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Remanufacturing of Automotive Spare Parts: Challenges in Ensuring Quality and Reliability

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Sommario

1. Introduction

1.1 The Circular Economy in the Automotive Sector

In recent years, it has become abundantly clear that our economic model needs a radical change. The old linear way of doing things — take, make, use, toss — just isn't working anymore. We're using up natural resources at an unsustainable pace, generating more waste than we can manage, and pushing emissions to dangerous levels. It's time to rethink how we produce and consume. This is where the circular economy steps in. Instead of creating products that are quickly discarded, this model focuses on giving them a longer life, reusing materials, and minimizing environmental harm. The European Commission describes it as a way to keep the value of materials and products in the loop for as long as possible, fighting back against the idea that everything is disposable. It's about designing products to last, to be fixed, upgraded, and reused, right from the start. In other words, it's a smarter, more sustainable way forward. If there's one industry where this shift really counts, it's the automotive world. We're talking about a giant sector, worth over $2.5 trillion in 2023, but also one of the biggest contributors to global emissions. And it's currently going through a major evolution. Electric vehicles are becoming the norm, cars are getting smarter with digital features, and what people expect from a vehicle is changing fast. At the same time, the industry is under pressure: key materials are getting harder to find, supply chains are feeling the strain, and environmental rules are becoming more demanding by the day.

In this context, remanufacturing automotive parts is emerging as one of the most effective ways to align industrial needs with sustainability goals. Unlike simple repairs, remanufacturing is a comprehensive process: it involves taking parts apart, replacing worn components, upgrading tech, and thoroughly testing everything to ensure it performs like new. The environmental benefits are huge, up to 90% of raw materials saved, 55–85% less energy used, and CO_2 emissions cut by as much as 80% compared to making new parts.

And it's not just good for the planet, it's smart business. Remanufacturing lowers production costs, which means companies can offer more competitive prices. That's a big deal for consumers too, especially now, with the rising costs of car maintenance and longer wait times for new parts. It also helps recover valuable materials that would otherwise go to waste, creating a more resilient, efficient, and circular industrial system.

1.2 Research Question

Given that the circular economy represents a concrete strategy to reduce the consumption of natural resources, limit waste production, and lower emissions, thus contributing to the transition towards a sustainable development model, this study aims to investigate how the remanufacturing of spare parts in the automotive sector can serve as a strategic lever to accelerate this transition. The analysis focuses on identifying the opportunities, challenges, and necessary conditions for a broader adoption of this practice. To address the research question, a qualitative methodology was adopted, as it was deemed the most appropriate for exploring in depth a phenomenon that is still relatively under-researched, namely remanufacturing in the automotive sector. The objective is not to quantify variables or generate broadly generalizable data, but rather to understand the cultural, operational, and strategic dynamics that influence the adoption of remanufacturing by the various stakeholders.

The analysis was built on a series of semi-structured interviews with a range of professionals from remanufacturers and distributors to representatives of consortia and people working directly in the automotive aftermarket. This approach allowed me to gather a wide variety of perspectives, giving space to the voices of those who live and breathe this work every day. Their stories revealed not just how the sector operates, but also the challenges they face, the potential they see, and the real-world experience behind remanufactured components. By diving into these conversations, I was able to spot recurring themes, pinpoint what's holding the sector back, and collect valuable insights, both practical and strategic, that could help promote remanufacturing as a sustainable, competitive solution for the automotive industry.

1.3 Findings

The qualitative analysis conducted through semi-structured interviews with professionals in the automotive aftermarket sector revealed a number of recurring themes that widely describe the current state, potential, and critical issues related to spare parts remanufacturing in the automotive industry. One of the key findings is linked to the cultural perception of remanufactured parts, both among end consumers and some repair shops. In many cases, remanufactured products are confused with used or refurbished components, which contributes to their marginal and undervalued reputation. This terminological confusion, compounded by the lack of clear and unified communication from manufacturers, distributors, and institutions, fosters a distorted perception. What comes out from the interviews is, for example, that consumers often associate remanufactured parts with lower reliability or safety, despite the fact that the industrial processes adopted frequently ensure quality standards equal to or even exceeding those of new products.

A second important issue relates to the regulatory weakness characterizing the Italian context. The lack of uniform technical standards, mandatory certifications, and common rules is identified as one of the main barriers to the growth of the remanufacturing market. Compared to other European countries, where more structured regulations exist, the absence of a centralized framework in Italy generates uncertainty for operators and discourages investment. The interviewees expressed a desire for greater institutional involvement, particularly through the introduction of incentives, tax benefits, and shared certification programmes.

Another critical issue that emerged involves logistical challenges, especially in the management of cores, which are the essential raw materials for the remanufacturing process. Difficulties in securing a stable and controlled supply of used components, exacerbated by competition with OEMs and the absence of an organized reverse logistics system, represent one of the major constraints for the sector. Independent operators suffer from a significant asymmetry in access to cores compared to car manufacturers, who often retain components within their official networks, thus limiting their availability for third-party remanufacturers.

