FOREIGN TRADE UNIVERSITY

HO CHI MINH CITY CAMPUS

MID-TERM REPORT

Major: Logistics and Supply Chain Management

Subject: Logistics Operation

EXAMINATION OF BARRIERS IN REVERSE LOGISTICS WITHIN THE AUTOMOTIVE INDUSTRY: A CASE STUDY OF VOLVO GROUP

Member:

1.	Nguyễn Minh Trí	2211535007
2.	Kiên Minh Trung	2214535046
3.	Trần Tuệ Linh	2213535034
4.	Phạm Minh Thuận	2213535038
5.	Nguyễn Gia Bình	2214535041

Class: K61CLC3 ML105

Lecturer: Ph.D Le Thi Thanh Ngan

Ho Chi Minh, December 04 , 2024

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

RL	Reverse Logistics
VBC	Volvo Bus Corporation
VTC	Volvo Truck Corporation
SO	Stock Order
DO	Day Order
IT	Information Technology
EOL	End Of Life
UK	United Kingdom
ELVs	End of Life Vehicles
3PL	Third Party Logistics
CAST	Common Architecture & Shared Technology
SDC	Support Distribution Center
RDC	Regional Distribution Center
BB	Buy-backs
SOP	Standard Operating Procedures
FL	Forward Logistics
KPI	Key Performance Indicator
GDP	Gross Domestic Product
ROI	Return on Investment
R&D	Research & Development
ACEA	European Automotive Manufacturers' Association

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

1. Rationale of the Research

According to the Research Nester's survey in 2024, The reverse logistics market is projected to grow significantly, from $799.84 billion in 2024 to over $1.43 trillion by 2037, with a compound annual growth rate of 4.6%. In 2025 alone, the market is expected to reach $829.27 billion. Meanwhile, nearly one fourth of the total market share will be for the automotive reverse logistics market.

The concept of reverse logistics (RL) is gradually becoming more important to manufacturing companies, driven by such factors as environmental awareness, competitiveness, and environmental regulations,... (Moktadir et al., 2019). With increasingly stringent regulatory measures, companies have little choice but to adopt reverse logistics. This implementation can be challenging for senior management as it involves financial and operational aspects that determine the long-term performance of the company. Especially in the automobile industry, this is one of the largest and most important industries in the world.

Extensive research has demonstrated that reverse logistics practices are already widely used within the automobile industry (Daugherty et al., 2003); (Thierry et al., 1995); (Qu and Williams, 2008). In reality, when a vehicle comes to its end-of-life, numerous of its components, such as engines, often remain in good condition and can be refurbished or remanufactured, preserving their utility which means the value can be recovered from other auxiliary components of automobiles like tires, batteries, etc. From these scenarios, the application of reverse logistics can promote resource reutilization, reduce costs and environmental impact by extending product life cycles in an eco-friendly manner..

Furthermore, according to the research of (Ravi and Shankar, 2017), they reveal that various variables within the automobile supply chain not only cause an impact on reverse logistics activities, but also interact with each other. Identification of mutual relationships among variables of reverse logistics deserves special attention. For these reasons, this research of the barriers to reverse logistics and their interaction with other aspects of integration planning can be a valuable source of information for decision makers.

To this end, the purpose of this report is to figure out all the obstacles that can prevent many firms in the automotive industry from successfully implementing reverse logistics. Through a comprehensive study on extensive research and a detailed case study in practices from a specific firm, the research will clarify the complexities and challenges inherent in the process of reverse logistics within the automotive industry. Concurrently, the insights gained from this report will be a valuable contribution to understanding the issues associated with reverse logistics, and helping firms to overcome these barriers while achieving more efficient and sustainable operations.

2. Literature Review

Research of reverse logistics concepts and circular economy can be widely accessed through large and reliable online databases such as: Google Scholar, ResearchGate, EconLit and ScienceDirect. Our review of existing research from four primary sources indicates that studies in this area can be broadly classified into two categories: (1) general research of reverse logistics and circular economy, and (2) specific explorations of reverse logistics & circular economy in the automotive industry.

2.1. Reverse logistics & circular economy in general

In 2010, **Joseph Raymond Huscroft, Jr** released the study: "**The Reverse Logistics Process in the Supply Chain and Managing Its Implementation**". This is a compilation of 3 research papers regarding 3 different perspectives: key drivers of RL performance and implementations, information system for coordination and performance metrics for RL process.

The first research provides a comprehensive overview of academic research in the field of reverse logistics. By analyzing existing literature, the study highlights key research areas and identifies gaps in knowledge. Additionally, the research compares the concerns of industry practitioners with academic perspectives, offering insights into the practical implications of reverse logistics. The study also prioritizes key factors that can improve reverse logistics processes, providing valuable guidance for managers seeking to optimize their operations.

The next research investigated the connection between information technology attributes and organizational innovation in reverse logistics. The study aimed to develop a model that can help both academics and practitioners identify the most critical IT attributes for improving reverse logistics performance. By understanding the impact of technology and innovation, organizations can prioritize resource allocation and optimize their reverse logistics processes.

The last study conducted a grounded theory investigation on the current use and significance of metrics in the reverse logistics sector. By analyzing and coding practitioners' feedback, the researcher created a model that emphasizes the balance between customer service, cost, and process performance within a firm's reverse logistics operations. This research aids practitioners by offering managers a list of prevalent reverse logistics metrics and current challenges faced by reverse logistics managers. However, there has been limited academic research focused specifically on evaluating and establishing performance metrics.

Although the field is still in its early stages, it requires more empirical studies and hypothesis testing to advance and continue utilizing the Carter and Ellram (1998) framework. As the global supply chain expands, the importance of an effective, measurable, and efficient reverse logistics system becomes crucial for firms. Such systems can transform cost and loss areas into value centers, potentially generating new revenue streams. Consequently, both academic researchers and managers need to deepen their understanding and development of the various factors and challenges within reverse logistics to drive the field and their companies forward.

The study " **A study on Reverse Logistics**" by **Dhananjaya Reddy** (2011) aimed to consolidate the fundamental concepts of reverse logistics and highlight the advantages of an effective reverse logistics process through surveys and interviews. The discussions with survey participants revealed that many firms already implement various reverse logistics strategies, although they are often unaware that the activities they routinely perform are collectively categorized under reverse logistics. The survey targets at answering 6 basic questions:

1. Which companies are affected by reverse logistics?
2. What do they know about reverse logistics?
3. How do customers choose their suppliers?
4. How do returns affect the manufacturers?
5. What happens to the returned goods?
6. How well have the reverse logistics concepts penetrated the manufacturing industry?

Participants indicated that they are actively working on improving their reverse logistics processes by cleaning and refining their waste before disposal and requiring their business partners to do the same.

The research also revealed the factors customers consider most important when selecting suppliers, as per participant responses. Through the survey, cost reduction and quality of service are the two most important factors which customers consider while choosing suppliers. Speed of delivery is the third most important factor according to the responses given by the participants. An effective reverse logistics process enhances delivery speed, which in turn improves the quality of service.

2.2. Reverse logistics & circular economy in the automotive industry.

The research "**Investigation on Reverse Logistics of End of Life Cars in the UK**" **(2019)** by **Farhana Sorker** extends previous research by delving deeper into the specific reasons and nature of end-of-life (EOL) car returns. While prior studies have generally categorized returns as simply "EOL cars," this research provides a more detailed analysis, considering factors such as car composition and the presence of dismantle marks. These details have significant implications for the reverse logistics (RL) process, particularly in terms of recycling and hazardous materials handling. For instance, the use of lightweight materials can impact the shredding stage, while the increasing number of electric vehicles and batteries can affect hazardous material collection and recycling. These findings highlight the need for car manufacturers to prioritize the recyclability of materials and for authorities to invest in infrastructure for handling hazardous materials.

This research provides a detailed examination of each stage of the EOL car RL process, including regulatory restrictions, activities, timelines, locations, and performance metrics. This level of detail is lacking in previous research, which has often focused on broader aspects of RL. By analyzing the UK automotive industry's success in recovering 95% of EOL cars, this study offers valuable insights into best practices for managing EOL vehicles. The findings can help other industries and countries identify gaps in their RL processes and implement strategies to improve efficiency, reduce environmental impact, and maximize resource recovery.

Additionally, the study contributes to the theoretical foundation of RL by applying established and emerging theories to the context of EOL car RL. It proposes a comprehensive framework that includes key aspects of RL and relevant government regulations, which can serve as a valuable resource for future research and practical applications in the automotive and other industries. This framework is a significant contribution to the field, as it offers a detailed and validated approach to understanding and managing RL processes.

This research provides valuable insights for practitioners in the automotive industry, highlighting the importance of collaboration between various stakeholders, including manufacturers, suppliers, dismantlers, and waste management companies. The study emphasizes the need for strong regulatory frameworks, investment in research and technology, and public awareness campaigns to promote sustainable end-of-life vehicle (ELV) management. By implementing best practices identified in the UK automotive industry, other countries and industries can improve their own RL practices and reduce environmental impact.

This literature also reviews "**Reverse logistics assessment in the automotive industry: A case study at Volvo Group**" **(2017)** by **JULIO MINAYA OSORIO** aims to assess the reverse logistics systems that are currently being employed in the focal company and suggest improvements. The purpose of study was fulfilled by the means of three research questions. First, the current situation regarding reverse flows was studied. Secondly, key factors influencing this situation within the focal company were exposed, and thirdly, recommendations to improve the control and the performance of the reverse logistics practices were provided.

This research initially aimed to explore reverse logistics practices within a specific company. However, due to data accessibility constraints, the scope was narrowed to the Swedish market. To gather information, the researcher conducted semi-structured interviews and analyzed operational data provided by a 3PL service company. The study focused on both forward and reverse logistics, examining order types, return processes, and performance metrics. This research provides valuable insights into the complexities of reverse logistics in the Swedish market.

To suggest improvements for the company's reverse logistics processes, the researcher first identified key factors influencing the current system. These factors included communication between Volvo, the 3PL company, and dealers, dealer experiences with return processes, return planning and policies, lead times, and performance measurement. This analysis provided a foundation for developing recommendations to optimize the system.

Once the key factors influencing return transports were identified, the research focused on developing recommendations to improve the company's reverse logistics practices. Nineteen recommendations were proposed, each addressing one of the five key factors. These recommendations were evaluated based on their potential impact on key performance indicators (KPIs) and the ease of implementation. By combining these two factors, the research prioritized recommendations that would yield the greatest benefits with the least effort. Finally, the best five ranked recommendations were: *Perform lead times measurements; Track and trace; Data collection (3PL); Establish same day deliveries; and Measure the performance of each dealer*.

3. Research Aims and Objectives

3.1. Research aims

The primary aim of this research is to conduct a thorough synthesis and analysis of factors that have repercussions on the reverse logistics of the Automotive Manufacturing industry through a specific case study of a specific Large Automobiles Enterprise. Those barriers will be clarified by comprehensively examining their effects through the in-depth analysis in different aspects of the reverse logistics in this business, and the mentioned case study.

3.2. Research objectives

To obtain the aim of the study, the following targets have been formulated:

- Analyze the basic process flow and current situation of RL in the Automotive Manufacturing Industry.
- Evaluate the potential barriers of RL implementation that this industry could face during their application and operation.
- Identify the most feasible practices and improvements when necessary.
- Analyze the case study of a Big Corporation to conclude several key learning points for future trends and implementation.

4. Scope of the Research

4.1. Subject

EXAMINATION OF BARRIERS IN REVERSE LOGISTICS WITHIN THE AUTOMOTIVE INDUSTRY: A CASE STUDY OF VOLVO GROUP.

4.2. Scope

Chronological: Using data and statistics from 2016 to trace the reverse logistics activities involved in Volvo Group's automotive manufacturing processes.
Geographical: The scope encompasses a global examination of reverse logistics barriers in the automotive industry, with a specific focus on
Industrial: The research confines itself to the automotive industry, with a specific focus on Volvo Group's operations.

5. Research Questions

a. What barriers hinder the effective implementation of reverse logistics within the automotive industry and specified in Volvo Group?
b. What practical solutions can be suggested to address and mitigate the challenges of reverse logistics in the Volvo Group?

6. Research Methodology

This report will apply a qualitative research method, including a comprehensive review of relevant literature and an in-depth case study analysis of the Volvo Group. Secondary data will be collected from books, academic articles, industry reports, and company-specific documents. This approach aims to provide a clear understanding of the barriers that exist in implementing effective reverse logistics within the automotive manufacturing industry.

7. Research Structure

This research is composed of four chapters. The Introduction provides the background, defines the research objective with the research questions to be addressed, and the method of the research.

Chapter 1 reviews key literature on reverse logistics in the automotive industry, providing a foundation for the study.

Chapter 2 analyzes barriers to reverse logistics in the automotive sector, categorized into economic-related, supply chain collaboration processes, management-related, policy-related, and environmental aspects.

Chapter 3 examines a case study of Volvo Group, identifying challenges and proposing recommendations to overcome barriers within the case.

Chapter 4 summarizes findings, highlights research limitations, and suggests directions for future studies.

CHAPTER 1: THEORETICAL FRAMEWORK

1.1. Reverse Logistics

1.1.1. Concept of Reverse Logistics

The APICS Dictionary defines reverse logistics as a complete supply chain dedicated to the reverse flow of products and materials for returns, repair, remanufacture, and/or recycling (APICS, 2008). The Reverse Logistics Association defines reverse logistics as all activity associated with a product/service after the point of sale, with the goal to optimize or make more efficient aftermarket activity, thus cutting down the costs and environmental resources (Reverse Logistics Association, 2013). Lastly, reverse logistics is a comprehensive set of activities that takes place after a product has been sold, with the primary goal of recapturing value and effectively managing the end of the product's lifecycle (Essex, 2021). This process typically includes all logistics operations that are involved in returning, inspecting, and processing products that have been shipped back from consumers, companies, or retail outlets to the logistics warehouses of distributors or manufacturers.

In essence, reverse logistics represents the conventional logistics flows but in reverse order. That means instead of moving products from warehouses to consumers, items are returned from the point of consumption or sale back to the warehouse. Once there, these products can undergo various processes such as being exchanged, refunded, reused, repaired, refurbished, recycled, and, if their condition permits, resold to new customers (Reflex, 2024).

1.1.2. Reason for the importance of reverse logistics

According to the research of (Ab, Nik and Yaakub, 2014), reverse logistics offers numerous benefits to customers, businesses and even the environment. For customers, reverse logistics plays an important role in ensuring the timely removal of defective or hazardous products. This process not only promotes customer's safety but also enhances their satisfaction.

When customers know that they can easily return faulty items or dispose of dangerous products, they feel more secure in their purchases and consumptions. This assurance can lead to increased trust in the brand and build a stronger customer relationship.

