers. Easing on such standards, however, is not necessarily low hanging fruit. The geometrical and esthetical standards (smooth paint surface, small gap between components) reflect expectations and preferences in society and among the customer group, and are thus important relating to sales. As expressed by *K*, the looks of the bumper cover are a way to demonstrate the car's quality. Conversations on relieving quality demands do happen among project partners, but *A* and *B* recognize that lifting the conversation from person-level to Volvo-institution level is challenging.

Inadequate quality control is another quandary. Due to human error, it is likely that some metal parts and non-PP plastic parts will enter the flow. Metal detecting machines can help to avoid getting metal parts in the machinery. Such detecting can be done both before or/and after the shredding process. The host of the recycler site visited mentioned how they had a very big and strong shredder which would be able to handle metal parts entering the system, in comparison to what a smaller shredder would do. If Volvo wants to shred at the LDC or CDC they might invest in a smaller shredder. Technical solutions can also be used to avoid plastic polymer contamination. *K* suggested that investing in IR-machines who can detect and distinguish between different types of plastic could be a good investment in the longer run. The host at the recycler site visit, however, pointed out how the technology is still young and mistakes still happen in addition to the process being slow.

Contamination from non-PP-plastic is not so much a risk for the machines but can negatively impact the plastic quality. There is currently much uncertainty regarding how much plastic contamination is acceptable and what the consequences would be. *K* proposed that a simple risk assessment could be performed by doing tests adding different "wrong" plastics to otherwise clean PP-EPDM mixes. Tests should be performed with both plastic types with melting point under 220 ˚C and above 230 ˚C, and with some different amounts to establish what levels and types of contamination can be accepted and not. It will be much easier to plan quality control measures when knowing what the critical limits are.

Manual quality control will still be needed, at least in the first years. Looking over the bumper covers to look for contaminants is easier than looking through shredded material. Therefore, postponing the shredding process and allowing some extra costs relating to transport can be a way to facilitate for quality control.

Finally, an alternative scenario for the flow and use of bumper covers can also offer bridges to overcome some challenges of quality. *K* introduced the possibility that Volvo could direct the collected bumper covers to their component producers' facilities in Norway, where they produce spare parts. Using the bumper cover material in spare part production rather than in new component production can offer a variety of benefits. Firstly, using recycled materials in spare part production instead of new part production, can make it easier to get acceptance to ease on demands. Secondly, at the spare part production facilities they already operate with a variety of different PP-EPDM recipes to make bumper covers for different Volvo models. This could allow for choosing which bumper covers' material goes into which new batch, depending on material specificities. Thirdly, they make smaller batches, thus, if a material batch is contaminated, consequences are lower if a material batch for 40 bumper covers is of bad quality rather than a batch for hundreds or thousands of bumper covers. Fourthly, the spare part producers are used to and specialized at adapting batches, and changing settings on the machinery and adapting additives for smaller batches entails less extra work for them than it will at the net part producer.

A last comment added by *A* and *B* on the challenges with using post-consumer bumper covers was that although there are challenges connected to it, it might be their best option. In order to reach Volvo's goals for recycled content post-consumer scrap must be used in addition to post-production scrap. To their knowledge there are no other post-consumer products which will be easier to use. And furthermore, the project offers a lot of learning experience which can be valuable in future projects too.

Below is a synopsis of enabling factors related to the category technical and quality:

- More testing: how much and what kind of material contamination is acceptable; how do flakes behave in the component production process versus pellets; and how easy and with how much added work can additives be prepared for each batch of bumper cover material to correct for the variations in PP-EPDM recipes.
- Produce less visible parts that will not be painted, like undershields.
- Easing on demands on aesthetical standards.
- Perform shredding at facilities with the best equipment which can handle metal contamination
- Use metal detection and potentially also IR-equipment for non-PP plastic detection
- Use recycled material for spare part production rather than production of new parts.

4.6.3 Economic

The economic aspects of the bumper cover project are highly uncertain. Many numbers depend on information that is not available yet, or on decisions that are yet to be made. In general *A* and *B* agree that direct profitability is of less importance in the early phase, and that long-term thinking and willingness to try are of importance. They emphasize the value of the learning process, and the experiences gained which can be valuable in future circular projects. Furthermore, being an early mover and gathering knowledge can be highly valuable if stricter

legislations for the use of virgin material or the responsibility of post-consumer waste are introduced, if virgin material prices raise or get highly taxed, or if other outside factors come.

The enabling factors are summarized as follows:

- Take a “big picture”-approach

4.6.4 People and attitudes

The most important enabler to deal with people- and attitude related impact factors is communication. *D* focused much on enabling factors during the interview. He had strong belief in the power of education and creating common understanding. He suggested that Volvo internally should start using their communication channels and intranet to share information about current projects, and success stories, and educate their employees on the purpose of the sustainability projects. An additional perk, *D* added, to sharing such stories is that more people could be inspired to develop and pitch ideas they have. *D* further pointed out how educating the general staff of Volvo could impact attitudes and create pressure upwards in the organisation – pressure which he saw necessary to turn words into action to an even larger extent.