The interviews also highlighted how the technical quality of remanufactured parts is often underestimated. The processes implemented by professional remanufacturers such as quality control, traceability, functional testing, and warranty provision are fully aligned with market standards. However, this level of quality is rarely communicated effectively. The lack of consistent traceability throughout the supply chain prevents consumers from understanding the added value of remanufactured products, which are often perceived merely as a low-cost alternative rather than a conscious and sustainable choice. An optimistic outlook for the future of the sector emerged, driven

by growing attention to sustainability, advances in remanufacturing technologies, and the European Union's regulatory push towards a circular economy. The interviewed stakeholders recognize remanufacturing as a concrete opportunity not only to reduce environmental impact but also to stand out in the market through a responsible, cost-effective offer that aligns with sustainable development goals.

This thesis fits into the academic panorama with a twofold contribution. On the one hand, it offers an updated and in-depth reconstruction of the world of remanufacturing in Italy, bringing together technical, cultural, regulatory and logistical aspects that are rarely considered as a whole. On the other hand, it gives direct voice to those who work in the sector, collecting experiences and points of view that help to convey the real complexity of the context, highlighting both the structural obstacles and the possible development levers. The goal is not only to describe a technical solution, but to describe remanufacturing as a system also made up of people, rules, culture and communication. The results that emerged suggest that remanufactured spare parts can truly become a pillar of the circular economy in the automotive sector, provided that current barriers are overcome and a solid framework is built that can support its large-scale diffusion.

2. Literature review

2.1 Transition and Challenges in the Automotive Industry between Sustainability, Global Competition and New Market Trends

The automotive industry is one of the most significant sectors globally with a turnover of USD 2.56 trillion in 2023, equivalent to 7% of EU GDP (Bladi, Parco, & Mancini, 2024). In recent years, the automotive industry has undergone profound transformations due to the development of new technologies, the increasing focus on sustainability and new consumer demands. Increasing pressure to reduce carbon emissions and the adoption of sustainable technologies are just some of the challenges the industry is facing. This transition is part of the broader context of Europe's circular economy, which promotes innovative and regenerative industrial solutions to address the environmental crisis and resource scarcity (OECD, 2020). In addition, the digitisation of mobility is radically changing the way vehicles are designed, built, sold and used, in the wake of business models based on software, connectivity and shared mobility services. One of the most noticeable developments in recent years is the progressive shift towards green mobility and electric vehicles, which are slowly convincing more and more consumers. However, the uptake of electrics is still strongly influenced by key critical factors such as the charging infrastructure, the cost of batteries, the availability of critical raw materials (such as lithium, cobalt and nickel) and government incentive schemes. Globally, the automotive sector is shaped by the presence of large groups resulting from mergers that took place years ago. Among the most important is the Japanese giant incorporating Toyota, Lexus, Daihatsu and Hino, which recorded sales of more than 10 million vehicles in 2023. A direct competitor is the Volkswagen Group, comprising several brands, including Audi, Porsche and Lamborghini, which slightly topped 8 million sold vehicles (Einaudi, 2023). Finally, Stellantis is worth a mention. This younger group formed in January 2021 from the merger of the already well-known PSA Group and Fiat Chrysler Automobiles (FCA) is a clear example of how two companies can exploit industrial synergies on a global scale by joining forces.

2024 has not been too blissful a year for the European industry: Chinese competition is becoming increasingly stronger, conquering new markets and negatively impacting the European automotive industry in two ways: firstly, by reducing Chinese demand for European cars, and secondly by boosting Chinese exports and expanding into foreign markets. Suffice it to say that in 2000 China controlled only 4% of the global demand, whereas today it has reached a remarkable share of 32% (Di Giulio, 2024). China's growth is not only due to aggressive industrial strategies, but above all to strong government support aimed at strengthening the country's leadership in the electric car sector. During 2020 there was an exponential increase in exports due to the expansion of Chinese

production capacity through massive government investment. Moreover, today, China is a leader in the production of electric vehicles and exports more of them than any other manufacturer; but the real strength of Chinese manufacturers is that they are able to offer good products at much lower prices than their European competitors. This strategy is made possible by exploiting economies of scale, integrated production chains and privileged access to indispensable raw materials. In addition, China has also managed to impose significant customs barriers for imports in the form of high levies, thus ensuring that most cars sold in the country are produced locally (Chang & Bradsher, 2024). Another factor that triggered this negative phase is the change in consumer preferences: consumers are increasingly switching to cheap cars, perhaps even at the expense of quality. Alternatively, they prefer used cars, which raises the average age of the car fleet.

Finally, it is crucial to consider the increasingly stringent emissions regulations, which are confronting car manufacturers with significant challenges. From 2025, it is expected that manufacturers will not be able to market vehicles with average emissions exceeding 93.6 grams of CO_2 per kilometre (Di Giulio, 2024). According to ACEA (European Automobile Manufacturers' Association), to meet this limit, the share of electric cars sold by European manufacturers would have to increase from the current 15% to at least 22%, or even to 37% in a more ambitious scenario. However, neither car manufacturers nor consumers seem yet ready for such a rapid transition to electric mobility (Magni, 2024)

2.2 Different types of spare parts: OE, OEM, OES, IAM

In Italy the average age of the car fleet is 12.5 years, making it one of the oldest in Europe. In France the average age of the car fleet is around 11 years, in Germany 10.1 and in the UK 8.6. The senescence trend in Italy started as early as 2008 with the average age of vehicles on the road going up by 4.6 years in just 14 years.