For businesses, there are various activities that are part of the reverse logistics programme. Each of these activities serves different purposes, such as efficiently removing defective and environmentally hazardous products from the hands of customers. This practice is not just about taking back products; it also leads to significant benefits for the environment. (Jayaraman, Patterson, & Rolland, 2003). By efficiently managing the return and recycling of products, companies can reduce waste, conserve resources, and enhance their environmental reputation. It can be said that this is increasingly important in today's market, where consumers are more aware of environmental issues and prefer to support businesses that demonstrate a commitment to sustainability.

At the same time, reverse logistics can lead to substantial cost savings for businesses. For companies that continually strive for achieving cost savings in their production processes, a reverse logistics program is a good option as it would lead to cost reduction (Fassoula, 2005; Gentry, 1999). When businesses can recycle or repurpose returned items instead of sending them to landfills, they not only save money but also contribute positively to the environment. This dual benefit of cost savings and environmental responsibility makes reverse logistics an attractive option for many companies.

Understanding reverse logistics is crucial for businesses aiming to enhance sustainability and improve customer satisfaction through efficient product returns and lifecycle management. By reusing the end-of-life products, the environment is benefited and the company' goodwill among the consumer might increase. Reverse logistics can also lead to production of green products through recycling, remanufacturing or reconditioning. These green products appeal to consumers, especially as modern consumers are increasingly willing to pay more for environmentally friendly options (Vandermerwe & Oliff, 1990). Moreover, Jayaraman and Luo (2007) stresses that high quality reverse logistics activities can also promote long term relationships where customers are more likely to repurchase from firms who do a good job at handling returns.

In conclusion, reverse logistics is not just a logistical challenge, it is also an opportunity for businesses to enhance their operations, improve customer satisfaction, and contribute positively to the environment. By embracing reverse logistics, companies can create a win-win situation for themselves, their customers, and even the environment.

1.1.3. Activities in reverse logistics

Clearly, reverse logistics can include a wide variety of activities. Some of these activities are summarized in Table 1.1 below.

Table 1.1: Common Reverse Logistics Activities

Material	Reverse Logistics Activities
Products	Return to Supplier Resell Sell via Outlet Salvage Recondition Refurbish Remanufacture Reclaim Materials Recycle Landfill
Packaging	Reuse Refurbish Reclaim Materials Recycle Salvage

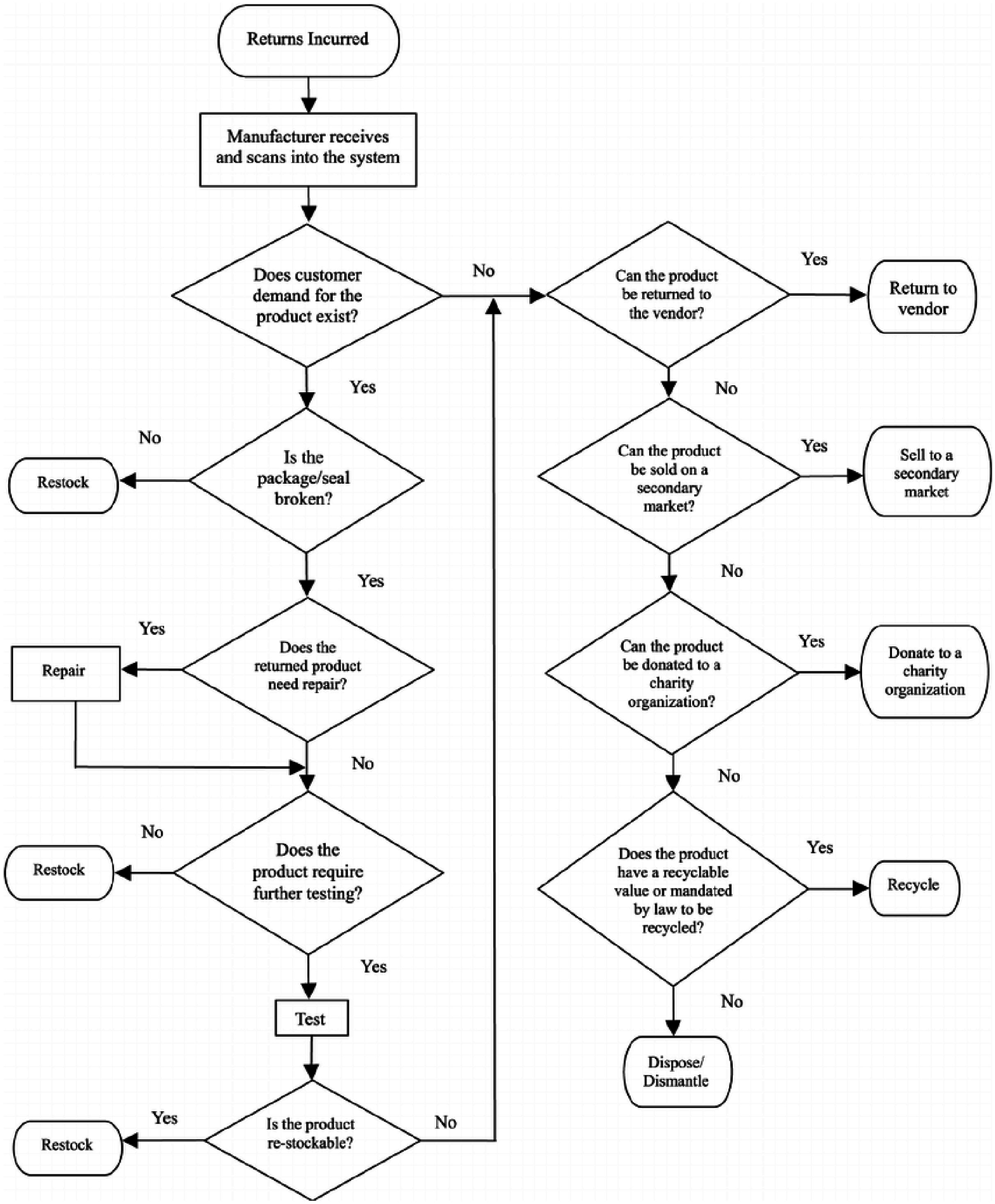
(Source: Dale, S.R. and Ronald, S.T.-L., 1998)

The reverse logistics activities can be categorized based on two main aspects: first, determining if the goods in the reverse flow are coming from the end user or from another member of the distribution channel such as a retailer or distribution center; and second, identifying whether the returning materials in the reverse flow are actual products or packaging components. These two factors help to establish a fundamental framework for understanding the reverse logistics operations, though additional classification criteria exist. All items in the reverse stream must undergo collection and sorting procedures before proceeding to their subsequent destinations, regardless of their ultimate endpoint. The point at which items enter the reverse flow significantly influences the configuration of the reverse logistics network.

1.1.4. The flow/process of reverse logistics

Typical reverse logistics activities would be the processes a company uses to collect used, damaged, unwanted (stock balancing returns), or outdated products, as well as packaging and shipping materials from the end-user or the reseller.

Figure 1.1: A typical return process at a manufacturing facility



(Source: Li and Olorunniwo, 2008)

When items are returned to a company, it has several disposal options to consider. If their supplier offers a complete refund for the returned product, they might choose this choice first. Besides, for unused products, the company can either sell them to another customer or distribute them through outlet stores. If the quality isn't suitable for these options, it might be transferred to a salvage business that exports goods to foreign markets.

If the product cannot be sold “as is,” or if the firm can significantly increase the selling price by reconditioning, refurbishing or remanufacturing the product, the firm may perform these activities before selling the product. When the company lacks in-house capabilities for these activities, they may either hire a third-party service provider or sell the item directly to a specialized reconditioning/remanufacturing/refurbishing business.

After performing these activities, the item can be sold as a reconditioned or remanufactured product, but not as new merchandise. When the reconditioning isn't feasible due to its poor condition, severe damage, legal constraints, or environmental regulations, the company will seek the most cost-effective disposal method by extracting any valuable components for reclamation and separating recyclable materials before sending the remaining waste to a landfill.

Generally, returned packaging materials will be reused by the company. Reusable totes, containers, and pallets are designed for multiple uses before disposal. Damaged containers and pallets can often be refurbished and returned to use. This restoration can be done internally or outsourced to specialized companies that focus exclusively on pallet repair and packaging renovation. When repairs are no longer possible, the reusable transport materials must be disposed of. However, all recoverable materials will be salvaged before the final disposal in a landfill.

1.2. About Automotive Industry

1.2.1. An introduction of automotive industry

The automotive industry, a cornerstone of modern manufacturing, has evolved significantly since its inception in the late 19th century. It includes the design, development, production, marketing, and sale of motor vehicles, including cars, trucks, motorcycles, and other motorized vehicles. The industry has seen rapid technological advancements, such as the introduction of the moving assembly line by Ford in 1913, which revolutionized production. Today, China leads the world in automobile production, with over 30 million vehicles produced annually. The automotive industry is known for its rapid technological advancements, which have led to the development of safer, more efficient, and environmentally friendly vehicles (Binder, 2019).

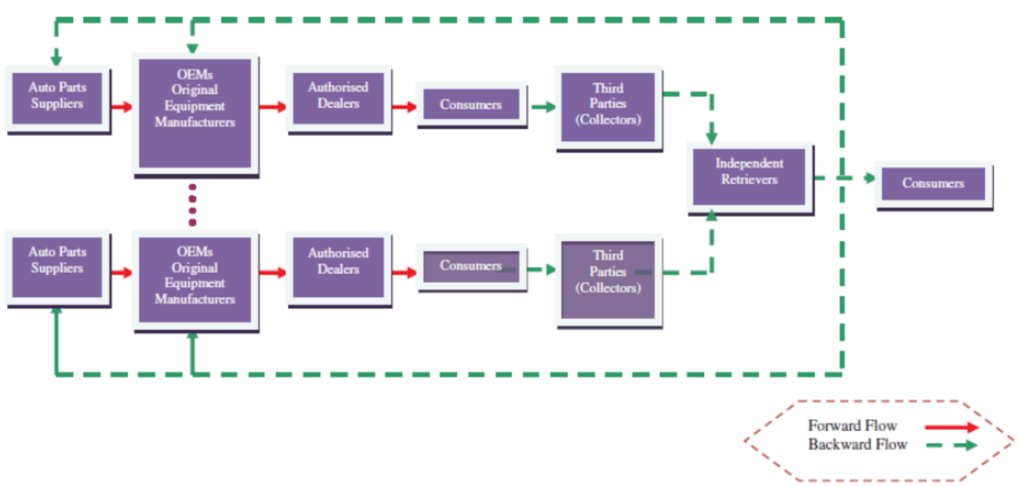
The industry is characterized by its global reach, with major manufacturing hubs in North America, Europe, and Asia. It plays a crucial role in the global economy, providing employment to millions of people and contributing significantly to GDP in many countries. The automotive industry is also a major driver of innovation, with continuous investments in research and development to improve vehicle performance, safety, and sustainability (Orsato and Wells, 2007).

1.2.2. The Supply Chain of Automotive industry

The supply chain in the automotive industry is a complex and intricate network that involves multiple stages and numerous stakeholders. It begins with the sourcing of raw materials, such as steel, aluminum, and plastics, which are essential for vehicle production. These materials are then processed and manufactured into various components and parts, including engines, transmissions, and electronic systems.

Once the components are produced, they are assembled into vehicles at manufacturing plants. This stage involves a high degree of coordination and precision, as thousands of parts must come together seamlessly to create a finished product. The assembled vehicles are then distributed to dealerships and retailers, where they are sold to consumers.

Figure 1.2: Supply Chain of the automobile industry (Extended view)



(Source: Chan, Chan and Jain, 2012)

The automotive supply chain is highly dynamic and can be influenced by various factors, including economic conditions, technological advancements, and regulatory changes. Companies in the automotive industry must continuously adapt to these changes to maintain efficiency and competitiveness. Additionally, the industry is increasingly focusing on sustainability, with efforts to reduce the environmental impact of production processes and promote the use of renewable materials. The supply chain also includes after-sales services, such as maintenance and repairs, which are crucial for customer satisfaction and brand loyalty. Effective supply chain management in the automotive industry helps reduce production costs, improve product quality, and ensure timely delivery of vehicles to the market (Masoumi, Kazemi and Rashid, 2019).

1.2.3. Importance of reverse logistics in the automotive industry

The world's business environment has entered a new era which is extreme of competitiveness. Companies within the supply chain networks cannot escape this situation. They can no longer operate in isolation to maintain profitability. Instead, to be competitive, they must act collaboratively with other players (i.e. suppliers, manufacturers, dealers) to enhance the entire supply chain's efficiency by sharing goals and objectives. These scenarios lead to the necessity to shift the supply chains toward to adopt Closed-Loop supply chains, where the product life is extended even after the selling. Hence, reverse logistics play an important role. However, in the automotive industry, firms do not seem to be able to manage the reverse logistics process effectively, this is a really major problem. Reverse logistics need to be further taken into consideration, to not only improve the quality of services of the firms but also ensure the end-customer satisfaction.

Reverse logistics processes have been an unseparated part of the automotive industry since its inception. They will be in charge of the returns from raw material surplus, quality-control issues, by-products, product recalls, overstocks, and EOL returns. These processes are essential for meeting economic, finance, legislative, and social engagement goals. To be more specific, reverse logistics is vital for salvaging parts and materials from EOL vehicles and remanufacturing used parts. For instance, components such as engines, alternators, starters, and transmissions, which can be refurbished or remanufactured to extend their life cycle (Rogers and Tibben-Lembke 1999; Ravi and Shankar 2005). In addition, parts that are still in working condition from end-of-life vehicles are also prime objects for reuse, adding substantial economic value by reducing the need for new raw materials. Shredded metals from vehicles, for example, can be recycled into raw materials for scrap-processing industries (Steinkuller 1994). These scenarios provide a major impact of reverse logistics for efficiently recycling and reducing environmental impact. It not only reduces costs but also meets environmental and regulatory standards, positioning companies for sustainable growth in a competitive market.

CHAPTER 2: BARRIERS TO IMPLEMENT REVERSE LOGISTICS IN THE AUTOMOTIVE INDUSTRY

2.1. Economic-related barriers

Financial and economic barriers are acknowledged as the main hindrance in the implementation of reverse logistics in manufacturing firms, (Ravi & Shankar, 2005) (Ülgen & Forslund, 2015) and the most important barrier of the automotive industry in particular (XUMEI ZHANG, 2024). The cost associated with creating and developing a synchronized reverse logistics system and other external economic-related factors have a significant impact on the choice of applying the circular economy. This is also one of main obstacles to small and medium enterprises with limited budgets (Rizos et al., 2015).