E spoke of making sure the people who interact with the bumper covers or bumper cover material understand the purpose, and the value of their work. If the dismantlers know how the process depends on the work they perform, they are more likely to do a good job. This also relates to what *B* said about making people start thinking of materials rather than waste. He reported being conscious of using the word material in “every other sentence” to embed the way of thinking in the people he met. *B* shared that communicating in a way which shaped attitudes towards sustainability and motivated partners was an enabler he uses actively in all his meetings, and that getting for instance repair shop and dismantler managers on board and motivated for the projects was a crucial part of the work and a way to avoid that attitude barriers even emerge.

Lastly, simply getting started with the project, and getting people used to the new ways of working, and demonstrating that it works, is an important means for convincing and motivating people. Some of the repair shops and the dismantler mentioned that the mechanics were on board and positive, but would have been happy to see some concrete products demonstrating the results of the work. Attending to such wishes can be important to maintain motivation and as a way of communicating the purpose of the tasks.

The enabling factors are summarized as follows:

- Communicate to share knowledge.
- Communicate to increase the process understanding.
- Communicate to motivate and to shape attitudes.
- Show results as a means to increase motivation.

4.6.5 Policy and regulations

The different policies and regulations in different geographical markets were mentioned as a challenge for when the bumper cover project scales up to cover more markets than Sweden. *A* and *B* expect that overcoming such challenges will not be too challenging. Volvo is already

present worldwide and familiar with such issues, and has lawyers and employees familiar with international policies.

Regarding the inhouse regulations and demands for quality and aesthetics, no effective enablers were identified. However, conversations and meetings with the purpose of identifying specific components where easing on demands could be acceptable was suggested by *F* and *K*.

4.6.6 Ownership and control

Volvo expressed some worry of ensuring return of the bumper cover material to their own products. Both the interviewed recycling company and the visited recycler affirmed that third-party collaboration agreements could be used to guarantee that the material returned to Volvo after being processed at their facilities. Another alternative for ensuring control over the material flow was suggested at one of the internal Volvo meetings with people actors not listed in this report. This suggestion was to pay the recycler and material producers for the service of processing the material rather than selling the bumper covers to them. Volvo could also choose to let go of the idea of controlling the material flow, and rather collect the bumper covers and sell them to the open plastics market. This way they can still report on aftermarket actions in their sustainability report and take part in the larger mass balance, but avoid the added administrative work of maintaining control.

To ensure that material can be traced back to the originating repair shop bumpers can be kept in separate containers or pallets marked with origin.

4.6.7 Information and communication

Some of the challenges with information sharing and information sufficiency are due to the nature of a pilot study. The project organizers, *A* and *B* have limited resources to keep all the involved partners in the loop. Also, much of the information lacking does not exist, and some information is held back in awaiting decision making on who will be involved or not. Much of this uncertainty is hard to avoid, but will not persist as the project gets properly established as a way of working.

In order to share information as a means for strengthening sustainability awareness and shaping attitudes, events like seminars and courses can be arranged in the working time, and easily digestible videos can be made available.

4.7 Alternatives for bumper cover handling

During the interviews and data collection activities several alternatives to enhance the circularity of bumper covers came up. These were not investigated in depth, and thus only a brief description will be given of these. The alternatives are not mutually exclusive, and can in most of the cases be combined with material recycling. These alternatives can be divided into two main categories. Firstly, strategies are available or could be developed to prolong the life of bumper covers through increased repair and reuse, and secondly, the collection and logistics can be made easier through alternative ownership models or removed through open-loop strategies.

4.7.1 Use phase extension

When cars enter car dismantlers for condemnation it is often that the bumper cover, along with parts connected to the bumper cover (lamps, sensors, grill, etc.), are intact and without damage. If the bumper covers have no sign of damage, scuff marks or other cosmetic marks the bumper cover can be directly resold, or if minor marks are present, it can be fixed and repainted for resale. *B* spoke eagerly of the option for direct reuse. Direct reuse entails that even if some smaller marks are present, and the paint might be impacted by UV-radiation and look bleaker, the bumper cover should be offered for direct resale and reuse, as long as all functions stay intact. For a car user, getting the option to buy this bumper cover might be even more attractive than buying a new one if the bumper cover was to be offered at a reduced price. *B* pointed out how the "worn" look of the bumper cover might even match the rest of the car better than a new or renovated bumper cover would. It should be possible to offer these bumper covers at a better price as renovation work would not be needed (grinding, paint), and new parts would not be needed (grill, clips, lamps, etc.).