Anno	Fascia di Anzianita	AV	Totale
2023	DA 0 A 1 ANNO	1.718.054	1.718.054
2023	DA 1 A 2 ANNI	1.457.565	1.457.565
2023	DA 2 A 5 ANNI	5.038.155	5.038.155
2023	DA 5 A 10 ANNI	8.553.925	8.553.925
2023	DA 10 A 15 ANNI	7.360.261	7.360.261
2023	DA 15 A 20 ANNI	7.393.703	7.393.703
2023	DA 20 A 30 ANNI	5.477.872	5.477.872
2023	DA 30 A 40 ANNI	2.219.570	2.219.570
2023	40 E OLTRE	1.656.523	1.656.523
2023	NON DEFINITO	39.601	39.601

Figure 1: Vehicles on the road in Italy in 2023

As shown in Figure 1, the distribution is uneven with the premium segment averaging between "5 and 10 years" (Bruckner, 2024).

The ageing of the car fleet directly affects the demand for spare parts, especially in the aftermarket sector. Older vehicles require more frequent servicing, both for routine maintenance and for the replacement of wear parts. Especially in Italy the spare parts sector is experiencing significant growth, obviously due to the extremely old car fleet. According to data provided by ANFIA, in 2024 the aftermarket grew by 5.7% compared to the previous year with a total turnover of more than 22 billion euro. Independent garages, i.e. car repairers not directly affiliated with manufacturers, account for 70% of this market. Obviously, unlike affiliated garages, independent garages can aim to offer services at lower costs without compromising on quality (Redazione Fleetime, 2024). Moreover, pursuant to EU Regulation 461/2010, the motorist can decide to go to an independent garage without losing the two-year warranty of the parent company (Di Pede, 2024). Of course, this only applies if original spare parts or parts of equivalent quality are used.

Indeed, in the aftermarket sector, the consumer is not obliged to purchase spare parts exclusively from the manufacturer of the original parts, but has several options, known under the acronyms OE, OEM, OES, IAM.

Original Equipment (OE) refers to parts and components that are built in a vehicle when it is assembled in the factory, in other words, all the original parts that make up the car at the time of production. OE are thus installed on new vehicles. Any part added once the vehicle leaves the assembly line is no longer considered OE.

The OEM (Original Equipment Manufacturer) is the producer of OE components, that is, the company that manufactures the parts intended to be fitted on the vehicles during production by the automotive manufacturer. The OEM thus provides the essential components that are found in the finished vehicle, which will then be marked with the manufacturer's brand. These components are developed for specific models and approved by the automotive manufacturer to ensure they are perfectly compatible with the target vehicle. In other words, the automotive manufacturer primarily focuses on vehicle assembly, while the production of individual parts is entrusted to OEMs. In the automotive sector, the term *primo impianto* ("first installation") refers to components produced in series by suppliers and assembled directly in the automotive manufacturer's plant for the production of new vehicles. When a vehicle requires repairs or replacements, the use of OEM parts allows to preserve the originality of the components supplied to the manufacturer. However, in the field of after-sales service, these components are marketed as OES (Original Equipment Services).

The term OES refers to spare parts distributed through the official manufacturer's network for maintenance and after-sales service, which may include repairs, updates, and installations. For technical or commercial reasons, some accessories may only be installed by the dealer or authorized distributor, and even if installed before delivery to the customer, still fall into the OES category. In the automotive industry, only components installed during production are strictly considered OEM, while those installed afterwards fall within the scope of OES.

Another category of replacement components is found on the Independent Aftermarket (IAM), which operates outside the official OEM network. IAM parts are produced by independent companies and can provide a more economical alternative. However, these components may not have the same technical specifications as the original parts, which impacts on compatibility and compromises the longevity of the vehicle. Using OES parts instead preserves the structural integrity of the car, as they are produced by the same OEMs and conform to the manufacturer's standards.

An analysis conducted by the Turin Polytechnic University allows to trace the trend of IAM turnover for automobile distributors in Italy, focusing on the top 20 product categories in the period 2019-2024 (car batteries, clutch kits + flywheels, brake pads, lubricants, discs…). The data show that the top 20 product categories increased their market share from 59.59% in 2019 to 60.40% in 2024. Car batteries show the most significant increase, gaining 2.11 percentage points compared to 2019 and rising from 6.11% to 8.22%. Oil filters and bumpers/masks also recorded an increase of 0.31 and 0.26 percentage points respectively. A notable growth was the 0.12% increase in steering linkages sales between 2023 and 2024. At the other end, clutch kits + flywheels show the most significant loss compared to 2019 and are down from 8.06% to 7.00% (-1.06%). Engines/alternators also dropped from 3.17% in 2019 to 2.39% in 2024, losing 0.78 percentage points. Clutch kits + flywheels were the worst performing category in 2024 as to 2023 with a decline of 0.13%. These data suggest that the growth of car batteries may be linked to increased demand due to greater vehicle electrification and the need for more frequent replacement. Conversely, the reduction in the market share of clutch kits + flywheels could stem from technological changes in vehicles or increased component reliability reducing the need for replacement. The decline in engines/alternators could be associated with a lower incidence of failures or an increase in the quality of these components (Politecnico di Torino, 2025).