2.1.1. Lack of initial investment

With regards to the initial investment for reverse logistics practices, infrastructure, technological and information system advancements, and human resources require significant considerations.

Specialized infrastructure, including dedicated warehouses for returned goods, sorting centers, and refurbishment facilities, plays a crucial role in the effective management of reverse logistics operations. These facilities allow companies to efficiently process returns, sort products, and prepare items for resale or recycling (None Temitayo Oluwadamilola Adesoga et al., 2024). However, many businesses lack dedicated spaces for handling and storing returned products, leading to overcrowded warehouses and operational inefficiencies, particularly during high-return periods such as Black Friday and Cyber Monday. This lack of infrastructure creates challenges in the efficient organization and processing of returned goods, ultimately causing delays and escalating operational costs (Symonds, 2023).

Technology streamlines return authorizations, inspections, and routing, improving overall efficiency (Revolutionizing Reverse Logistics through Modern Technology, n.d.). It allows companies to track returned items throughout the supply chain, enabling better decisions on restocking or refurbishing (Stocs, n.d.). Additionally, disruptive technologies in Industry 4.0/5.0 will drive a paradigm shift in remanufacturing reverse logistics (Yu, 2022). It is important to support the process of managing returns with IT and information technologies in reverse logistics (Starostka-Patyk, 2021). Smaller companies often use cost-effective solutions like one-dimensional and two-dimensional barcodes for tracking inventory, returns, and shipments. Key benefits of IT support in reverse logistics include improved data quality, better coordination, and enhanced decision-making. The most important barriers in reverse logistics processes management with IT support are integration with existing systems, and skills shortages (Starostka-Patyk, 2021).

Green human capital within an organization promotes the adoption of environmental management practices, including green supply chain management, green manufacturing, and reverse logistics, to achieve sustainability (Bag & Gupta, 2019). Resources are key to this process, with sustainability extending to recruitment, performance evaluation, training, and employee separation (Galpin et al., 2015) However, insufficient financial and personnel resources remain a major barrier to developing an effective reverse logistics program (Glenn Richey et al., 2005). In the automotive industry, for example, a lack of a dedicated reverse logistics management center leads to reliance on shared human resources, which can result in delays (Mao & Jin, 2014). Firms' strategic resource differences are linked to variations in product attributes, competitive advantage, and performance, as companies continuously strive to develop resources that provide an edge in their respective markets (Glenn Richey et al., 2005).

2.1.2. High labour cost

Regarding the labor cost for reverse logistics, this expense in the automotive industry refers to the salary paid to workers involved in exchanging and returning vehicle components and accessories from the point of consumption back to the manufacturer or supplier (Monica, 2023). Those costs, to be more specific, include:

- Customer relation labor cost.
- Customer service labor costs.
- Financial reconciliation labor costs
- Sales labor cost.
- Transportation and coordination labor costs.
- Handling and processing returns labor cost.
- Remanufacturing, and recycling labor costs.
- Quality inspection labor costs.

As there are various stages in the whole reverse logistics process, this will require more additional work force if the process is not automated, or high cost of qualified employees in case the stage demands more specialized knowledge and technical skills, like quality inspection for example (E. Genchev, 2009).

2.1.3. High remanufacturing cost

Remanufacturing is one of the reverse logistics activities, which has gained importance in recent times due to government legislations and increasing awareness among people to protect the environment and reduce waste (Mitra, S.,2007). This is the process of restoring the quality level of a used product to that of a new product. Once the finished products are ready after rework, they cannot be sold in the primary market as fresh products. Therefore, they are directed to a secondary market where defective or lower quality products are sold at a comparatively lower price than in the primary market.

The process of repairing, recalling, and adding extra parts to these returned products constitutes unplanned cost drivers that impact the disposition and sortation processes. These costs encompass various aspects such as disposition costs related to stock returns, original equipment manufacturer returns, secondary market liquidation, repair and reshipping to the customer, spare parts recycling, and destruction. Some of the products will be prepared for resale after a certain amount of rework, necessitating additional costs related to labor, machinery, and other resources. The cost of remanufacturing is typically 40–60% of the cost of manufacturing a new product with only 20% of the effort. This is more attractive in the sense that the remanufactured product is of the same quality as a new product, and sold with the same warranty. Also, since the same product is sold more than once, there is considerably less pressure for pricing the product when it is sold for the first time.

2.1.4. Variation in demand for RL

According to Rubio, Chamorro, and Miranda (2008) most of the companies do not know how large reverse logistics costs are, which constitutes a big problem. In a study conducted by Counterman Magazine (2009) to 126 aftermarket workers, it was published that the average return rate was 9.7% in the automotive aftermarket. It is quite hard to determine which is the acceptable price range for the company and customer to be willing to pay for. Customers will consider and take into account if the process of returning that car back to the manufacturer is more expensive than leaving it outside of the street or self-handling. The concept of sustainability in RL affects much of the price a customer can pay, besides operational costs and logistics costs. Especially customers now demanding green reverse logistics but they hardly accept the price for that exclusive process, this may be due to the lack of knowledge of the customer and the low transparency of the company policy.

Due to the randomness of product returns and recycling, predicting and managing these processes becomes challenging (Vlachos & Dekker, 2003). The quantity of returned products is influenced by their quality, lifespan, service time, and environment, which are themselves unpredictable. Damage conditions vary widely and are not always caused by the same issues, making it necessary to test products to identify specific problems. Handling return products is also unpredictable, as different reasons for returns require different treatments, leading to uncertainties in processing times and raw material needs. Additionally, product recycling is uncertain because the demand for reused products in reverse logistics is highly unpredictable, unlike regular market demand. This results in an ineffective information system and thus affects the return policy as well as the customer relations.

2.1.5. Lack of industrial infrastructure

Infrastructure plays an essential and vital role in the successful implementation of RL. Many researchers and practitioners have consistently emphasized that the availability of affordable recycling technologies, combined with the support and coordination of all stakeholders involved, would enhance the overall success of RL implementation efforts (Rogers and Tibben-Lembke, 2002; Jack et al., 2010). The presence of a good and well-designed RL infrastructure provides a company with the necessary capabilities to manage returns and/or recalls in a manner that is both swift and efficient (Dibenedetto Bill, 2007). Moreover, having an effective returns-handling system in place can lead to substantial cost savings and even function as a profit center for the organization (Stock et al., 2002).

On the other hand, the absence or lack of RL infrastructure can severely hinder a company's ability to respond promptly and effectively to returns and/or recalls. In such cases, any attempts to manage returns may become a significant financial burden, with the associated costs often outweighing the benefits derived from these efforts (Jack et al., 2010). This situation can lead to inefficiencies, increased operational costs, and even negative impact on customer satisfaction and loyalty. Significant infrastructure barriers include:

- Lack of sufficient in house facilities (Storage equipment and vehicles)
- Lack of system to monitor returns
- Lack of coordination with 3PL providers
- Lack of logistics infrastructure facilities (warehousing, returning center)

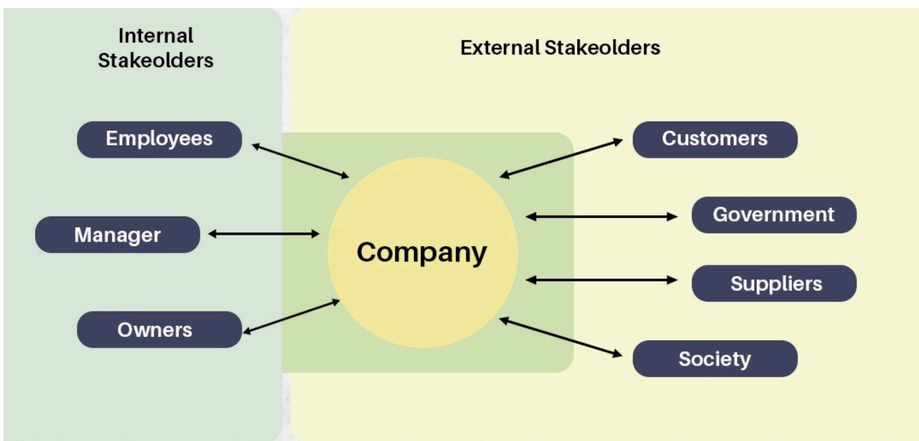
2.2. Supply Chain collaboration process barriers

Collaboration in the supply chain involves coordinated efforts among various stakeholders, including companies, suppliers, and customers, to achieve shared objectives. This process is particularly challenging in the reverse logistics of the automotive manufacturing industry, where barriers such as economic constraints, organizational issues, and technological disparities can impede effective collaboration. According to Fawcett et al. (2008), Jayaraman et al. (2007), Mahadevan (2019), and Xiang and Yuan (2019), true collaboration requires the exchange of resources, information, personnel, and technology to create synergy and competitive advantage. However, managing diverse stakeholder expectations and interests, as highlighted by Hernández et al. (2011), can create tension and hinder collaboration if not addressed properly. Addressing these barriers is crucial for developing an environmentally responsible supply chain that mitigates the environmental impacts of production processes (Cruijssen et al., 2007a; Olorunniwo and Li, 2010).

2.2.1. Problems with collaboration between stakeholders

Collaboration refers to the coordinated effort among two or more parties in a supply chain aimed at achieving shared objectives. It requires cooperation among various stakeholders, including companies, suppliers, and customers, and involves exchanging resources, information, personnel, and technology to create synergy that leads to a competitive edge (Fawcett et al., 2008; Jayaraman et al., 2007; Mahadevan, 2019; Xiang and Yuan, 2019). According to Hernández et al. (2011), true collaboration happens when all participants along the supply chain actively work together towards common goals, characterized by the sharing of information, knowledge, risks, and profits.

Figure 2.1 : Identifying stakeholders in the automobile business



(Source: Iyamu, 2021)

There are two main kinds of stakeholders in the automotive industry: internal and external stakeholders. internal stakeholders, such as employees, managers, and owners, play essential roles in the company's day-to-day functioning and decision-making processes. They are directly invested in the company's success and wellbeing.

On the other hand, external stakeholders, including customers, government bodies, suppliers, and society at large, influence the company from outside its immediate structure. Customers drive demand and shape product offerings, while suppliers ensure the necessary resources and materials are available. Government entities impose regulations and standards, guiding company practices, and society represents the broader community impact of the company's actions.

In the context of collaboration, fairness in task and benefit distribution is essential for building trust, which is critical for the satisfaction of all parties involved and the success of cooperative efforts (Paula et al., 2019). A vital aspect is integrating these elements into RL while also developing an environmentally responsible supply chain that mitigates the environmental impacts of production processes (Cruijssen et al., 2007a; Olorunniwo and Li, 2010).

Collaboration barriers in managing stakeholder relationships can significantly impact an automotive manufacturer's success. One of the key challenges is managing diverse stakeholder expectations and interests. Just as a skilled driver adjusts their driving style based on road conditions, manufacturers must adapt their strategies to navigate the varying priorities of their stakeholders. Some may prioritize cost-effectiveness, while others emphasize quality or environmental sustainability. This divergence can create tension and hinder collaboration if not addressed properly. By finding common ground and exploring creative solutions, they can build consensus and foster productive relationships. However, if these discussions are not managed effectively, the result can be frustration and disengagement among stakeholders.

In research of Grisch Liebel (2016) found seven problems/challenges related to organi-sation structure and communication:

- Lack of product knowledge: the lack of sufficientknowledge about the product in early stages;
- Lack of context knowledge: the lack of context information regarding requirements on low levels of abstraction;
- Unconnected abstraction levels: a mismatch between requirements on different abstraction levels;
- Insufficient communication and feedback channels:lacking communication with other people within or across the organisation;
- Lack of common interdisciplinary understanding:the lack of common understanding across multiple disciplines;
- Unclear responsibilities and borders: the lack of clear and communicated responsibilities between dif-ferent parts of the organisation;
- Insufficient resources for understanding and main-taining requirements: to lack enough resources in early phases to get an understanding of the needs and to maintain requirements later on.

2.2.2. Lack of information system and proper performance metrics

Another main factor of supply chain management is a lack of appropriate metrics. Since RL falls under supply chain management activities, the type of performance system used is also among the most essential: it allows for the performance management process, improvement, documentation, and so on. If the company initiates linking its performance measurement system to the RL practice, the company will be in a better position in its struggle to achieve successful RL programs. It has to effectively synchronize all the processes, design environmentally friendly products, focus on recapturing value or proper disposal of products, and establish a performance measurement system that provides information as to whether the RL program meets the expectations or not. However, the industry often finds it difficult to establish these metrics for several reasons.

Firstly, the complexity of processes in reverse logistics makes it difficult to define the appropriate metrics. Reverse logistics is a set of operations, including collection, sorting, disassembly, and processing of end-of-life vehicles. Each of these activities can be further divided into several sub-processes, thus, it is very hard to come up with performance indicators that are both comprehensive and effective. Unlike the conventional logistics industry where clear metrics such as delivery time and cost are used, reverse logistics needs a more sophisticated approach to measure the efficiency and sustainability of recycling and upcycling activities, for example (Waqas et al., 2018).

Secondly, in most cases, there is usually a lack of standardization in the industry. Various companies might employ different approaches and standards in recording performance, thus, bringing about inconsistencies and difficulties in benchmarking (Waqas et al., 2018). Due to the lack of standardized metrics, companies can hardly compare their performance with their industry peers and thus identify better practices. This absence of standardization might also hamper the regulatory bodies' work of putting in place consistent policies and guidelines, hence making it more difficult for reverse logistics to be implemented (Nunes et al., 2011).

Besides, the gap between operational and strategic aims is also a frequent characteristic. Most of the time, many companies are only concerned with short-term operational parameters, such as cost savings and time reductions, and therefore fail to consider other longer-term strategic goals like sustainability and environmental impact. As it happens, the negative impacts of the poor coordination of reverse logistics initiatives can be seen in the decision-making process and even the overall effectiveness of the program. A company, for example, can prefer cost-cutting measures that can be quickly implemented but in turn, lead to the destruction of its own recycling and upcycling processes in the future (Nunes et al., 2011).

As well as that, data collecting and analysis are major obstacles to be dealt with regularly. Good performance measures based on reliable and up-to-date data are a necessity, but the task of getting and analyzing such data is not easy and costs many resources. Enterprises may not have the appropriate equipment and expertise to record full data on reverse logistics operations. Poor data may result in metrics that are either incomplete or wrong, thus making it almost impossible to measure performance correctly and figure out which areas need to be improved (Waqas et al., 2018).

In the end, many employees within companies are reluctant to embrace change. Metrics and performance measurement systems that are implementing new ones might need substantial alterations to the existing processes and practices. Managers and employees may be hesitant about these changes, which they view as additional complexity or a crowded workload as impediments (Nunes et al., 2011).