As mentioned above, many minor impacts to a bumper cover can be fixed, but not all car dismantlers do this. The case is similar for bigger repairs at car repair shops, where some damages are fixable, but the bumper covers are still changed for new ones due to cost issues or equipment and knowledge available at the repair shop. This leads to many bumper covers having shorter use phases than what they potentially could have had. When repairs are performed, however, an awareness and method is needed to avoid that non-PP material is used in rendering cracks, which would cause difficulties for recycling of the bumper cover. Another barrier for repairs is the guidelines for what repair shops are allowed to repair, as illustrated in Figure 7. *C* informed that repair shops are forbidden to repair certain areas of the car due to security reasons. Repairing the bumper cover can lead to tensions in the plastic or changed thickness. Increased tensions could cause the bumper cover to crack again, and increased thickness could disturb the functions of sensors and thus diminish the security and safety of the car. Developing better methods for repair so that more repairs could be performed without leading to such risks could prolong the use phase of bumper covers and reduce the need for spare bumper covers production.

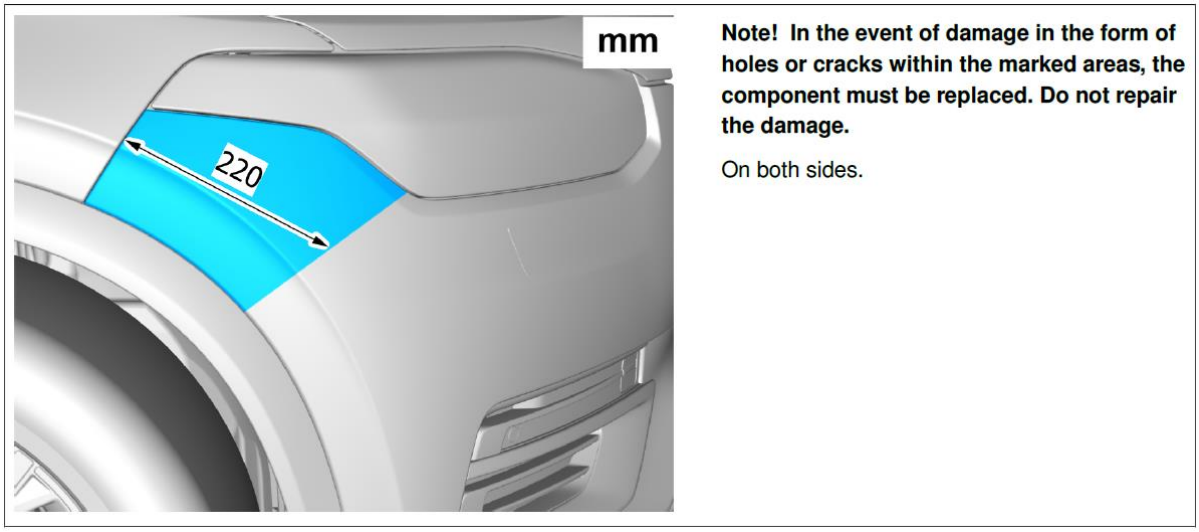

Figure 7: Example of area of a bumper cover that cannot be mended due to guidelines issued by Volvo.

4.7.2 Logistics

In the initial phases of the bumper cover recycling project, bumper covers will only be collected at certified Volvo repair shops. This requires that a large portion of the Volvo bumper covers will leave the circular system and be out of Volvo's control. Bumper covers can "leak" out of the loop through non-Volvo certified repair shops or through dismantlers, or through people discarding of the bumper covers themselves. A way for Volvo to gain better control of the cars and components is through leasing programs. Volvo could either own the cars themselves, use a daughter company or have agreements with a third-party leasing company. Leasing alternatives do exist today, but cars are sold out of the leasing system after reaching three years. Developing a leasing system, potentially combined with car sharing models, where the cars stay in the system until reaching EoL would allow Volvo full control over what happens to bumper covers and other components in case of damage, and what happens to the car and all the components at EoL.

Another alternative for the bumper cover handling is to disregard the idea of closed-loop recycling or that Volvo themselves are to use the recycled bumper cover material. As explained above, a complicated system needs to be organized and maintained to manage the reversed logistics of the bumper covers and to control the return and reuse of the bumper cover material. Volvo could choose to keep the system bumper cover collection at the repair shops, and maybe even the collection and gathering at the LDCs, but from there simply sell out the sorted material and let it become a part of the global loops, and trust that the buyers choose to use the bumper cover material for new plastic component production. This way Volvo could still refer to CO_2 emission reductions and circularity initiatives in their sustainability reporting, and know that they put efforts in for the environment, but avoid the added organisation and costs of controlling the entire loop.

5 DISCUSSION

The purpose of this thesis was to map out what the circularity of bumper covers could look like in terms of involved actors, material flows, information flows and activities. In addition, this thesis aimed to identify what factors can impact the success of such a flow, and how potential barriers can be overcome.