Finally, OES components are also distinguished by the presence of the trademark of the automotive manufacturer for which they were made, while IAM components bear solely the name of the independent producer. The same principle applies to maintenance and repair services: operations can be carried out at authorized centres (OES) or at independent garages (IAM) operating outside the official circuit.

2.3 Remanufacturing as an answer to spare parts shortage in the automotive industry

A growing demand for spare parts can clearly result in difficulties for most car manufacturers to provide the necessary after-sales support to their customers. When compounded by adverse events, such as the Covid-19 pandemic or the recent tensions in the Suez Canal, which compromise the supply chain, the risk of supply shortages becomes even more tangible. Currently, the situation in the Red Sea is becoming more and more worrying, leading to an increase in delivery times for new cars, but above all to a shortage of spare parts and delivery delays of up to 60 days. As Davide Galli, president of Federcarrozzieri, puts it: “Many parts of cars on the road today travel by ship and cannot be

replaced by parts produced in European factories", referring in particular to the so-called laminates, i.e. engine bonnets, mudguards, doors, body shell parts, etc., which are essential elements of car repairs as they are the first parts of cars to be damaged in the event of a road accident. Without these parts repairs are interrupted, causing inconvenience to consumers, who are forced to idle their cars for up to 60 days in the worst cases. All this inevitably leads to an increase in car and individual car parts thefts, which are more and more in demand. Consequently, motor insurance rates are becoming more expensive. At the end of 2023 the yearly increase was already 7.8% (Dean, 2024). A similar shortage situation occurred in 2022 when, following the Covid-19 pandemic and restrictions in Europe, car manufacturers reduced their stocks of and orders for semiconductors. When demand resumed, chip availability was limited, since manufacturers had redirected production capacity towards growing sectors such as consumer electronics, servers and PCs. The damage to the global automotive industry totalled almost 100 billion euro (Pini, 2022). According to a survey conducted by Federcarrozzieri, the car manufacturers that are experiencing the most problems with the supply of spare parts are DR, MG, Link & Co, SsangYoung, Nissan and Renault with delays ranging from 15 to 60 days (Gillespie, 2024).

On these grounds, the Competition and Market Authority (AGCM) sanctioned DR Automobiles with two fines worth 6 million euro, one of which specifically related to the delay problem. As investigations revealed, neither the company nor its subsidiary DR Service & Parts S.r.l. had allegedly been ensuring an adequate supply of spare parts at least since 2022, thereby compromising the efficiency of after-sales services. These shortcomings had repercussions on consumers, who were forced to wait for repairs for a long time, and damaged the brand image, underscoring the criticalities of ineffective supply chain management. The case of DR Automobiles highlights how the absence of a clear organisation strategy for supply and service can result in significant economic and legal consequences and erode customer trust and the company's competitiveness on the market (AGCM, 2024).

In response to this crisis, a practice has been developing in recent years that is becoming increasingly common: the remanufacturing of spare parts. Remanufacturing has been a strategic tool for the circular industrial economy for decades, offering tangible benefits in terms of both sustainability and production efficiency (Lund R. T., 2021) Indeed, a vehicle that has reached the end of its life cycle and is destined to demolition can be an excellent "donor" of still usable parts. These may provide useful components for the remanufacturing of that same part, resulting in savings in both economic and environmental terms. Clearly, all remanufactured parts must undergo quality testing and inspection to receive a warranty certificate. This practice is estimated to save up to 88% in

material consumption, 56% in energy demand, and 53% in CO_2 emissions for each component (Collazzo, 2017).

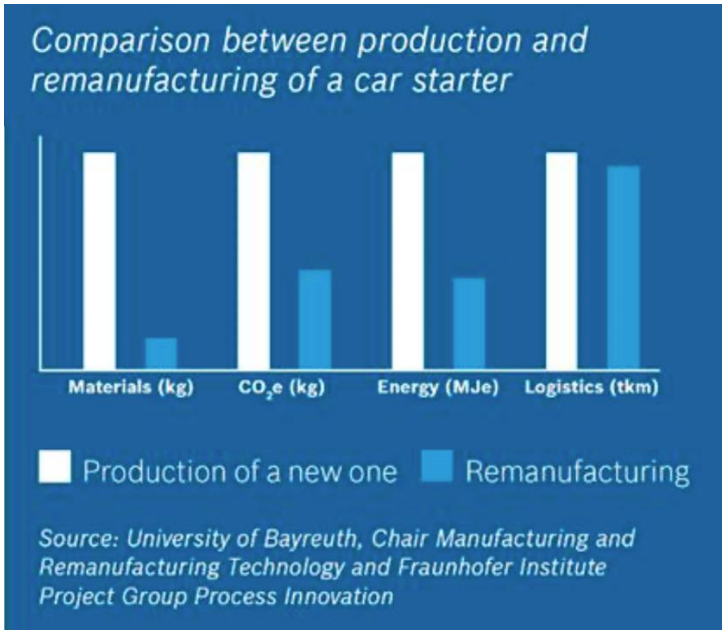

Figure 2: Comparison between production and remanufacturing of a car starter

Figure 2 compares the new production of a car starter to its remanufacturing, highlighting the differences in terms of material consumption, CO_2 emissions, energy consumption, and transportation impact.