2.3. Management-related barriers

Dashore and Sohani identified seven main barriers in their study: lack of advancement in new technology, lack of commitment from top management, lack of customer awareness, lack of knowledge training, and experience, low integration with information and technology systems, lack of skilled professionals, and lack of waste management and energy management. According to Mudgal., lack of CSR and lack of commitment from top management are the most significant barriers to the implementation of RL. Sharma, Panda, Mahapatra and Sahu examined management negligence, lack of initial capital, lack of SCM performance, lack of improved management systems and company strategies, and administrative issues as barriers that have both strong dependence and driving power.

Organizational and managerial barriers play a critical role in the inefficiencies of reverse logistics processes in the automotive industry. These barriers often stem from internal shortcomings in human resource management, expertise, and strategic alignment, which can severely hinder reverse logistics performance.

2.3.1. Lack of experts at management level

Effective management of reverse logistics processes requires strategic oversight and technical expertise, which are often lacking in the automotive industry. Managers with limited experience in reverse logistics may struggle to design and implement efficient systems or make informed decisions about resource allocation and technology adoption. The absence of expertise at the managerial level can also lead to inadequate risk assessments and missed opportunities for cost reduction through optimized processes or collaborations with third-party logistics providers. For instance, without experienced management, companies may fail to establish partnerships with recycling firms or miss potential innovations in remanufacturing and product lifecycle management (Mudgal et al., 2010).

Moreover, this lack of expertise can create a disconnect between organizational goals and reverse logistics objectives, further hindering the alignment of reverse logistics with broader sustainability and profitability goals.

2.3.2. Lack of strategic planning

Strategic planning corresponds to the identification of reverse logistics goals and the long-term plans for their management. It implies the manager's effort that will be required in the implementation of the solution for reverse logistics. In the current situation, the fast development of technology and the changes in the behaviors of competitors, consumers, suppliers, etc. necessitate a sound strategic planning process for the reverse logistics programs. For the implementation of reverse logistics in any organization, the strategic planning is the most important role in the achievement of the organization's goals for the survival in the global market (Ravi and Shankar, 2005). Despite these major functions, strategic planning for reverse logistics still remains as a limitation. Because the fact that, There are plenty of managers of manufacturing firms still showing a very low commitment to the reverse logistics practices, they may not fully understand the importance and the potentials of reverse logistics for a firm's future competitiveness (Abdulrahman, Gunasekaran and Subramanian, 2014). As a result, businesses lack strategic plans that enable them to effectively implement reverse logistics, and this also has been proven by according to the article "Navigating barriers to reverse logistics adoption in the circular economy (Harshad Sonar et al., 2024). Lacking of strategic planning comes up as a consequence of lacking of commitment management.

Figure 2.2 : Ranking the effect of barriers

Table 6
Cause-effect matrix.

Sr. No.	Barriers	D	R	D-R	D+R	Ranking	Group
Ch1	Lack of visibility for recycling/reuse	4.5972	5.2081	−0.6109	9.8053	2	Effect
Ch2	Difficulty in segregating waste/returns at collection points	3.7633	3.6291	0.1342	7.3924	8	Cause
Ch3	Difficulty in deciding 3PL to partner with	4.2714	4.8156	−0.5442	9.087	5	Effect
Ch4	Less return on investment	4.4403	3.5701	0.8702	8.0104	7	Cause
Ch5	Lack of KPI's to track the reverse logistics activities	3.6151	3.2376	0.3775	6.8527	10	Cause
Ch6	Lack of government policies on recycling	3.9144	3.4523	0.4621	7.3667	9	Cause
Ch7	Lack of top management initiation	4.8327	4.2148	0.6179	9.0475	6	Cause
Ch8	Demand uncertainty for return products	4.9629	4.3738	0.5891	9.3367	4	Cause
Ch9	Lack of strategic plans for returns	5.2526	5.5878	−0.3352	10.8404	1	Effect
Ch10	Lack of information on RL for stakeholders	4.0896	5.6503	−1.5607	9.7399	3	Effect

(Source: Harshad Sonar et al., 2024)

2.3.3. Lack of trained personnel

The absence of adequately trained personnel poses a significant challenge to implementing and managing reverse logistics operations effectively. Employees often lack the requisite skills to handle complex processes such as the collection, inspection, sorting, and refurbishment of returned automotive parts. Without proper training in reverse logistics operations, even well-designed systems may underperform, leading to inefficiencies in cost, time, and quality (Dashore, 2024).

For instance, reverse logistics in the automotive sector often requires knowledge of advanced technologies, such as RFID tagging or automated inventory systems, which may be unfamiliar to untrained staff. The lack of specialized training can also impede adherence to environmental and regulatory standards, resulting in operational delays or compliance issues.

2.4. Policy-related barriers

The key policy barriers to RL implementation have two sides. First, there is a significant lack of enforceable laws, regulations, and directives governing the take-back and waste management of end-of-life vehicles. Second, there is an absence of supportive government economic policies that would incentivize proper vehicle recycling and disposal practices. These policy gaps not only affect reverse logistics activities but also impact the manufacturing sector's sustainability efforts. (Abdulrahman, M. D., Gunasekaran, A., & Subramanian, N.,2014)

2.4.1. Lack of clear return and waste management policies

One significant barrier to implementing reverse logistics practices in the automotive industry is the lack of clear return and waste management policies and regulations. This regulatory uncertainty creates confusion among manufacturers, suppliers, and recyclers about their responsibilities and requirements. Without well-defined guidelines, companies struggle to establish standardized processes for collecting end-of-life vehicles (ELV), recovering valuable materials, and properly disposing of automotive waste, which ultimately hinders the widespread adoption of essential sustainability initiatives like vehicle recycling, component reuse, and material recovery across the automotive supply chain.

Besides, the manufacturing sector, the majority of which are SMEs that compete on pricing, may struggle to retain their market advantage or potentially face closure if stringent regulations such as RoHS (Restriction of Hazardous Substances), REACH (European Community Regulation on chemicals (EC 190/2006) that focusing on the registration, evaluation, authorization, and limitation of chemical substances), and WEEE requiring manufacturers to handle the gathering, processing, and reuse of end-of-life products—become mandatory. Not surprisingly to predict, the absence of binding regulations and laws from governmental bodies has served as a significant barrier, discouraging manufacturers from investing in or partnering for reverse logistics implementation and operations (Lau and Wang, 2009).

2.4.2. Lack of supportive laws

Furthermore, insufficient government support also represents a significant obstacle to RL implementation, particularly in the automotive industry where it stands as the most influential barrier. These supportive measures can encompass regulatory frameworks, tax benefits and incentives, and investments in necessary infrastructure.

The companies' reliance on government assistance and support may be linked to their strong focus on cost management to maintain global competitiveness and their preference for immediate returns over long-term benefits. Foreign corporations, on the other hand, might less depend on government support for their RL implementations due to the fact that they typically have greater familiarity and awareness with environmental protection standards and guidelines similar to those in their home countries, where such frameworks are already well-established and clearly defined.

2.5. Environmental-related barriers

When it comes to reverse logistics, we usually think of a desirable outcome that might lead to better environment practices by reducing waste emission into the environment. But in reality, the process of reusing, recycling or remanufacturing can concurrently affect the environment both positively and negatively (Nunes et al., 2011). In this section, we are going to study about some environmental barriers that stand in the way of firms to be successful in applying reverse logistics.

2.5.1.Complexity of RL implementation in recycling & upcycling

Adopting reverse logistics in the automotive sector is accompanied by some different difficulties, particularly in the areas of recycling and upcycling. These challenges arise from the intertwined financial, regulatory, technological, and social factors that make it cumbersome and less efficient to adopt reverse logistics.

The high costs associated with recycling and upcycling processes are amongst the biggest impediments. Building up facilities that can recycle and upcycle automotive components requires a lot of capital, thereby making it an uphill task. For example, advanced machinery and specialized equipment are crucial for vehicle disassembly and material handling, making it unaffordable for many firms. According to the research of (Ellen MacArthur Foundation, 2016), the cost of launching these facilities could be more than a couple of million dollars, with a long time for the ROI to get back. This financial load on companies can prevent them from implementing full-scale reverse logistics strategies.

Another problem is the lack of skilled experts. Efficient recycling and upcycling processes require knowledge in a variety of areas such as materials science, engineering, and management of the environment. Nevertheless, oftentimes the demand for skills is not satisfied as the workforce is lacking these candidates. According to a study by the European Automotive

Manufacturers' Association (ACEA), the industry is experiencing a significant skills shortage, which is thus a bottleneck to the implementation of, e.g., recycling and upcycling (ACEA, 2024).

Regulatory barriers are another crucial factor that makes reverse logistics more complicated. In many places, the legal framework for recycling and upcycling is either not fully developed or is made up of a combination of regulations that are not consistent. Government policies are yet to be generating a serious problem for companies. For instance, in certain areas, waste disposal regulations are so stringent that companies find it easier and more cost-effective to opt for regular disposal over recycling and upcycling. Besides, the differences in rules from one region to another can make cross border logistics operations even more challenging to the point of running business to cost (Waqas et al., 2018).

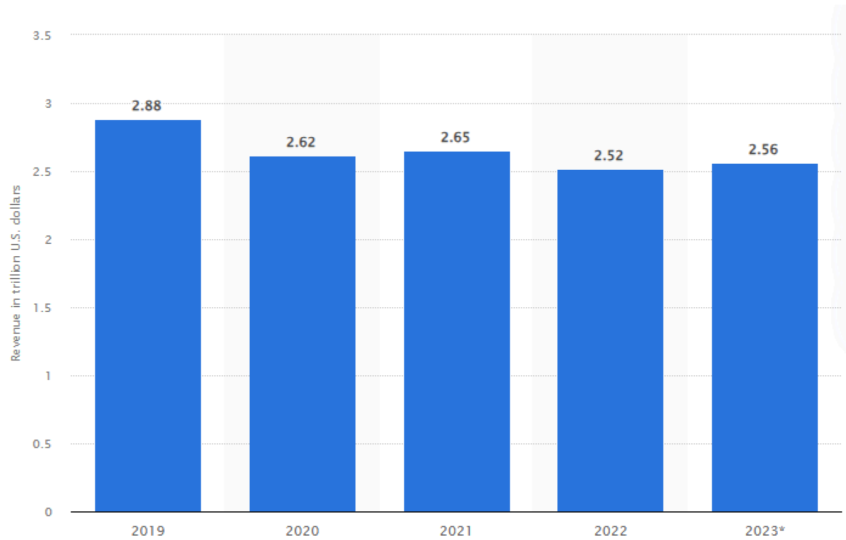
With regard to technology, the advanced technologies that are necessary for efficient recycling and upcycling of automotive components are not always affordable or available. For instance, the technology to recycle the complex materials used in modern vehicles, e.g. carbon fiber composites, is still in its early stages and it will take large R&D investments to develop it. This technological gray area has the potential to stunt the sector's efforts to efficiently process vehicles that have reached the end of their life. The Journal of Automotive Technology and Management (2023) recommends that more investments in R&D can close the gap, however, it can only be done with a strong and joint approach (IJTAM·, 2019).

Furthermore, consumer ignorance of using such schemes and the absence of demand for recycled and reused automotive products create major obstacles. Consumers are often ignorant of the fact that the products produced using recycled materials are eco-friendly, thus they rather choose new and glossy items. A shortage of demand limits the companies' decisions in their backward logistics (Sousa, 2023). As a result, to solve such problems, it is crucial to use a combination of measures, including finances, regulatory policies, technical advances as well as consumer education. The automotive industry will be in a better position for a better future through reverse logistics practices by solving them.

2.5.2. Waste management issues

The global automotive manufacturing market was worth about 2.88 trillion U.S. dollars in 2019 before experiencing a slight decrease to 2.52 trillion U.S. dollars in 2022. By 2023, this growth showed a slow recovery at 2.56 trillion US. dollars (Carlier, 2023) as the graph has shown below.

Figure 2.3 : Global car manufacturing industry revenue between 2019 and 2022, with a forecast for 2023 (in trillion U.S. dollars)



(Source: Statista, 2024)

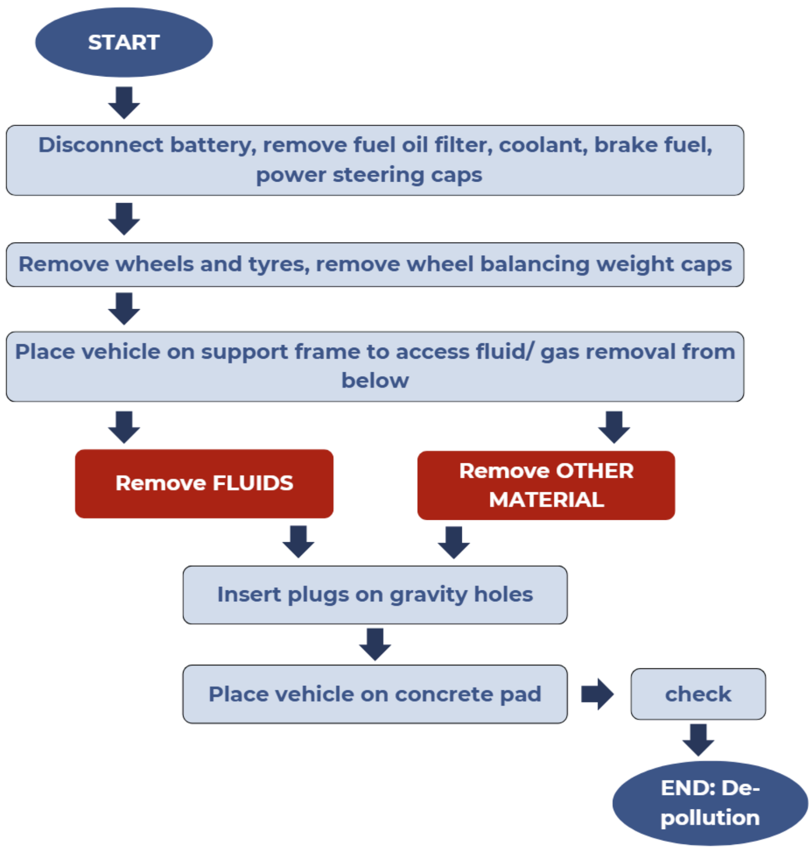
According to the research of (AWJ Research Desk, 2024), automotive waste can be broadly divided into hazardous and non-hazardous materials. Each category poses unique environmental challenges due to the nature and volume of waste produced.