A number of actors must be involved for a circular flow to be possible. How this flow looks, and what activity is performed where is not completely set in stone, and must be decided on by the organizer, which in this case is Volvo. The choice can be based on factors like economy, control and administrative burden. The options are not necessarily better or worse, just different. For the flow to run smoothly there are many considerations to make the participation as effortless as possible for all involved, and to avoid easily avoidable issues. Most of these considerations are easy to perform and keeping them all in mind might be the bigger challenge than performing them. In addition, a major barrier for getting the project moving from a pilot study to a full-scale project is making decisions. Going with an option that entails low investment can be the safer choice to avoid being locked in to a solution and buys time to collect more experiences to base the choice on. There is much uncertainty connected to the project due to it being relatively new of its kind.

5.1 Discussion of results

There are several options for what the circular bumper cover flow can look like. Many actors must be involved, but exactly who and how many links must be in the chain, and which activity is done by whom is up for choice. Decisions must be made regarding, amongst other, where to do the shredding, which recycling company to use, in which type of containers to transport the bumper covers and how to organize logistics. Making these is partly challenging since the availability of information still is limited. Furthermore, the uncertainties concerning feasibility and quality of the bumper cover material and reuse thereof must be resolved, and results of further testing will also impact which processes are needed and which actors to involve. Volvo's priority in the beginning is to get the flow going and gather experiences. Deciding for an option which entails higher investment costs for Volvo can wait until they have more experience and more facts available. Independent of which material flows and process allocation are chosen, many actors must be involved, and many information flows will be needed.

Impact factors in the bumper cover project. Seven impact factor categories were identified: *Operational and logistics, Technical and quality; economic; people and attitudes; policy and regulations; ownership and control;* and *information and communication.* As explained in the results, many of the impact factors are closely related, and the categories thus overlap. However, a categorisation like this was found to be convenient for organizing and structuring the results. The majority of the impact factors were spoken of as issues to be aware of, or factors which could impact the success or costs of the project, but few were described as urgent barriers.

Some impact factors were identified as especially important, these are *feasibility of material reuse; quality control; employee engagement and competencies; and material flow control*. These are aspects which need to be in place for the flow to work. The bumper-to-air ratio was given much attention and described as quite critical during the interviews, but in the follow up meeting with *A* and *B*, when the impact factors were reviewed, they concluded that the added costs of transport were acceptable. The judgement of *A* and *B* were given high preference, since in they are among the most important actors. However, it should be noted that the logistics representative, *D*, especially emphasized the bumper-to-air ratio factor too.

Impact factors and barriers in literature. Although overlaps are present between impact factors and barriers in the literature and in the bumper cover project, there is a large discrepancy. The impact factors identified to be of most importance in the literature are costs, economic justification, and lack of initial capital; company policies, administrative burden and lack of management support; public awareness and customer reluctance; and policies and regulatory environment. In general, one could say that the literature paints a grimmer picture of how challenging it is to initiate and run reverse logistics and circular systems. Interviewees in the bumper cover project often hesitated to use the word barrier and challenge, and had attitudes like "yes, this factor could cause some challenges, but we will be able to solve that".

One main difference between the literature approaches and this project is that the current literature takes a more general approach. The articles conducting interviews and using questionnaires in general asked different companies who were not working on the same projects. The current literature focuses on different industries or automotive in general. No articles looked at one specific car part, or only one company and their partners. Asking interviewees or questionnaire subjects to report on general attitudes and experiences, or even on hypothetical expectations might have caused more aspects to be named barriers than what would have been the case in actual projects. It should also be noted that the reviewed articles were published in the timeframe 2010-2021. The attitudes, experience levels, and context of operation for the companies used for data collection might have changed over time, especially for those interviewed or questioned more than five years ago.

The above explanatory reasons can be part of why physical and technical challenges were not given much attention in the literature, but the lack of focus on this was still surprising. Some of the literature mentioned the cost of technological systems, or the need for technical information systems or software for tracing the products, but not the technical feasibility of material handling. One article, however, did mention strict quality demands in the regulatory environment, and linked this to public reluctance.

Costs, economic justification, and lack of initial capital. Costs and economic factors were given substantial attention in the literature. Several articles talked of the need for initial capital as challenging (Abdulrahman, 2014; González-Torre et al., 2010; Kaviani, 2020; Richnák & Gubová, 2021; Sharma et al., 2011). Some also described the challenges of economic justification and financial constrains in general while Sharma et al. (2011) and Zailani et al. (2017) specified how such capital could be needed for human resources, training of personnel, machinery and system development. The findings from this case stud at volvo, however, found that costs were of low concern. The literature articles interviewed and collected data from different sized companies, which may operate under different economic frames and the economic situations in the different countries of residence are very different. In the case of the

bumper covers, Volvo will be carrying the additional costs. Volvo is a large, economically stable company, and the initiation of the bumper cover project is a small added expenditure for them. Furthermore, varying culture, and attention to sustainability and climate can affect how company decision makers view the importance of sustainability initiatives, and thus also how they view costs related to them.