Given the profits from remanufacturing, an increasing number of companies are investing in this sector, while states are introducing specific regulations to promote the use of remanufactured parts. In France a provision obliging mechanics to offer their customers the possibility to choose remanufactured components has been in force for several years now (Belfiore, 2017). So far, France is the only country to have implemented such a measure, but it is known that in Europe the circular economy is considered a priority. Yet, special attention is required to detect counterfeit parts. Like original components, also remanufactured parts are subject to counterfeiting, a market that, according to European data, costs mechanical parts suppliers approximately 10 billion euro every year. Among the most counterfeited spare parts are brake pads, belts, tensioners, water pumps, headlights, taillights, and license plate lights, pistons, alternators, and starter motors, but also spark plugs, windshield wipers, clutches, and wheel covers. Obviously, these products lack any certification or warranty and are offered to buyers with substantial discounts, clearly representing a real danger for the consumers who use them. Italy and Germany are home of the most flourishing counterfeit markets with a value of about 120 million euro (Collazzo, 2017).

The remanufacturing market is constantly growing, and it is no coincidence that several car manufacturers are investing in the remanufacturing of parts. One of these is certainly Stellantis, with a remanufacturing programme called SUBSTAINera. This initiative aims to give components a second life. According to analyses carried out by Stellantis, this innovative solution saves on average 60% to 95% of raw materials and cuts CO_2 emissions by 30% to 80% compared to the production of new parts. The main goal of the French-Italian group is to reduce carbon emissions to zero by 2028. To achieve this ambitious goal, the carmaker is able to offer around 13,000 remanufactured parts as an alternative to new parts (Gori, 2023). Stellantis is not alone. Renault also offers remanufactured parts under the Motro brand (Notiziariomoristico, 2020) with its network of multi-brand repairers. BMW has also joined the list by offering remanufactured parts in its own service centres. Further names are Nissan, Volkswagen, Volvo, Mercedes, and Peugeot. In short, all the major brands in the automotive sector are investing in remanufacturing, which could well be the future of repair. A study carried out by ERN (the European Remanufacturing Network) shows that some 2,363 companies are active in the remanufacturing sector in Europe, with a production capacity of around 27 million remanufactured parts per year. Yet, the ratio of remanufactured parts to new production is still relatively low at only 1.1% with a turnover of just under 7.4 million euro. In the USA the situation is completely different, reaching a turnover of 30 billion dollars. This difference, however, is not due to inefficiency on the part of European companies but to more frequent replacement of parts in US garages, higher prices for new products and greater satisfaction on the part of end consumers with remanufactured parts. This situation is, however, set to change in a few years' time. Proof of this is the increasing dynamism with which European companies specialising in the remanufacturing and rebuilding of automotive components are investing in the sector. The adoption of new technologies, optimisation of production processes and attention to environmental regulations are helping to make remanufacturing an increasingly competitive solution (Collazzo, Remanufacturing, la seconda vita dei ricambi è un business in crescita. Ma occhio alla contraffazione, 2017)

2.4 Definition of spare parts refurbishing and analysis of different models for recycling: Model M, Model R and Model HT

Before looking into the different models of recycling, the difference between remanufacture, overhaul and repair will be explained for better understanding. Although at first sight they may appear to be identical, these practices are in fact profoundly different. Remanufacturing is a comprehensive process that goes from completely disassembling the unit to replacing damaged and non-damaged components to even improving the spare part by upgrading its components. It goes without saying that to safeguard consumers remanufactured products must pass stringent checks before they can be

sold. Overhaul is a less invasive process but still allows the functionality of the spare part to be restored. In this case, the product is only partially dismantled and only the damaged parts are replaced. Clearly, this does not guarantee the same quality standards and longevity of a product that has undergone a remanufacturing process. The reason for choosing this option is obviously the lower price.

Finally, repair is the least comprehensive process of the three and is exclusively focussed on repairing the defective or damaged component without a complete overhaul. Undoubtedly, this allows the part to function again but does not ensure its durability. Repaired products, however, are the cheapest that can be found on the market. The choice between remanufacturing, overhaul and repair depends mainly on the consumer's budget but also on the durability and safety required. Whatever the approach, they all contribute to extending product life, reducing waste and saving natural resources. As already mentioned, remanufacturing is a comprehensive but very long and complex process. This can be divided into several consecutive steps that eventually result in a product ready for sale.