Hazardous waste includes materials requiring careful handling due to their toxic properties. First, batteries, which account for 12 million tons of lead-acid waste annually, can release harmful lead and sulfuric acid into the environment if the waste management process is not correctly followed (Patel and Gaines, 2016). Regarding the used oil, over 1 billion gallons of used motor oil are generated globally each year, with just one gallon capable of contaminating a million gallons of freshwater if the managing process is not well-organized (Mississippi Department of Environmental Quality, 2024). Also, antifreeze and brake fluids containing ethylene glycol pose severe threats to aquatic ecosystems when leaked into waterways (Fahrion, 2024b).

In contrast, non-hazardous waste encompasses recyclable and reusable materials like plastics and metals. With plastic comprising 25-30% of a car's weight, or more than 1,000 pounds per vehicle, the automotive industry is a major contributor to the global plastic waste crisis. Every year, an estimated 5.6 million metric tons of plastic waste from cars finds its way into landfills and oceans, adding to the staggering 400 million metric tons of plastic waste produced worldwide (Le Vu, 2024). Also, according to this article, the automotive sector produces 1.3 billion metric tons of metal scrap each year, exacerbating the global metal waste problem. Furthermore, particulate emissions from vehicles significantly contribute to air pollution, with the transportation sector accounting for 23% of global CO_2 emissions as of 2019. The situation has also revealed the global interconnectedness of complex automotive-waste streams.

The old cars will experience many two huge stages to be recycled, reused and refurbished which are depollution and dismantled. Regarding the depollution, it is the process that chemicals, substances, materials and components that pose a risk to human and environmental health, are removed (ELV Training, 2023).

Figure 2.4 : Depollution Process



(Source: Kapil, 2021)

Table 2.1 : Sequence of Depollution

Operation	De-pollution Sequence
A. Before Lifting the vehicle	
Remove Battery	A
Remove fuel filter cap & oil filler	A
Set heater to maximum	A
Remove wheels and tyres and separate balance weights	A
Remove any parts identified as containing mercury	A
B. Lift the vehicle on de-pollution frame or lifting device	
Degas air conditioning unit (if fitted)	A
Drain engine oil and remove oil filter for crushing or disposal	B
Drain transmission oil, including rear differential	B
Drain coolant	B
Drain brake fluid	B
Remove catalyst (if fitted)	B
Drain washer bottle	A
Drain brake/clutch reservoir(s)	A
Drain power steering reservoir (if fitted)	A
Drain fuel tank	B
Drain shock absorbers or remove suspension fluid	B
Replace drain plugs/fit plastic stoppers	B
C. Remove vehicle from de-pollution frame or lifting device	
Deploy airbags and other pyrotechnics in-situ (if fitted and able to conduct this operation)	A
Remove air bags and other pyrotechnics (if fitted, and cannot be deployed in-situ)	A

(Source: Kapil, 2021)

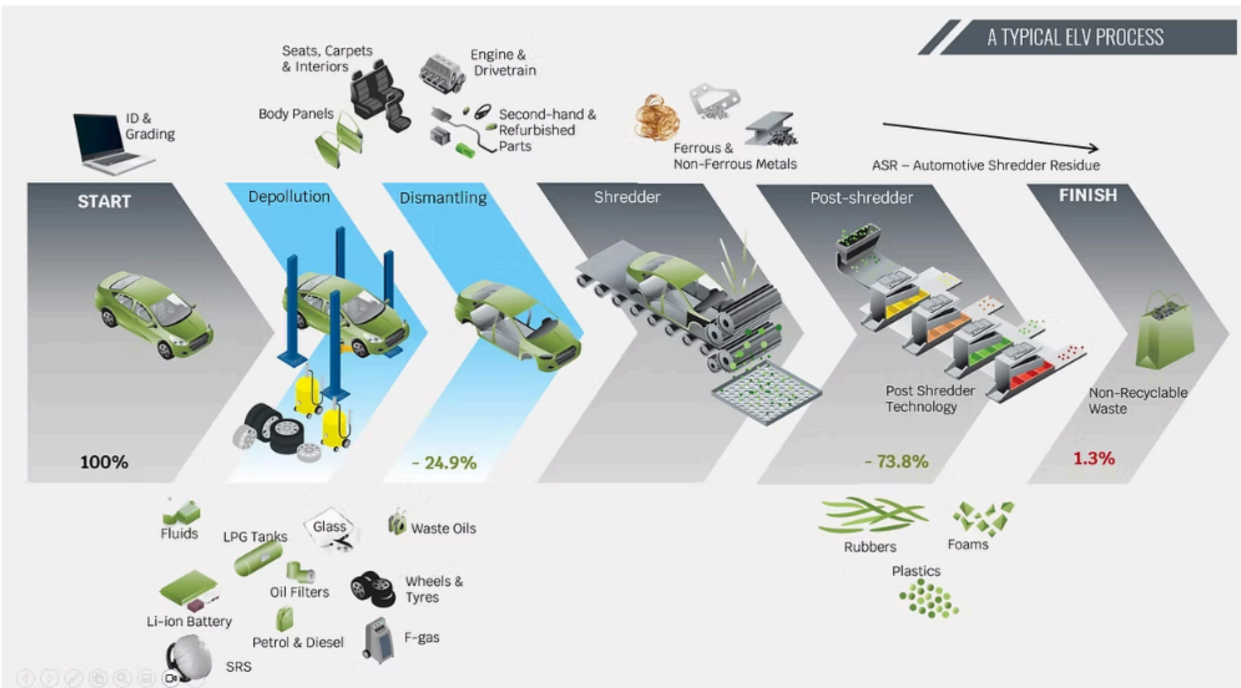
About Dismantling, This process focuses on separating and gathering recyclable and reusable components such as engines, tires, bumpers, and various other parts. The dismantling can be carried out either manually or mechanically, depending on the vehicle's type, size, and the volume being processed. Further information will be provided in the Inventory Management Issues.

According to the report of (Fahrion, 2024)**,** inefficient automotive waste management can lead to significant operational costs and administrative burdens, impacting not only finances but also environmental, health, and safety aspects. Because the automotive industry generates a wide variety of waste, including hazardous materials like oils, solvents, and batteries, as well as non-hazardous materials like plastics and metals. Managing these diverse waste streams requires specialized handling and disposal methods. Therefore several approaches have been suggested regarding the calorimetry for Plastic and Rubber Recovery, Waste Valorization, and Hydrocarbon Recycling (AWJ Research Desk, 2024).

2.5.3. Inventory Management Issues

End of Life Vehicles (ELVs) represent one of the most important waste streams in terms of volumes and material contents (D'Adamo, Gastaldi and Rosa, 2020). The diagram below shows the process of how the cars are scrapped, and their automotive spare parts are recycled, reused and remanufactured (Kapil, 2021).

Figure 2.5 : The typical ELV Process



(Source: ELV Training, 2023)

The depollution has been discussed in the Waste Management Issues part. After depollution, cars can be dismantled safely to salvage parts for resale, while other components such as metals, plastics, and fibers are separated, crushed, shredded, and eventually recycled. Since the automotive manufacturing industry heavily relies on primary raw materials like steel, aluminum, copper, and plastics, it is crucial for governments to promote the use of recycled materials in vehicle production. Recycling and reusing these materials require less energy compared to manufacturing products directly from raw resources.

According to the report of Kapil, each material had different inventory management and storage policy in order not only to keep the surrounding environmentally clean but also maintain the quality of the inventory for further reuses. For example, ELVs need to be stored at the Collection and Dismantling Centers facilities which are in dry areas where there is no water logging or water will not be flowing under the vehicle during rain or snow melt periods. Furthermore, one of the inventory management policies of ELVs is that they shall not be stored until the fuel, oil, antifreeze, and other fluids are completely drained, and the fuel tank, radiator, and other fluid containing parts have been removed.

Thus, manufacturers and suppliers in the automotive industry face challenges in managing intricate and costly equipment. One major difficulty is maintaining equipment that is no longer in production. Since replacement parts are essential for keeping such equipment operational but are often discontinued, companies resort to stockpiling spare parts to meet future demands, ensuring they are stored in an accessible manner (Mandala, 2024). Stocking many parts ensures customer service but can result in unused overstock (Naveen Reddy Dolu Surabhi, Vali Buvvaji and Reddy Sabbella, 2024).

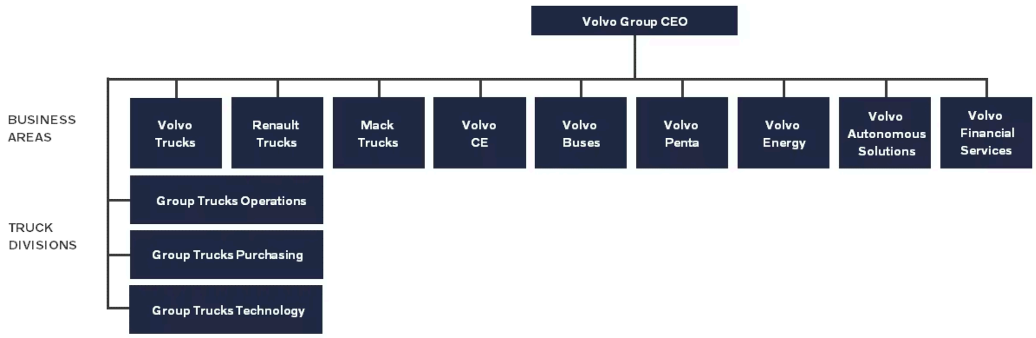
CHAPTER 3: CASE STUDY OF VOLVO GROUP

3.1. Situation

3.1.1. Introduction to Volvo Group

Volvo was established in 1927 by Assar Gabrielsson and Gustaf Larson with the goal of producing high-quality and safe vehicles. In 1999, the company's diamond division, Volvo Cars, was sold to the Ford Motor Company for SEK 50 billion. Today, the AB Volvo Group, referred to as "Volvo," is a leading global manufacturer of transportation solutions, producing trucks, buses, construction equipment, and marine and industrial engines. The company also focuses on governmental sales and Volvo Financial Services. It operates in over 190 markets, has production facilities in 18 countries, and employs around 100,000 people. Volvo's core values include customer success, trust, passion, change and performance with the aim of becoming the most sought-after company in transport solutions.

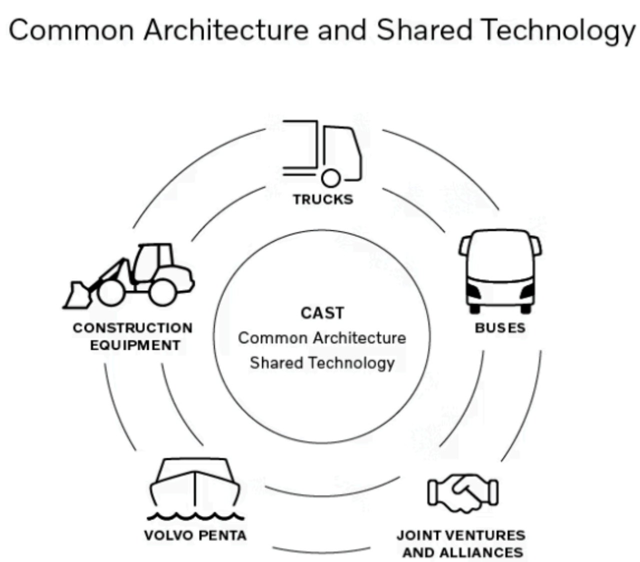
Figure 3.1: Volvo Group Truck, Construction Equipment, Bus, and Marine and Industrial Engines Brands



(Source: Volvo, 2024)

For its sustainable strategy, Volvo Group and its partners benefit from the Group's modular platform Common Architecture & Shared Technology (CAST). The ambition with CAST is to develop a competitive set of modular products and services that are easy to integrate, meet future legal, market and society needs, as well as exceeding customer expectations.

Figure 3.2: Volvo Group's modular platform Common Architecture & Shared Technology (CAST)

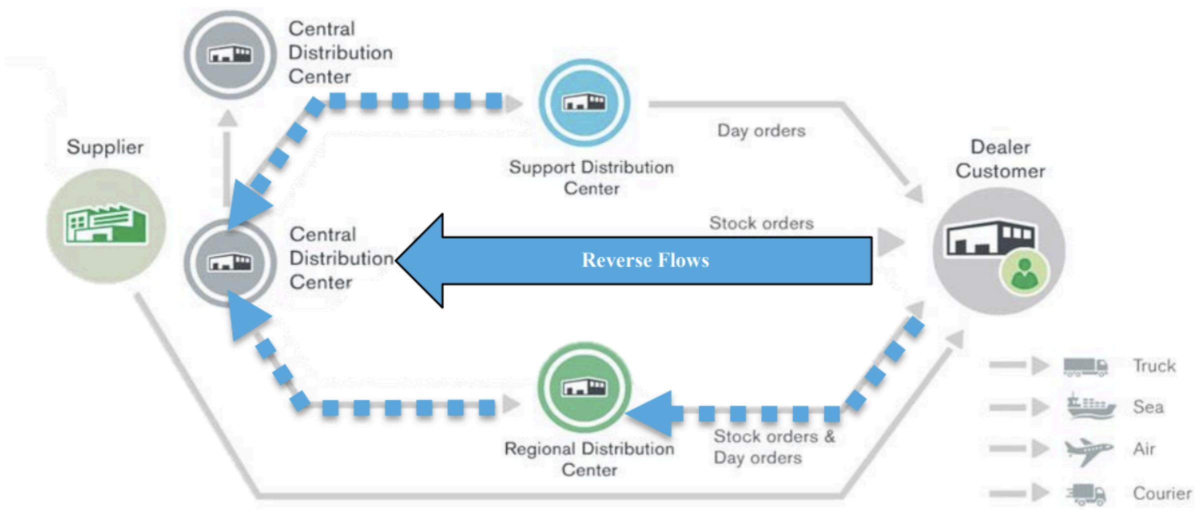


(Source: Volvo, 2024)

3.1.2. The VBC/VTC forward and reverse logistics flow

The image below illustrates both the forward and reverse flows, with the reverse flows highlighted in blue

Figure 3.3: Materials management and distribution structure in the aftermarket supply chain (adapted from Julio, 2018)



3.1.3. Types of Distribution Centers

There are three types of distribution centers. The Central Distribution Center is the largest of the three, serving as the hub for all forward flows. To better serve dealers and end-customers, Support Distribution Centers (SDCs) and Regional Distribution Centers (RDCs) are strategically located across Sweden, based on lead time needs, to meet dealer demand. There are two main differences between SDCs and RDCs. First, SDCs only handle Day Orders (DOs), while RDCs manage both Day Orders and Stock Orders (SOs). Second, RDCs process return orders, whereas SDCs do not.

3.1.4. Stock and Day orders

On one hand, Stock Orders (SOs) refer to products that are automatically replenished and managed by Volvo. These orders are meant to restock dealer inventories with items that are regularly used, ensuring that they are always available to meet demand.