Company policies, administrative burden, and lack of management support. Management support and attitudes were given attention both in the literature and in the bumper cover project, but they were framed differently. While management support was described as a barrier and something which was lacking in the literature (Abdulrahman, 2014; González-Torre et al., 2010; Kaviani, 2020; Sharma et al., 2011; Simões et al., 2017), the interviewees in the bumper cover project agreed that management was supporting, and even pushing for sustainability initiatives. A reason for this difference can be that there is a different focus in businesses operating in different cultures, contexts, countries/regions. Volvo is an economically stable company which operates in a relatively rich country, and thus "can afford" to focus on sustainability. Operating in the EU with the directives and expectations from EU as steering regulatory environment management might take it more for granted that a sustainability focus is needed. Furthermore, Chinda (2017) identified experience with RL among managers as an important factor for successful RL implementation. Lack of RL experience was recognized at Volvo and among several of the managers from involved companies. However, interest and a learning approach was valued high, and they had trust that learning as the project developed would be sufficient.

Public awareness and customer reluctance. Public awareness and customer reluctance are also topics which were looked at very differently in the literature and by the bumper cover project interviewees. The reviewed literature emphasized this a lot (Chan et al., 2012, Kaviani et al., 2020; Gonzalez-Torre et al., 2010), but when Volvo representatives were asked about the matter, they replied that customers in the Swedish market, on the contrary, often preferred components with a higher recycled content. However, both *A* and *C* mentioned that they were aware that customer reluctance could be an issue in different markets than in Sweden and Europe. Furthermore, some of the literature articles did not specify if the returned products or materials would be recycled or remanufactured or handled with other R-strategies, or spoke of a variety of R-strategies. Attitudes towards components containing recycled material and remanufactured products could also differ. Attitudes can also have changed over the last decade(s). Chan et al. (2012) stated that people are becoming increasingly aware of sustainability. This is in line with the experiences of the interviews of this study, who reported that the younger generation of employees had high awareness of sustainability.

Policies and regulatory environment. Policies and regulations were not seen as barriers at all, and rather as potential driving factors, by the interviewees in the bumper cover project. In literature policies and the regulatory market were seen as a barrier, as not strict enough, or not adapted (Abdulrahman, 2014; Chinda, 2017; González-Torre et al., 2010; Kaviani, 2020; Rameezdeen et al., 2016; Richnák & Gubová, 2021; Sharma et al., 2011). The EU has worked actively to facilitate for circular economy within the EU and EEA, while such active work might not have been done in all other regions. Furthermore, interviewees pointed out how working with plastics was easy. Since the reviewed literature had more general approaches, interviewees and questionnaire respondents in those studies might have had a wide range of materials and products in mind. If an interviewee works with air bag systems or batteries, for

instance, they might experience more regulations impacting their work. In contrast to this thesis study, the reviewed literature articles did also not focus on a specific R-strategy. Interviewees and questionnaire respondents in those articles have, therefore, most likely also been working with different R-strategies, and are thus exposed to a wider range of regulations and policies.

Enablers. Volvo is already working with several of the identified valuable enablers. They are aware of ways of communicating, actively motivate and take the time to let partners, especially repair shops, understand the purpose and the value of the stripping work, and they exercise patience and apply a bigger picture approach to avoid getting stuck in less important challenges. It was expected, both by the author and by Volvo representatives to experience more reluctance and scepticism among repair shop and dismantler managers and mechanics. Surprisingly these partners have been very positive and cooperative. Repair shop and dismantler managers explained how the generations they employ today are quite environmentally aware, and that separating waste is a familiar concept. The mindful approach taken by the Volvo representatives, and their genuine interest in the topic can also have helped set the right tone in the project cooperation.

Much uncertainty was identified around how much material contamination is acceptable, and the time and effort which might be needed for controlling the stripping quality of the bumper covers has been repeated multiple times. In spite of this, only a few tests have been conducted to assess material quality. The absence of proper and elaborate testing is quite surprising, seeing that this is easily accessible and relatively cheap risk assessment which could remove much uncertainty and be valuable information to decision making.

Regarding the easing of demands on aesthetics and geometry, this seems like among the more challenging tasks. Volvo is a large institution. Communication flows are partly slow, many people would need to be involved in changing such demands, and it is a sensitive topic, as it is coupled with the communication and visualisation of quality.