The first step is the collection of the components or "cores", which is one of the main challenges for regenerators (supply issues will be addressed specifically later). Additionally, not all cores are suitable for regeneration. To better understand this aspect, it is useful to refer to CoremanNet, a platform offering qualified core return solutions for the automotive spare parts market. On their website, it is possible to learn what cores are accepted for regeneration. Once the regenerator has selected the cores, processing starts. The second step is dismantling the component and evaluating which parts need to be replaced. The parts that can still be used will be cleaned to restore them to like-new conditions. Subsequently, the actual regeneration phase begins, where the selected parts undergo restoration processes, such as surface grinding, replacement of worn or damaged elements (e.g., bearings, seals), and the updating of any electronic or software parts to correct known defects or improve performance. At this point, the component can be reassembled. After regeneration, perhaps the most important step is the testing. Obviously, before being sold, the spare part undergoes functional and performance tests, often using test benches that simulate real operating conditions. These tests ensure that the remanufactured part functions properly and is safe for use. If the remanufactured part passes all the tests and is suitable for sale, it is painted, which not only protects the part from corrosion but also improves aesthetics. After that, it is packaged and distributed to customers or service centres. Car manufacturers issue a two-year warranty for remanufactured products, which is the same as for new parts.

There are different recycling models involving different actors such as suppliers, manufacturers, retailers, government and third-party remanufacturers. The supplier plays the main role supplying the manufacturer with the raw materials needed for remanufacturing, in particular cores, as mentioned above. The manufacturer, in turn, participates in the process by acquiring automotive components for remanufacturing. Dealers play a crucial role in marketing by offering both new and remanufactured parts to consumers, thus helping to strengthen the quality perception of the latter. In addition, they can also engage in recycling activities in compliance with existing regulations. Finally, the government plays a supervisory and regulatory role, monitoring the recycling activities of companies and levying taxes in compliance with environmental policies.

Based on these actors, four different models for recycling are constructed: the no-recycling model (Model N), the Model M, the Model R and the Model HT.

The N-model, also called no-recycling model, represents a basic scenario. It is the simplest model where the supplier gives the raw materials to the producer who uses retailers to reach consumers. As can be seen in the figure, there is no way to recycle products for scrapping, so it is not a suitable model for remanufacturing spare parts. (Hui Liu a, 2022).

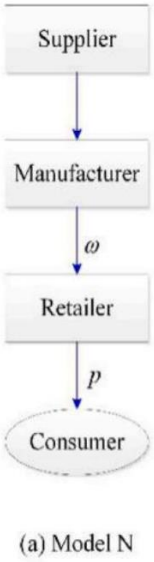

Figure 3: Model N or no-recycling model

Model M in Figure 4 includes recycling: in this case it is the manufacturer who collects and remanufactures the products. Another role in to distinguish between parts that can be resold to suppliers for remanufacturing and those that cannot. In this model, the government plays a central role by regulating, controlling and sustaining the recycling and remanufacturing of end-of-life

vehicles. One of its main functions is to set clear rules, such as the introduction of a “mandatory recycling quota”. In practice, this involves imposing an obligation on manufacturers to reuse a certain percentage of components from end-of-life vehicles (ELVs) in remanufacturing processes. This type of intervention serves to reduce waste, lower the environmental impact and push companies to invest more in the recovery and remanufacturing of parts. Another measure that can be taken is the introduction of a licence fee to operate in the recycling sector: in this case only companies who own this licence, and are thus recognised as qualified, would be allowed to take part in the process, thus reducing the risk of illegal or unsafe operations. Then there is the control aspect: the government is in charge of monitoring the whole process to make sure that environmental standards are met. Monitoring is also essential to counter the illegal trade in non-certified components and to ensure that remanufacturing operations are safe and reliable. Finally, the government can also influence the economic balance of the sector by affecting the purchase prices of cores. If taxes are too high, for example, manufacturers will have less leeway to offer a competitive price to those who want to scrap their vehicles. Conversely, if it decides to intervene with incentives or subsidies, it can make the remanufacturing model more competitive and attractive to companies, thus stimulating investment and innovation in the sector (Hui Liu a, 2022).

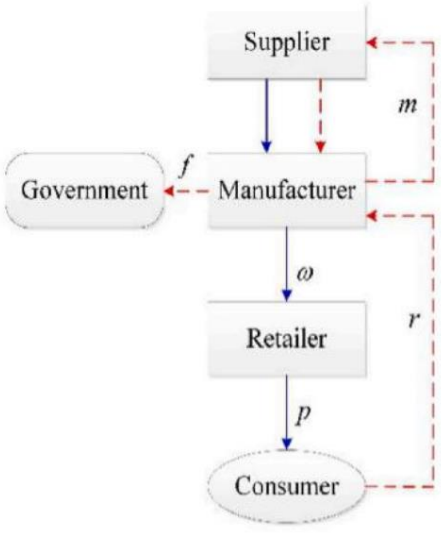

Figure 4: Model M

Model R identifies the dealer as being responsible for recycling used components and selecting the parts that can be transferred to suppliers against not suitable ones. Here, the government has the same functions as in the previously mentioned model. The recycling cost in this model is generally higher compared to Model M, due to more complex logistics. (Hui Liu a, 2022).