On the other hand, Day Orders (DOs) are placed by dealers for items that are not intended to be kept in stock. For example, if an end-customer (such as a truck driver) visits a dealer with a specific issue and the dealer lacks the necessary parts to resolve it, the dealer will place a DO for those parts. DOs are primarily aimed at maximizing customer satisfaction by ensuring that the customer's truck can be repaired as quickly as possible. Typically, lead times for DOs in forward flows range from *one to two working* days.

3.1.5. Transport operations

All transportation operations are outsourced. As a result, Volvo and the dealers are *not directly linked*; instead, dealers are responsible for arranging transportation for any products they wish to order or return, specifically for day orders. Volvo will not be responsible for managing transportation, while 3PL services handle the movement of products. This indirect relationship means that dealers must navigate different systems to process product returns.

3.1.6. Types of return

The products can be returned for several reasons:

- *Buy-backs:* They refer to dealer inventory that Volvo repurchases and sends back, primarily to a Central Distribution Center. All buy-backs are directed to a Central Distribution Center located outside of Sweden and are classified as returns of Stock Orders.
- *Core returns:* They are replacement parts primarily sent to a central hub of the company which is included in the remanufacturing process.
- *Wrongly shipped parts:* These are parts that were incorrectly sent to a dealer or customer, meaning the wrong items were delivered. They are returned to a shipping Distribution Center (DC) and are typically associated with issues in the shipping process or inventory management.
- *Wrongly ordered parts* (Code 72): These refer to parts that were mistakenly ordered by the dealer or customer. These parts are also returned to a shipping DC but are specifically classified as returns of Day Orders. This indicates that the error occurred at the order stage rather than during shipping.
- Warranties. Parts subjected to warranty claims.
- Packaging. (Out of scope)

3.2. Complication

Currently, Volvo experiences a notably high volume of return flows, which include both spare parts (Day Orders and Stock Orders). These return flows originate from the dealers and are sent back to the company’s distribution centers, representing a cost to the company. However, there are no established controlled processes or management for these transports, making it impossible to improve their quality and cost. The existing situation involves uncontrolled systems, resulting in a lack of data that would provide insight into the current state of operations.

3.2.1. Communication

Lack of knowledge transfer:

The process of obtaining this data has been more time-consuming than expected, leading to incomplete information, such as missing pick-up dates from third-party logistics (3PL) providers. This lack of data jeopardizes effective analysis and performance monitoring. Additionally, the knowledge transfer between Volvo and its 3PL partners has been inadequate, necessitating clearer agreements on data sharing and performance control. Furthermore, the gathered data often requires extensive processing, with irrelevant internal references and inconsistent free-text comments from dealers complicating analysis and reducing its value.

Lack of feedbacks from dealers

During interviews, dealers expressed surprise at the focus on reverse logistics, highlighting a gap in understanding the initiative's importance. Despite a willingness to help, effective knowledge sharing requires strong commitment and collaboration between Volvo and its dealers.

Lack of awareness of RL (Bad practices of Dealers & DCs)

In distribution centers, returned items are often held until enough volume accumulates for processing, which can take up to a week. This delay means that products may not be available for resale until long after they are returned, resulting in missed opportunities and potential customer dissatisfaction. Similarly, dealers often store returns for a week before processing them, either due to infrequent pick-up schedules by third-party logistics providers or inefficient return procedures. This practice further delays product availability in the aftermarket.

3.2.2. Dealer's experiences

Amount of systems

Volvo is encountering significant challenges in its returns process due to a lack of integration among various systems used by dealers. This disconnection leads to inefficiencies, particularly for high-return categories like wrongly ordered parts, where dealers find the systems cumbersome and time-consuming. While some systems, such as those for cores or buy-backs, do not pose major issues, the overall lack of correlation between different systems creates frustration for dealers, as they must repeatedly enter product specifications across multiple platforms. This inefficiency not only complicates the return process but also contributes to higher return volumes, underscoring the need for a more cohesive approach to system integration.

Lack of notifications

Dealers face a lack of notifications throughout the return process, forcing them to manually check the status of their claims, approvals, and reimbursements. Additionally, the lengthy lead times between steps in the return process are seen as excessive, negatively impacting product availability in the aftermarket. Dealers also do not receive updates when returned products arrive at distribution centers or when payments are processed, leaving them reliant on the existing system. In cases of payment issues, they must contact the Help Desk for resolution, further complicating the returns process and highlighting the need for a more efficient and transparent system.

Instability in the pay-back of the returns

Dealers are unaware of whether their returns have been successfully delivered or if payments have been processed, leading to frustration as they must frequently check the status without any updates. The lead times for processing returns and payments are unstable, sometimes extending to several months, indicating a need for more reliable and expedited processes. Additionally, Volvo lacks visibility into the reverse logistics transactions, as dealers book transportation without sufficient operational data available to Volvo. This disconnect makes it difficult for Volvo to control costs effectively.

3.2.3. Returns planning and policies

Excessive amount of BB & C72 returns

Volvo faces significant challenges with returns, particularly concerning wrongly ordered parts in the C72 category, which are the most common type of return. Dealers are encouraged to order surplus components to ensure they have everything needed for vehicle repairs, which often leads to over-ordering. This practice, aimed at maximizing customer satisfaction by minimizing vehicle repair times, inadvertently results in a high volume of returns due to inaccurate diagnoses and unlimited ordering limits. Moreover, the lack of a tracking and tracing system for ordered parts exacerbates the issue, as dealers can freely order more than necessary without consequences. While Volvo notifies dealers about components nearing their return expiration, this system allows for a cycle where dealers can return parts and re-order them almost immediately, further inflating return rates. The absence of controls or penalties for excessive ordering prevents effective management of returns, highlighting the need for a more structured approach to their returns policy.

Poor forecasts

Volvo faces significant challenges in forecasting and managing returns, particularly in the BB and C72 categories. Forecasting returns is complex, and many companies, including Volvo, struggle with accuracy. The BB category, which refers to buy-backs of stock orders, often sees returns that do not align with forecasts, leading to either unexpected stock returns or insufficient availability for dealers. This uncertainty compels dealers to place more day orders, further inflating return rates and complicating inventory management.

Additionally, the lack of reliable data on customer demand exacerbates these issues, as Volvo primarily relies on historical data for forecasting, which may not accurately reflect current needs. This situation is compounded by unstable lead times for stock orders, making it difficult for dealers to predict when they will receive components. The result is a reactive supply chain that fails to meet the demands of a sensitive aftermarket, emphasizing the need for improved data awareness and better forecasting practices in reverse logistics.

Self-interest behaviors

With no limits on returns and Volvo bearing all associated costs, dealers are incentivized to over-order parts. The "X days rule" enables them to hold onto excess inventory until just before the return deadline, which decreases product availability in the aftermarket. Additionally, instability in stock orders leads dealers to rely on day orders, further increasing returns in both the BB and C72 categories.

While these practices enhance dealer satisfaction, they create a lose-win situation for Volvo, where rising return rates translate into higher costs for the company. The existing full return policy encourages overstocking, jeopardizing the balance between customer satisfaction and operational efficiency.

3.2.4. Lead times

Lack of measurements

Volvo is struggling to collect adequate data for analyzing its reverse logistics operations, particularly regarding lead times. Missing pickup dates hinder effective tracking, and dealers often find that specified lead times in Standard Operating Procedures (SOP) are not met. In some cases, the period from booking transport to product pickup can extend up to five days, followed by an additional one to three days for transport itself. Upon arrival at distribution centers, returned products are not processed immediately; instead, they accumulate until there are enough to warrant processing, which can take from one to five days. This inefficient handling results in prolonged lead times, impacting overall operational effectiveness and product availability in the aftermarket.

Table 3.1: Comparison between theoretical and current performance lead times

	Theoretical	Real performance
Transport booking	1 day	1-5 days
The return is picked up and delivered	1- 3 days	1-3 days
The return is process	As soon as possible	1-5 days

Dealer-to-Dealer support

Volvo is facing significant challenges related to lead times and order fulfillment that impact dealer and customer satisfaction. Dealers have expressed a strong need for same-day access to day orders, as the current system requires at least one day for delivery. This delay forces dealers to rely on each other to meet customer demands, undermining efficiency and responsiveness.

There exists a tradeoff between stock orders and day orders: if dealers are discouraged from overstocking, they will resort to placing more day orders, leading to higher return rates. However, implementing same-day deliveries could encourage more accurate ordering, albeit at a higher operational cost. This situation calls for a careful analysis of the tradeoff between same-day delivery and transportation expenses.

Moreover, in an increasingly uncertain market, Volvo must adopt a more agile supply chain approach, shifting from a forecast-driven model to a demand-driven one. This shift is essential for maintaining competitiveness and enhancing overall responsiveness to customer needs.

Uncertain deliveries

Volvo is facing significant challenges in both forward logistics (FL) and reverse logistics (RL) flows due to a lack of transparency and communication regarding product deliveries. Dealers do not receive notifications about the status of returned products once they have been picked up, making it difficult to track whether items have arrived at distribution centers (DCs). The complexity of tracking returns, compounded by the varying transportation sources from multiple dealers to a limited number of DCs, creates additional challenges. This lack of visibility means that dealers must rely heavily on the 3PL company for accurate delivery information, leaving them uninformed if issues arise during transport.

3.2.5. Performance measurements

Lack of track & trace

The inability to track shipments means that dealers cannot anticipate delays, prompting them to order additional products to meet immediate repair needs. This creates a cycle of over-ordering and returns, which ultimately increases costs for Volvo. Implementing a robust track and trace system would not only reduce return rates by providing dealers with accurate delivery information but also enhance the coordination of inventory flows. For instance, if a returned product from one dealer could be redirected to another dealer in need, it would optimize resource use and improve overall product availability in the aftermarket.

Lack of scanned deliveries

The delivery status has been categorized as either "Delivered" or "Probably delivered but missing scan." This situation highlights the significance of reverse logistics flows and the need for effective knowledge transfer from the 3PL service provider. Currently, Volvo cannot be completely certain whether a specific returned product has been delivered. The understanding of reverse logistics is crucial in this context. The presence of unidentified products in the distribution centers (DCs) indicates that the return management process needs to be reevaluated (Dawe, 1995). Furthermore, it was noted that workers responsible for handling returns at the DCs do not prioritize scanning returned items, opting to process them only when a substantial quantity has accumulated.

3.3. Question

Question 1: What are the key factors influencing the flow of returns at the Volvo company?
Question 2: How can the Volvo company improve the control and the performance of its return logistics set-up?

3.4. Answer

Q1: What are the key factors influencing the flow of returns at the Volvo company?

Five different factors were identified to focus on: Communication (between Volvo and both 3PL company and dealers), Dealer's experiences (regarding the systems used to return a product); Returns planning and policies; Lead times; and Performance measurements. These five factors served as a baseline to identify recommendations for improving the current systems.

Figure 3.4: Identified factors influencing the practices concerning reverse logistics (adapted from Julio, 2018)

Q2: How can the Volvo company improve the control and the performance of its return logistics set-up?

Once the key drivers of the return transports were identified, it was crucial to further investigate how the focal company could improve in its practices to better handle return flows. Nineteen different recommendations are provided based on the five key factors previously identified.

Table 3.2 : Summary of the recommendations

Related fields	Recommendations
Communication	Data Collection (3PL)
	Workshops with dealers
	Data collection (Dealers)
	Workshops with workers handling the returns in the DCs
Dealers´ experiences	Build a new system
	Reduce procedures' lead time
	Stabilize payment lead time
	Gain knowledge about what it is paid
	Send pop-up notifications
	Self-booking transport
Returns planning and policies	Measure the performance of each dealer
	Establish incentives/penalties (Dealers)
	Enhance forecasts
Lead times	Ensure proper data collection (3PL)
	Perform lead times measurements
	Establish incentives/penalties (3PL)
	Reduce stock orders
	Establish same day deliveries
	Track and trace

KPIs are essential for quickly assessing the performance of reverse logistics flows. Thus, it is important to establish the most representative indicators of these practices' performance. The selection of these KPIs is primarily based on the significance of choosing the right ones, as highlighted by Charron (2006).

Table 3.3 : Proposed KPIs

KPIs	Description
Communication	An agreement with the 3PL service company has to be established to ensure proper data collection. Regarding the dealer, workshops have to be performed (twice a year)
Awareness of RL	Proper communication to the workers in the DCs and the dealers handling the returns have to be performed, to increase to awareness and the importance the of RL
End-customer satisfaction	Expectations VS Perceptions of dealers' services
Customer satisfaction	Expectations VS Perceptions of Volvo's services
On time pickups	Measured from the point of transport booking by the dealers to the point of picking the products up by the 3PL service company
On time deliveries	Measured from the point of picking the products up by the 3PL service company to the point of delivering the products by the 3PL service company in the DCs
On time scanning of the deliveries	Measured from the point of delivering the products by the 3PL service company in the DCs to the point of processing the products by the workers handling the returns
Average end customer time	Measured from the time of an end-customer entrance at the dealers' expenses to the time of exit
Quick returns procedures	Measured from the point of when the dealer wants to return a product until the transport booking is done
Stable Pay-backs	Measured from the point of delivering the products by the 3PL service company in the DCs to the point of when the dealer receives the payment
% of Sales Vs Returns	Ratio between what it is sent (forward flows) to a specific dealer and what it is sent back (backward flows)
Tied-up capital	Value of the product in possession of the dealer

Thereafter, these nineteen recommendations were evaluated with respect to each KPI. Each recommendation was assigned different symbols based on its relationship with each KPI, with a stronger connection to the KPIs indicating a greater impact on current practices.

Additionally, a coefficient reflecting the difficulty of implementation was applied to each recommendation. More complex implementations, whether due to costs or incompatibility with existing systems, received a lower coefficient of 0.5. Recommendations that are less complicated were assigned a coefficient of 1, indicating they are not at risk, while those with moderate complexity received a coefficient of 0.75.