5.2 Methods and validity of the findings

Three main sources of data were used: observations and casual conversation at site visits; semi structured interviews; and access to documents produced by Volvo. The site visits at repair shops and the car dismantler allowed for a deeper understanding of the practical work relating to the bumper cover handling there, and conversations with people taking part in the project added to the data on experiences from this kind of stakeholder. The group of interviewees was broad and thus allowed for many perspectives to be included, in addition to the feedback from people active in different stages of the reverse logistics of the bumper covers and the rehandling of the material. However, in the case of the component producer, only one representative from each department at Volvo or from each type of stakeholder included was interviewed. Including representatives from more material producers, recycling companies, engineering design, etc. could have been beneficial to increase the validity of the results. This was challenging due to the time limitation of this thesis study and also since Volvo's bumper cover project is in the pilot study stage and only a few people have actually been involved in the project. Interviewing other industry representatives would have only contributed with hypothetical opinions seeing that they have not been involved in the project. In the case of the component producer, a second

interview was conducted with a former materials expert at the component producing company in addition to the company representative linked to the pilot project. This person was included to increase the validity of the findings relating to technical and quality related issues. Seeing that the person no longer is employed at the company, but worked with bumper cover production for Volvo for many years, they were seen as a reliable and objective source. In the case of operational experiences and attitudes at repair shops, the validity is also seen as high since information came from an interview, site visits at two different repair shops, and notes from a third site visit conducted by a Volvo representative.

The use of Actor-system mapping as a framework allowed for coupling all the data and ensured the system approach. The actor identification of the second and third step of the ASM was elaborated with a stakeholder analysis to provide a better understanding of the relevance of the interviewees and to evaluate and visualize their power- and interest status.

Semi-structured interviews have the benefit of allowing the conversation to float in different directions, and to let additional topics be included ad hoc. Furthermore, more attention can be given to the topics relevant for the specific interviewee. For instance, questions regarding the concrete handling for the bumper or the technical aspects of recycling are less relevant for the LDC representative, while costs and questions relating to transport of the bumper covers and materials are less relevant for the repair shops. These benefits can allow for the discovery of aspects the interviewer had not yet thought of, but can also lead to “false negatives”. For instance, an interviewee could potentially agree that a topic is of importance, but since the topic did not occur during the interview, this was not noted. One must rely on that all the relevant information came forth during the interviewee. Another source of variance of data collected in different interviews are personality types. Some people are talkative, and elaborate and emphasize on topics, while others give short replies, and are less likely to elaborate unless invited to. The author believes that this was tackled well by being consistent in asking about thoughts on all potentially relevant aspects of bumper-handling, while also mindfully sorting through the information in the analysis part. Furthermore, meetings and conversations that the interviewee had earlier in the week or in the day can lead to them putting more or less emphasis on certain topics.

The data was analysed qualitatively. This allowed for more nuance in description of the identified aspects. This form of data analysis did not allow for numerical and concrete ranking and valuation of the different impact factors. On the one hand numerical valuation and ranking can make it easier for the reader to compare the impact factors, and offer a higher certainty that the reported results match the respondents’ opinions. On the other hand, however, putting a concrete decimal number on an impact factor’s importance might not offer higher value. Such numbering might be misleading since the importance of a factor may vary from case to case. Understanding why something is important, how it relates to other factors and how one can work with it can offer more applicable insights for people working with reverse logistics and circular systems.

5.3 Relevance of this study's findings

A case study has the advantage of depth, but thus is limited in with. Factors like national or regional culture, company culture, company size, economy of the company and region of operations all impact the execution and experiences of a project. Thus, the findings of this case study are not necessarily translatable to similar projects performed at other car manufacturing companies and their value networks. That being said, there are still many potential applications of this thesis' findings. This is portrayed well in the overview of factors and barriers identified in this study compared to the factors and challenges identified in previous studies. There is both overlap and variance between this study and the other studies, and between the other studies.

Many of the impact factors could be described as potential barriers, if neglected. Having an overview of impact factors is thus helpful to maintain the broad focus and to prevent problems from occurring. Since this study is focused on a specific project and a specific product, the study not only adds to but also offers some new insights and more detailed insights to the current literature. The overview of impact factors can be of value for both Volvo and other companies who wish to initiate or improve reverse logistics and circular initiatives.

This study goes into the line of many articles investigating factors and barriers relevant to reverse logistics and circularity. However, it is unique in its specific and detailed product focus, and the multi actor perspective. The perspectives from different actors who are all involved in the same project for example offers comparability of their views.

6 CONCLUSION

This thesis project's objectives were to explore what the circularity of bumper covers could look like, within the frames of Volvo's recycling project, in terms of actors involved, material flows, information flows and activities, and to identify what factors to pay attention to in order to ensure the success of the bumper cover flow, and what enabling activities can be implemented to avoid or overcome barriers.

A number of actors, activities and information exchanges must be involved for a circular bumper cover flow to be possible. There is no set answer for exactly how this should be organized, and more experience and knowledge is needed to decide which alternative is more preferable. The choices of involved actors and allocation of activities also depends on how much control Volvo wants, what kind of investments they want to put in, and on technical possibilities and limitations.