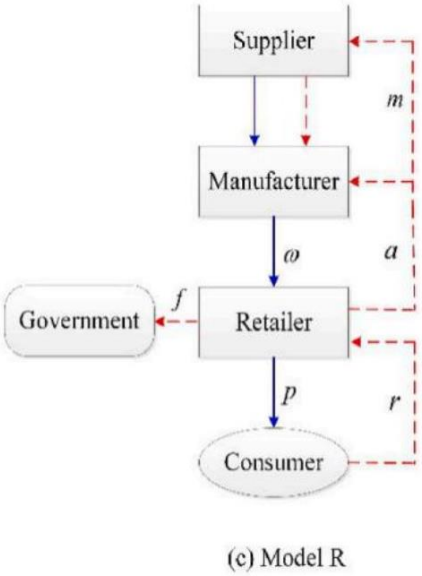

Figure 5: Model R

The last model is Model HT as shown in Figure 6. Here, recycling is outsourced to third-party centres that take care of the entire remanufacturing process of the recovered parts. As can be seen from the figure, manufacturers and customers supply third-party recycling centres with cores. After remanufacturing, the centres distribute the finished products to suppliers, manufacturers, retailers and customers. This model also benefits from government subsidies and is exempted from government-imposed recycling licence fees. (Hui Liu a, 2022).

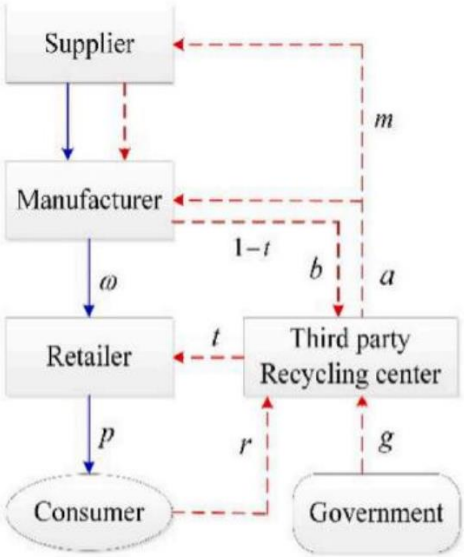

Figure 6: Model HT

In the automotive aftermarket sector, models M and HT are generally used. In the first case, as explained earlier, the manufacturer takes care directly of the recycling and remanufacturing of end-of-life components. This approach guarantees high quality control and the integration of technological updates into the remanufactured parts. This model, for example. is followed by Cummins in its ReCon programme for high-end remanufacturing of engines and turbochargers (Cummins Inc, 2024).

In Model HT independent recycling centres see to the remanufacturing of components, often benefiting from government incentives. Companies like LKQ Europe operate in this field, remanufacturing a wide range of components, including brake calipers, starter motors and alternators, through their specialised divisions (Sicurauto, 2023).

2.5 Challenges and opportunities for the automotive parts remanufacturing sector: between fragmented regulations and reverse logistics

The remanufacturing of spare parts is a key practice in the circular economy, promoting sustainability through the reuse and valorisation of used components that would otherwise go to waste. However, this sector is facing several challenges from both a regulatory and an operational perspective. Within the European Union, the remanufacturing of car parts is regulated by a set of directives and regulations aimed at promoting component reuse and sustainable waste management. Among the most relevant is Directive 2000/53/EC on End-of-Life Vehicles, which sets clear targets for the recovery, reuse and recycling of end-of-life vehicle components. (European Union, 2023). To allow independent manufacturers to recondition and market their components as an alternative to the original equipment manufacturer (OEM) without violating competition regulations, EU Regulation 461/2010 (Block Exemption Regulation) was introduced. This was conceived to regulate competition in the motor vehicle distribution and servicing sector in the European Union. It also establishes the conditions under which agreements between car manufacturers, parts suppliers and independent garages do not violate EU antitrust rules, in particular Article 101 of the Treaty on the Functioning of the European Union (TFEU) (European Union, 2010).

In Italy, the automotive parts remanufacturing sector is not governed by an organic set of rules but is subject to environmental laws and sectoral regulations. First of all, there is Legislative Decree 152/2006, also known as the Consolidated Environmental Act, which regulates waste management and material recovery, affecting the remanufacturing of components such as engines, turbines and gearboxes (Italian Government, 2006). Finally, the Ecodesign Regulation 2024/1781 was adopted in 2024, amending Directive 2008/98/EC and Regulation (EU) 2019/1020, repealing Directive 2006/66/EC. This provision promotes the eco-design of products by improving the durability, reparability and upgradeability of components, including automotive components. This approach aims to facilitate the remanufacturing and reuse of spare parts, helping to reduce the environmental impact of the sector (Italian Government, 2024).

The absence of unified regulatory policies for automotive aftermarket parts in Italy significantly affects efficiency on the market, limiting sustainable growth. There are no laws or governance boundaries in the industry, which further complicates standard operating procedures between the various players. The establishment of common technical standards and the provision of specific certifications could strengthen confidence in the used parts market and ensure greater use of remanufactured parts (Sicurauto Editorial, 2024). In this respect, an ANFIA statement underlined the existence of grey areas within the current regulations, which create uncertainties for the sector's

operators and hampers the full development of the spare parts remanufacturing market. The association emphasises the need for a clearer and more precise regulatory framework that would not only ensure greater competitiveness for Italian companies but would also contribute to the achievement of sustainability objectives set at European level. In addition to regulatory uncertainties, the automotive parts remanufacturing sector is also faced with issues related to the sourcing of cores for remanufacturing. This is perhaps one of the biggest difficulties that a company wishing to enter this market has to face. The traditional supply chain involves the raw material suppliers, the manufacturers, who own the production facilities and process the raw materials supplied to them, the distributors, whose purpose is to sell the finished products, and finally, of course, the customers. This above is an example of a Forward Logistics Process (FLP), this model is depicted in Figure 7.