Table 3.4: Ranking of the recommendations

🟩 = 5 ; 🔶 = 3 ; 🟡 = 1 ; None = 0

Actions			Communication	Awareness of RL	End-customer satisfaction	Customer satisfaction	On time pickups	On time deliveries	On time scanning	Average end customer time	Quick returns procedures	Stable Pay-backs	% of Sales Vs Returns	Tied-up capital	Total KPIs	Implementation	Total	Ranking
			KPIs															
Actions	Communication	Data Collection (3PL)	■	◆		●	◆	◆	●				■	●	**22**	1	22	3
		Workshops with dealers	■	◆	■	■								◆	**21**	1	21	6
		Data collection (Dealers)	■	◆	■					■				◆	**21**	1	21	6
		Workshops with workers handling the returns in the DCs	■	■	■										**15**	1	15	13
	Dealers´ experiences	Build a new system	■		■	■					■	■	■	■	**35**	0,5	17,5	12
		Reduce procedures' LT			■	■				●	■				**16**	0,75	12	17
		Stabilize payment lead time			◆	■					◆	■		●	**17**	0,75	12,75	16
		Gain knowledge about what it is paid			◆							■	■		**13**	1	13	15
		Send pop-up notifications				■					■	■			**15**	0,75	11,25	18
		Self-booking transport			◆	■				◆	◆		●	■	**20**	0,5	10	19
	Returns planning and policies	Measure the performance of each dealer	●	◆	■	■				■			■	■	**29**	0,75	21,75	4
		Establish incentives/penalties (Dealers)		◆	■	◆				●	■		◆	■	**24**	0,75	18	9
		Enhance forecasts			■	■							◆	■	**18**	0,75	13,5	14
	Lead times	Ensure proper data collection (3PL)	■	◆		◆	●	●	●				■		**19**	1	19	8
		Perform lead times measurements	◆		●	◆	■	■	■		■	■			**32**	0,75	24	1
		Establish incentives/penalties (3PL)			●	◆	■	■	◆				◆	■	**24**	0,75	18	9
		Reduce stock orders			◆	●	◆	◆	●	◆	■			■	**24**	0,75	18	9
		Establish same day deliveries			■	■	◆	◆	◆	■				■	**29**	0,75	21,75	4
		Track and trace			◆	■	■	■	■			◆	■		**31**	0,75	23,25	2

After this grading, which provided which recommendation had the most impact if applied, they were given a difficulty of implementation coefficient. The more complicated the recommendation was the less the multiplier value was assigned. Thus, these recommendations were ranked based on the impact they have if applied and based on the easiness of implementation.

Finally, the best five ranked recommendations were: Perform lead times measurements; Track and trace; Data collection (3PL); Establish same day deliveries; and Measure the performance of each dealer.

CHAPTER 4: CONCLUSION

4.1. Summaries of key findings

a. What barriers hinder the effective implementation of reverse logistics within the automotive industry and specified in Volvo Group?

The automotive industry's reverse logistics has such a high level of complexity that it requires in-depth collaborations of different stakeholders and departments to join forces. Barriers, in this research, are divided into 5 main categories: Environmental Challenges, Operational Challenges, Economic Challenges, Regulatory and legislative Challenges, Organizational and Managerial Challenges.

Although reverse logistics is often known as a solution toward more environmentally friendly operations, implementing reverse logistics in the automotive sector may encounter many challenges. For instance, the process of recycling and upcycling faces many types of costs that arise from building infrastructure, a situation of shortage of skilled professionals, unclear legal frameworks, and underdeveloped recycling technology. Furthermore, the automotive industry annually generates a large amount of both hazardous and non-hazardous waste, requiring restricted and specialized handling and management processes. Ineffective management of this waste can lead to environmental pollution and high operating costs.

Shifting to operational challenges, managing the inventory of recycled and upgraded parts also poses additional challenges on manufacturers. This includes storing used parts and ensuring their quality for reuse. Companies often suffer from inventory surpluses due to inaccurate demand forecasting and the management of obsolete parts. Effective collaboration among stakeholders, including companies, suppliers, distributors, and customers in terms of sharing information, resources, and expertise can help optimize these processes and reduce costs.

However, managing the expectations and benefits of different stakeholders can be challenging. Due to the lack of trust, insufficient information, and lack of commitment from senior management, stakeholders usually come up with a less efficient collaboration.

In a different vein, financial factors have also been a potent factor in adopting reverse logistics. These costs which include labor, initial investments, infrastructure, and remanufacturing are the main obstacles. Furthermore, quantifying the right pricing for recycled and upgraded products coupled with tackling market demand fluctuations can be problematic for companies.

Regulatory and Legislative Challenges further complicate the application of reverse logistics. The lack of proper laws and regulations for taking back or managing end-of-life vehicles causes confusion among manufacturers, suppliers, and recyclers, making it difficult to follow standard methods for collection, recovery, and disposal. In addition, companies are not encouraged to operate in an environmentally sustainable manner as supportive economic policies, such as tax incentives and regulatory frameworks, are not in place. SMEs, in particular, experience difficulties with heavy regulations like RoHS, REACH, and WEEE, which may make it hard for them to remain competitive.

Finally, Internal organizational factors are capable of heavily influencing the success of reverse logistics operations. The lack of employees, who do not possess the appropriate skills and are even ignorant of such fundamental reverse logistics procedures, can cause team productivity downtimes and time delays. Chronic staff shortages or the lack of people who know the proper training skills necessary for effective reverse logistics can curtail organizations from making errors and cause more unneeded delays. Furthermore, a small group of underqualified, and unqualified managers can make the problems identified at the strategic level, such as insufficient planning, making bad decisions, and lack of relevant technological knowledge, worse in reverse logistics. Poor leadership often pulls down the morale within an organization and this along with the other issues commonly left unaddressed helps the causes of strategic plan failures, inadequate adjustments, and poor interdepartmental interaction to blossom. Besides, the performance indicators and inefficient information systems that exist in this space are barriers to proper monitoring, evaluating, and improving the reverse logistics processes.

Throughout the case study of Volvo Group, the 5 main barriers impacting the RL process of the company were identified including: Communication, Dealers´ experiences, Returns planning and policies, Lead times, Performance measurements. Besides, there are also sub-barriers that were studied and proposed recommendations based on that information.

b. What practical solutions can be suggested to address and mitigate the challenges of reverse logistics in the Volvo Group?

After the five main barriers are identified, the following list presents five key recommendations derived from the analysis conducted:

1. Perform lead times measurements. It refers to get the proper data to be able to measure lead times regarding the transportation of goods both in the forward and backwards flows, as well as measure lead times concerning dealers returns (systems wise dealer's experiences)
2. Track and trace. It refers to the availability of both dealers and Volvo to track and trace the products, both in forward and reverse flows).
3. Data collection (3PL). It refers to collecting data from the 3PL service company. Nowadays Volvo is not performing any analysis in the reverse logistics flows. To be able to analyze reverse flows, data has to be collected.
4. Establish same day deliveries. It refers to being able to deliver a product the same day as ordered.
5. Measure the performance of each dealer. Measuring the performance of the dealers (% Sales VS Returns) is a crucial indicator to study. Based on this ratio, measures need to be taken, such as putting incentives/penalties based on the dealer's behavior (revealed as important suggestions).

4.2. Implications for practice and research

4.2.1. Implications for practice

Practitioners need to address the identified barriers to reverse logistics practices in the automotive industry, as it can lead to improved efficiency and sustainability within this sector.

First of all, practitioners can implement effective strategies that foster transparency throughout the entire supply chain by recognizing the importance of information sharing and collaboration among various stakeholders. This involves embracing advanced digital solutions that enhance collaboration, such as investing in cutting-edge technologies and systems like RFID tracking, artificial intelligence, and machine learning that facilitate real-time communication and seamless data exchange. Digital tools and procurement systems enable companies to focus on more than just price considerations because they provide real-time visibility, promote efficient communication, and support comprehensive supplier management. As a result, this can improve collaboration and enhance information sharing between companies and their suppliers, ultimately streamlining their operations.

Moreover, enterprises can integrate sustainable practices into the core of their operations to significantly mitigate environmental concerns and contribute positively to the circular economy. By adopting innovative solutions such as comprehensive recycling programs, effective product refurbishment initiatives, and responsible disposal methods, companies can not only enhance their corporate social responsibility but also create a distinct competitive advantage in an increasingly environmentally conscious market. This proactive approach to sustainability can resonate well with consumers and stakeholders alike.

Besides, companies must design and implement effective marketing campaigns and educational initiatives. They can encourage responsible consumer behavior, which is essential for the success of reverse logistics practices. Educating consumers about the benefits of returning products for recycling or refurbishment can lead to higher participation rates in these programs, ultimately resulting in a more sustainable life cycle for automotive products.

In conclusion, addressing the barriers to reverse logistics in the automotive industry is not just a logistical challenge but also an opportunity for practitioners to enhance operational efficiency, promote sustainability, and engage consumers in meaningful ways. As the automotive industry continues to evolve, embracing these strategies will be crucial for the business long-term success.

4.2.2 Implications for research

The identified barriers to reverse logistics within the automotive industry offer a rich and promising area for future research. Scholars and researchers have the opportunity to explore various strategies aimed at enhancing collaboration among the diverse stakeholders involved in the supply chain. Besides, companies and their suppliers should also focus on developing trust-building mechanisms and establishing robust contractual agreements that can effectively address and overcome the prevalent challenges associated with the information-sharing process.

Additionally, researchers can also investigate the development and thorough assessment of innovative technologies and systems that are designed to promote sustainable practices in reverse logistics. It is essential to consider the scalability and feasibility of these technologies and systems to ensure they can be implemented on a broader scale across the industry. Furthermore, examining how reverse logistics practices can be adapted to fit various cultural and regulatory contexts will provide valuable insights that can facilitate global implementation. Another promising avenue for research lies in integrating circular economy principles into automotive supply chains, which involves transforming waste into valuable resources.

In general, by addressing these significant research gaps, scholars and researchers can make meaningful contributions to the development of comprehensive frameworks and guidelines. These frameworks will empower practitioners to effectively navigate the complexities of reverse logistics, ultimately driving sustainable and efficient practices within the automotive industry.

4.3. Limitations and suggestions for further research

Although the research has provided valuable insights into the barriers of reverse logistics within the automotive industry, certain limitations have affected the depth and breadth of the study.

One significant limitation is that our research lacks quantitative data analysis and primary data, which can not reflect real-time and practical decisions instead of using only secondary information. Further research should be conducted on the investigation form or different approaches to gain real insights for the report. Also, technical tools should be collaborated throughout the analyzing and estimating process to autonomously clear and visualize the dataset.

Another limitation stems from the reliance on the Volvo Group as the sole case study. While this choice allowed for an in-depth examination of a well-established organization, it also constrained the research's ability to generalize findings across the automotive industry. The advanced supply chain infrastructure and financial resources available to Volvo Group may not accurately represent the challenges experienced by smaller companies or those operating in less developed markets. Thus, future research should consider incorporating multiple case studies from a diverse range of companies in different geographic regions, particularly those in less developed markets. This approach would give a general view of the findings by including organizations of varying financial capacities, and supply chain infrastructures.

Lastly, Data and information unavailability, such as cost breakdowns for remanufacturing, waste management, and collaboration efforts, are restricted due to confidentiality concerns. For instance, sensitive financial data and proprietary operational details were not disclosed, limiting the ability to conduct a comprehensive assessment of economic and regulatory barriers. Additionally, the study focused on identifying barriers without exploring practical solutions or innovative strategies, reducing its value in providing actionable guidance for industry stakeholders in reverse logistics. To address these issues, future research should collaborate with organizations under confidentiality agreements to access detailed data. It should also prioritize exploring innovative strategies and solutions to improve reverse logistics, providing industry stakeholders with actionable insights and guidance for overcoming identified challenges.

REFERENCES

Abdulrahman, M. D., Gunasekaran, A., & Subramanian, N. (2014). Critical barriers in implementing reverse logistics in the Chinese manufacturing sectors. International Journal of Production Economics, 147, 460–471. doi:10.1016/j.ijpe.2012.08.003

Ab, N., Nik, H. and Yaakub, S. (2014). REVERSE LOGISTICS: PRESSURE FOR ADOPTION AND THE IMPACT ON FIRM'S PERFORMANCE. *International Journal of Business and Society*, [online] 15(1), pp.151–170. Available at: https://www.ijbs.unimas.my/repository/pdf/Vol15No1paper9.pdf.

Abdulrahman, M.D., Gunasekaran, A. and Subramanian, N. (2014). Critical barriers in implementing reverse logistics in the Chinese manufacturing sectors. *International Journal of Production Economics*, 147, pp.460–471. doi:https://doi.org/10.1016/j.ijpe.2012.08.003.

ACEA (2024). *Trends, challenges and opportunities in the EU transport labour market Study Policy Department for Structural and Cohesion Policies Directorate-General for Internal Policies PE EN STUDY*. [online] Available at: https://www.europarl.europa.eu/RegData/etudes/STUD/2024/747266/IPOL_STU%282024%29747266_EN.pdf.

APICS – The Association For Operations Management, 2008. Reverse Logistics. In: APICS Dictionary. 12 Ed. S.L.:S.N.

Audo, S. (2011). *A study on Reverse Logistics Dhananjaya Reddy SCHOOL OF INNOVATION, DESIGN & ENGINEERING (IDE) MASTER THESIS WORK (KPP231) MASTER PROGRAM IN PRODUCT AND PROCESS DEVELOPMENT- PRODUCTION &LOGISTICS*. [online] Available at: https://www.diva-portal.org/smash/get/diva2:396019/fulltext01.pdf.

AWJ Research Desk (2024). *Automotive Waste: Challenges and Sustainable Solutions*. [online] Auto World Journal | Feel The Responsible Auto Industry News. Available at: https://www.autoworldjournal.com/automotive-waste-challenges-and-sustainable-solutions/ [Accessed 2 Dec. 2024].

Binder, A. (2019). Automotive industry - Ford and the assembly line. In: *Encyclopædia Britannica*. [online] Available at: https://www.britannica.com/technology/automotive-industry/Ford-and-the-assembly-line.

Carlier, M. (2023). *Global automotive market size 2030*. [online] Statista. Available at: https://www.statista.com/statistics/574151/global-automotive-industry-revenue/.

Chan, F.T.S., Chan, H.K. and Jain, V. (2012). A framework of reverse logistics for the automobile industry. *International Journal of Production Research*, 50(5), pp.1318–1331. doi:https://doi.org/10.1080/00207543.2011.571929.

D'Adamo, I., Gastaldi, M. and Rosa, P. (2020). Recycling of end-of-life vehicles: Assessing trends and performances in Europe. *Technological Forecasting and Social Change*, 152(0), p.119887. doi:https://doi.org/10.1016/j.techfore.2019.119887.

Dale, S.R. and Ronald, S.T.-L. (1998). *Going Backwards: Reverse Logistics Trends and Practices*. [online] Available at: https://www.icesi.edu.co/blogs/gestionresiduossolidos/files/2008/11/libro-lr.pdf.

Dashore (2024). *Green Supply Chain: A hierarchical framework for barrier*. [online] Google.com. Available at: https://scholar.google.com/scholar_lookup?title=Green+supply+chain+management:+A+hierarchical+framework+for+barriers&author=Dashore.

Daugherty, P.J., Glenn Richey, R., Hudgens, B.J. and Autry, C.W. (2003). Reverse Logistics in the Automobile Aftermarket Industry. *The International Journal of Logistics Management*, 14(1), pp.49–62. doi:https://doi.org/10.1108/09574090310806530.