Seven impact factor categories were identified: operational and logistics, technical and quality; economic; people and attitudes; policy and regulations; ownership and control; and information and communication. Most of the impact factors were spoken of as issues to be aware of, or factors with potential to impact the success or costs of the project, but few were described as barriers. The impact factors identified as most important in the bumper cover project are feasibility of material reuse; quality control; employee engagement and competencies; and material flow control. In general, one could say that the literature paints a grimmer picture of how challenging it is to initiate and run reverse logistics and circular systems. While there are overlaps between impact factors and barriers identified in the literature and in the bumper cover project, the discrepancy was surprisingly large, especially regarding which are of high importance. The main barriers and factors identified in literature were, costs, economic justification, and lack of initial capital; company policies, administrative burden and lack of management support; customer reluctance and lack of public awareness; and policies and regulatory environment.

The impact factors identified as most important in the bumper cover project are to a large degree possible to deal with, and Volvo is practicing enabling activities. They are aware of ways of communicating, actively motivate and take the time to let partners, especially repair shops, understand the purpose and the value of the stripping work, and they experience that partners cooperate well. Much uncertainty was identified around how much material contamination is acceptable and what possibilities and limitations exist in the material processing and component production activities, and the time and effort which might be needed for controlling the stripping quality of the bumper covers has been repeated multiple times. To reduce uncertainty and facilitate decision making, increased testing and exploration would be an important enabler to introduce.

Due to the focus on a specific project and product, this thesis study offers new and more detailed insights. The overview of impact factors and enablers can offer valuable support for both Volvo and other companies who wish to initiate reverse logistics and circular initiatives.

6.1 Recommendations: practical actions to be taken

A list of recommendations for the team at Volvo is drawn up. The first four points of the list are in prioritized order and are more concrete measures. The last three recommendations on the list are measures which should be given continuously attention.

Concrete measures

1. **Get familiar with the impact factors**
   The bumper cover project coordinators at Volvo should take the time to familiarize themselves with impact factors they themselves are less familiar with, those who were mentioned by other actors solely, to ensure they are acting with a proper understanding of the project and their project partner's perspectives and insights.
2. **Investigate the possibility to implement enablers**
   The project coordinators should explore the possibility to incorporate the enablers identified in this report. The team at Volvo should take the time to look into which enablers are easy to implement, and which can have large effect, and based on this make decisions on which enablers to implement.
3. **Conduct more tests on material and component production**
   This is a concrete measure which can bring great rewards. Initially, tests should be conducted to remove the uncertainties around the use of flakes in production and the tolerance levels for non-PP-plastic.
4. **Investigate channelling the used bumper covers to spare part production**
   The alternative enabler of sending the bumper covers and bumper cover material to the spare part producer should be explored, since this possibly can be a way to deal with or avoid many of the factors relating to technical and quality aspects.

Continuous measures:

5. **Information sharing and education**
   Increased education and information sharing within the entire Volvo organisation. This could for example include education seminars or videos showing information about projects at Volvo.
6. **Keep the big picture approach**
   A general recommendation is for the project coordinators is to stay patient and focus on the learning and exploratory approach to gathering experiences. Being aware of the impact factors, actively listening to project partners and having exploratory and solution-oriented meetings or even workshops can be good to increase the understanding of the alternatives for the bumper cover flow, and to both discover and narrow down on best option solutions.
7. **Focus on attitudes**
   A focus on attitudes of colleagues and people connected to the bumper cover project should be maintained. Continuously stimulating colleagues' and partners' interest can create a self-enforcing circle of motivation.

6.2 Further research

More studies are needed on component level and from multi actor perspectives to strengthen the research in this field. Combining qualitative, interview-based research with rating-based questionnaires could strengthen the validity of the findings. Another possible line of future research is to take a more specific focus on impact factors for performing circular initiatives in different geographical regions. This would be valuable since many larger companies with large impact operate internationally. Furthermore, investigations of experienced versus actual management support and management prioritisation of circular initiatives could be valuable, especially since the findings in the report contrasted the literature findings drastically. Finally, research should be conducted on whether and potentially how servitisation could ease or impact the practice of reverse logistics for circular initiatives.

An additional recommendation for further research for Volvo is to investigate how they can move more towards circularity an increase product value retention through increased reuse, repair, and remanufacturing. Pilot projects on increased implementation of these R-strategies could be a good start.