Dibenedetto Bill, 2007. Reverse logistics: be prepared. The Journal of Commerce (15307557) 8 (35), pp16.

E. Genchev, S. (2009). *Reverse logistics program design: A company study*. [online] Available at: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=4e47fd6af226a1f807f5af9c427943bdee28eb2e.

EasyBA (2023). *How to Handle Stakeholder Analysis as an Automotive Manufacturer - EasyBA.co*. [online] easyba.co. Available at: https://easyba.co/blog/business-analysis/how-to-handle-stakeholder-analysis-as-an-automotive-manufacturer/.

Ellen MacArthur Foundation (2016). *The New Plastics Economy: Rethinking the future of plastics*. [online] www.ellenmacarthurfoundation.org. Available at: https://www.ellenmacarthurfoundation.org/the-new-plastics-economy-rethinking-the-future-of-plastics.

ELV Training (2023). *End of Life Vehicles | ELV Training*. [online] ELV Training. Available at: https://www.elvtraining.com/elvs-explained [Accessed 3 Dec. 2024].

Essex, D. (2021). *What Is Reverse logistics? Definition from SearchERP*. [online] SearchERP. Available at: https://www.techtarget.com/searcherp/definition/reverse-logistics.

Fahrion, D. (2024a). *Automotive Waste Management And Waste Control: Reducing Costs And Administrative Workload With The Right Strategy*. [online] Waste Control Incorporated. Available at: https://wastecontrolinc.com/2024/02/19/automotive-waste-management/.

Fahrion, D. (2024b). *Safe and Sustainable Automotive Waste Disposal: A How-To Guide*. [online] Waste Control Incorporated. Available at: https://wastecontrolinc.com/2024/08/28/automotive-waste-disposal/.

Fassoula, E. D. (2005). Reverse logistics as a means to reduce the cost of quality. Total Quality Management and Business Excellence, 16(5), 631–643.

Galpin, T., Whitttington, J.L. and Bell, G. (2015). Is Your Sustainability Strategy sustainable? Creating a Culture of Sustainability. *Corporate Governance: the International Journal of Business in Society*, 15(1), pp.1–17. doi:https://doi.org/10.1108/cg-01-2013-0004.

Gentry, C. R. (1999). Reducing the cost of returns. Chain Store Age, 75(10), 124-125.

Glenn Richey, R., Genchev, S.E. and Daugherty, P.J. (2005). The role of resource commitment and innovation in reverse logistics performance. *International Journal of Physical Distribution & Logistics Management*, 35(4), pp.233–257. doi:https://doi.org/10.1108/09600030510599913.

Harshad Sonar, Bishal Dey Sarkar, Joshi, P., Nikhil Ghag, Vardhan Choubey and Sandeep Jagtap (2024). Navigating barriers to reverse logistics adoption in circular economy: An integrated approach for sustainable development. *Cleaner Logistics and Supply Chain*, pp.100165–100165. doi:https://doi.org/10.1016/j.clscn.2024.100165.

IJTAM· (2019). *International Journal of Automotive Technology and Management (IJATM) Inderscience Publishers - linking academia, business and industry through research*. [online] Inderscience.com. Available at: https://www.inderscience.com/jhome.php?jcode=ijatm.

Jack, E., Powers, T., Skinner, L., 2010. Reverse logistics capabilities: antecedents and cost savings. International Journal of Physical Distribution & Logistics Management 40 (3), 228–246

Jayaraman, V., & Luo, Y. (2007). Creating Competitive Advantages Through New Value Creation: A Reverse Logistics Perspective. Academy of Management Perspectives, 21(2), 56-73.

Jayaraman, V., Patterson, R. A., & Rolland, E. (2003). The design of reverse distribution networks: Models and solution procedures. European Journal of Operational Research, 150(1), 128-129.

Kapil, D. (2021). *Recycling of End-of-Life Vehicles (ELVs)- An Overview*. [online] Available at: https://autorecyclingworld.com/wp-content/uploads/2021/05/PPT_ELV_April-2021.pdf [Accessed 3 Dec. 2024].

Lau, K.W., Wang, Y., 2009. Reverse logistics in the electronic industry of China: a casestudy. Supply Chain Management: An International Journal 14 (6), 447–465

Le Vu (2024). *Global Automotive Waste: Challenges and Sustainable Solutions*. [online] Automotive - Thông tin, hình ảnh, đánh giá xe ôtô, xe máy, xe điện | VnEconomy. Available at: https://vneconomy.vn/automotive/chat-thai-nganh-o-to-toan-cau-thach-thuc-va-giai-phap-ben-vung.htm [Accessed 2 Dec. 2024].

Li, X. and Olorunniwo, F. (2008). An exploration of reverse logistics practices in three companies. *Supply Chain Management: An International Journal*, 13(5), pp.381–386. doi:https://doi.org/10.1108/13598540810894979.

Liebel, G., Tichy, M., Knauss, E., Ljungkrantz, O. and Stieglbauer, G. (2016). Organisation and Communication Problems in Automotive Requirements Engineering. *Requirements Engineering*, [online] 23(1), pp.145–167. doi:https://doi.org/10.1007/s00766-016-0261-7.

Mandala, V. (2024). Revolutionizing Automotive Supply Chain: Enhancing Inventory Management with AI and Machine Learning. *Universal Journal of Computer Sciences and Communications*, 3(1), pp.10–22. doi:https://doi.org/10.31586/ujcsc.2024.918.

Mao, Z. and Jin, Y. (2014). *Reverse Logistics in Automotive Industry --A multiple case study in automotive industry*. [online] Available at: https://www.diva-portal.org/smash/get/diva2:725973/FULLTEXT01.pdf.

Masoumi, S.M., Kazemi, N. and Rashid, S.H.A. (2019). Sustainable Supply Chain Management in the Automotive Industry: A Process-Oriented Review. *Sustainability*, [online] 11(14), p.3945. doi:https://doi.org/10.3390/su11143945.

MINAYA OSORIO, J. (2017). *Reverse logistics assessment in the automotive industry: A case study at Volvo Group*. [online] Chalmers Open Digital Repository. Available at: https://odr.chalmers.se/server/api/core/bitstreams/88eac908-2d5d-49ad-9315-985884d63f2c/content.

Mississippi Department of Environmental Quality (2024). *Used Motor Oil – MDEQ*. [online] www.mdeq.ms.gov. Available at: https://www.mdeq.ms.gov/land/waste-division/solid-waste-management-programs/recycling/faqs/motor-oil/.

Mitra, S. (2007). *Revenue management for remanufactured products. Omega, 35(5), 553–562.* doi:10.1016/j.omega.2005.10.

Mohammed, I. (2021). *The Automobile Stakeholders you need to know.* [online] www.linkedin.com. Available at: https://www.linkedin.com/pulse/automobile-stakeholders-you-need-know-iyamu-mohammed/.

Moktadir, Md.A., Rahman, T., Ali, S.M., Nahar, N. and Paul, S.K. (2019). Examining barriers to reverse logistics practices in the leather footwear industry. *Annals of Operations Research*, [online] 293(0). doi:https://doi.org/10.1007/s10479-019-03449-y.

Monica (2023). *Sustainable Wheels: The Role of Reverse Logistics in Autos*. [online] Learn Transformation. Available at: https://learntransformation.com/reverse-logistics-and-automobile-industry/.

Mudgal, R.K., Shankar, R., Talib, P. and Raj, T. (2010). Modelling the barriers of green supply chain practices: an Indian perspective. *International Journal of Logistics Systems and Management*, 7(1), p.81. doi:https://doi.org/10.1504/ijlsm.2010.033891.

Naveen Reddy Dolu Surabhi, S., Vali Buvvaji, H. and Reddy Sabbella, V.R. (2024). *The AI-Driven Supply Chain: Optimizing Engine Part Logistics For Maximum Efficiency*. [online] Available at: https://www.researchgate.net/publication/381023046_The_AI-Driven_Supply_Chain_Optimizing_Engine_Part_Logistics_For_Maximum_Efficiency/fulltext/6659fcfd479366623a34bd67/The-AI-Driven-Supply-Chain-Optimizing-Engine-Part-Logistics-For-Maximum-Efficiency.pdf.

Nunes, B., Bennett, D., Shaw, D. and Neto, F. (2011). Challenges and opportunities for reverse logistics initiatives in the automotive industry. *18th International Annual Conference of the European Operations Management Association*. [online] doi:https://doi.org/10.13140/2.1.3791.6966.

Orsato, R.J. and Wells, P. (2007). The Automobile Industry & Sustainability. *Journal of Cleaner Production*, [online] 15(11-12), pp.989–993. doi:https://doi.org/10.1016/j.jclepro.2006.05.035.

Pan, Y. and Li, H. (2016). Sustainability evaluation of end-of-life vehicle recycling based on emergy analysis: a case study of an end-of-life vehicle recycling enterprise in China. *Journal of Cleaner Production*, 131(337), pp.219–227. doi:https://doi.org/10.1016/j.jclepro.2016.05.045.

Patel, P. and Gaines, L. (2016). Recycling Li batteries could soon make economic sense. *MRS Bulletin*, [online] 41(6), pp.430–431. doi:https://doi.org/10.1557/mrs.2016.116.

Qu, X. and Williams, J.A.S. (2008). An analytical model for reverse automotive production planning and pricing. *European Journal of Operational Research*, 190(3), pp.756–767. doi:https://doi.org/10.1016/j.ejor.2007.06.041.

Ravi, V. and Shankar, R. (2005). Analysis of interactions among the barriers of reverse logistics. *Technological Forecasting and Social Change*, 72(8), pp.1011–1029. doi:https://doi.org/10.1016/j.techfore.2004.07.002.

Ravi, V. and Shankar, R. (2017). An ISM-based approach analyzing interactions among variables of reverse logistics in automobile industries. *Journal of Modelling in Management*, 12(1), pp.36–52. doi:https://doi.org/10.1108/jm2-08-2014-0066.

Raymond Huscroft, J. (2024). *Redirect Notice*. [online] Google.com. Available at: https://www.google.com/url?q=https://etd.auburn.edu/bitstream/handle/10415/2438/Huscroft_FINAL_Ver_3_Dissertation_TC_good.pdf [Accessed 3 Dec. 2024].

Reflex, L. (2024). *Reverse logistics: definition, challenges, and opportunities*. [online] Reflex Logistics. Available at: https://www.reflex-logistics.com/en/blog/reverse-logistics-definition-management-and-advantages/.

Research Nester (2024). *Reverse Logistics Market Size & Share | Global Report 2037*. [online] Researchnester.com. Available at: https://www.researchnester.com/reports/reverse-logistics-market/6267 [Accessed 3 Dec. 2024].

Reverse Logistics Association, 2013. What Is Reverse Logistics. [Online] Available At: Http://Www.Reverselogisticstrends.Com/Reverse-Logistics.Php [Accessed 16 Aug 2013]

Rogers, D.S., Tibben-Lembke, R.S., 2002. Differences between forward and reverse logistics in a retail environment. Supply Chain Management: An International Journal 7 (5), 271–282.

S. K. Sharma, B. N. Panda, S. S. Mahapatra and S. Sahu (2011). *Analysis of Barriers for Reverse Logistics: An Indian Perspective*. [online] ResearchGate. Available at: https://www.researchgate.net/profile/Chakradhar-D/publication/281027497_Multi-Objective_Optimization_of_Electrochemical_machining_of_EN31_steel_by_Grey_Relational_Analysis/links/5824614f08aeb45b58899b01/Multi-Objective-Optimization-of-Electrochemical-machining-of-EN31-steel-by-Grey-Relational-Analysis.pdf.

Sorker, F. (2019). *Investigation on Reverse Logistics of End of Life Cars in the UK*. [online] Available at: https://repository.mdx.ac.uk/download/da311bf7b85e27da75218f60293f18de81293919908f633004faa7943cfad415/8176078/FSorker%20thesis.pdf [Accessed 3 Dec. 2024].

Sousa, F.D.B. (2023). Consumer Awareness of Plastic: an Overview of Different Research Areas. *Circular Economy and Sustainability*, [online] 3, pp.1–25. doi:https://doi.org/10.1007/s43615-023-00263-4.

Stock, J., Speh, Tomas, Shear, Herbert, 2002. Many Happy (Product) Returns. Harvard Business Review, July 2002

Thierry, M., Salomon, M., Van Nunen, J. and Van Wassenhove, L. (1995). Strategic Issues in Product Recovery Management. *California Management Review*, 37(2), pp.114–136. doi:https://doi.org/10.2307/41165792.

Vandermerwe, S., & Oliff, M. D. (1990). Customers drive corporations green. Long Range Planning, 23(6), 10-16.

Volvo (2024a). *Redirecting*. [online] Google.com. Available at: https://www.google.com/url?q=https://www.volvogroup.com/en/about-us.html&sa=D&source=docs&ust=1733215944065123&usg=AOvVaw3GAKAXEIordkx-INWXaSQX [Accessed 3 Dec. 2024].

Volvo (2024b). *Redirecting*. [online] Google.com. Available at: https://www.google.com/url?q=https://www.volvogroup.com/en/about-us/company-values.html

&sa=D&source=docs&ust=1733215944065456&usg=AOvVaw3Z_VIgRTDarCmpyyMnQPj7 [Accessed 3 Dec. 2024].

Waqas, M., Dong, Q., Ahmad, N., Zhu, Y. and Nadeem, M. (2018). Critical Barriers to Implementation of Reverse Logistics in the Manufacturing Industry: A Case Study of a Developing Country. *Sustainability*, 10(11), p.4202. doi:https://doi.org/10.3390/su10114202.

XUMEI ZHANG (2024). *IEEE Xplore Full-Text PDF:* [online] Ieee.org. Available at: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=10121158 [Accessed 3 Dec. 2024].

Zailani, S., Govindan, K. and Rizaimy Shaharudin, M. (2016). *Journal of Cleaner Production*. [online] Barriers to Product Return Management in Automotive Manufacturing Firms in Malaysia. doi:https://doi.org/:%2010.1016/j.jclepro.2016.08.160.

Zhou, F., Lim, M.K., He, Y., Lin, Y. and Chen, S. (2019). End-of-life vehicle (ELV) recycling management: Improving performance using an ISM approach. *Journal of Cleaner Production*, 228(337), pp.231–243. doi:https://doi.org/10.1016/j.jclepro.2019.04.182.

Zinser, J. (2023). *How Closed-Loop Recycling Programs Benefit Automobile Manufacturers*. [online] www.waste360.com. Available at: https://www.waste360.com/aluminum/how-closed-loop-recycling-programs-benefit-automobile-manufacturers.