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Appendix I: Interview questions

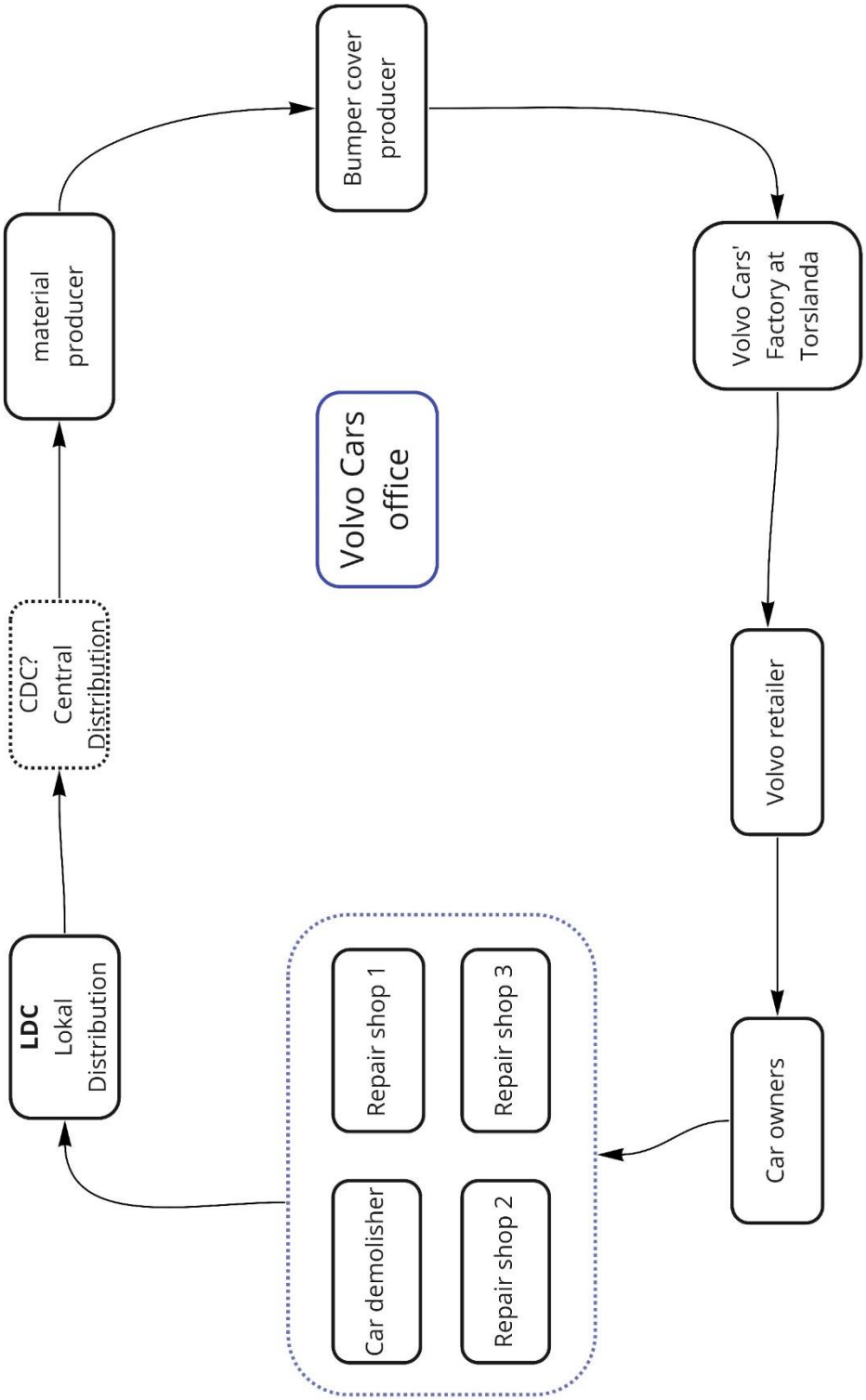
The original interview questions were in Swedish, a translation is provided here.

1. What is your position at this job, and have you worked here long?
2. How did you get involved in the bumper cover project and how long have you/your organization been involved?
3. How do you experience taking part in this project?

4. (If they handle bumper covers or bumper cover material), who do you get the bumpers or material from?
5. What do you do with the bumper covers/bumper cover material at your facilities?
6. Potentially ask to elaborate on what they share.
7. Who do you communicate with in relation to this project?
8. Who do you receive information from?
9. Do you miss any information?

10. Have you taken part in other reverse logistics projects?
    If yes, how would you say this project differs from other?
11. Has taking part in this project led to any benefits or disadvantages for you/your organization?
12. Are there any aspects (practical, information related...) with this project that you wish are difficult or unpractical, which you think could be improved?
13. If they didn't mention anything related to the below listed aspects, more specifically about those aspects
    a. Information from actors
    b. Transport
    c. Storage
    d. Costs
    e. Variations in amounts and timing
    f. Competencies
    g. Management support
    h. Policies and laws
    i. Product design
    j. Attitudes of colleagues or employees
14. Have you thought of any other changes that could improve the bumper cover project or make it more attractive to take part?
15. Do you think anything will be different if the project is scaled up geographically or to include more/different types of car components?
16. Is there anything else you would want to add in relation to the return logistics of bumper covers and/or the handling of them/the material?

Appendix II: Simple Flowchart used during interviews



Appendix III: Pictures of bumper covers

Picture 1: Cables and green clips on the inside of a bumper cover

Picture 2: Stripped and cut bumper covers stacked on a trolley at a repair shop

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