Figure 7: The Forward Logistics Process (Difference Between Forward And Reverse Supply Chain, 2014)

In the remanufacturing of spare parts, the Reverse Logistic Process (RLP) is used in line with the principles of the circular economy. While FLP is simply concerned with providing value to the end consumer through the distribution of products, RLP focuses primarily on recovering the economic and environmental worth of used products. As can be seen in Figure 8, in this model materials, components and products are recovered and placed back onto the market. When purchasing a new piece, consumers are encouraged to bring back their broken parts for a discount. By doing so, remanufacturers obtain cores.

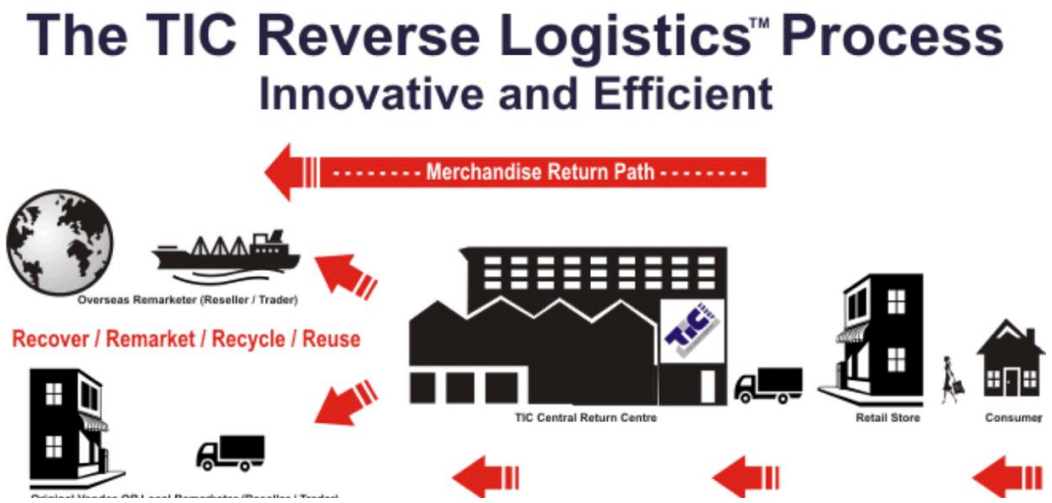

Figura 8: The TIC Reverse Logistics Process (Difference Between Forward And Reverse Supply Chain, 2014)

Reverse logistics has always been managed separately by companies from traditional logistics. This, however, is changing as remanufacturers are increasingly integrating the two supply chains, thus creating a closed-loop industrial system. As can be seen in Figure 9, production is the initial phase of the cycle, in which the components are produced. This is followed by utilisation, in which the parts are used in vehicles, both cars and trucks. After use, the used parts are returned through remanufacturing, marking the beginning of the reverse flow. At this point, remanufacturing takes place, in which the parts undergo repair, reconditioning or remanufacturing processes to be restored to like-new condition. After remanufacturing, the parts can be reused and put back onto the market, reducing the need for new production. The next stage is collection, where recoverable materials are sorted and sent to new production cycles, while those that cannot be reused are disposed of or recycled. Finally, the cycle is closed with the use of recovered materials for the production of new components, completing the loop.

Figure 9: Closed loop industrial system (Bosch, 2021)

Yet supply is still a problem for remanufacturers. The availability of cores is very limited, one of the main reasons being the legal or illegal export of used vehicles to countries outside Europe. Indeed, exports of second-hand vehicles can reduce the availability of vehicles for proper disposal and resource recovery. In this respect, the scrapping premium, which was introduced in Germany in 2009, has shown controversial effects. Although initially there was a significant increase in the number of recycled vehicles, it was also observed that some well-preserved cars were dismantled and subsequently exported, bypassing the resource recovery process and reducing the availability of cores. This phenomenon was not limited to Germany, but was observed in other European countries and, in general, reflects a lack of adequate controls in the monitoring of exports outside the EU.

Original equipment manufacturers (OEMs) and independent remanufacturers (IRs) compete for access to the necessary resources. OEMs have well-established distribution channels through authorised dealers, which facilitate the collection and ordering of the cores needed for remanufacturing. Moreover, in most cases when authorised repair shops carry out repairs, they are obliged to retain the cores in order to supply the OEMs. This control over the networks allows them to reduce their search and negotiation costs, but above all creates imbalances in the supply channels.

On the other hand, independent remanufacturers, who operate mainly through market channels, depend on external players such as wholesalers, dealers and repair shops. In most cases they source their supplies from scrapping centres at higher prices than OEMs, which makes them vulnerable to supply shortages and stronger competitors. Another difference between OEMs and IRs

emerges as to their core management practices. OEMs can strategically decide which cores to remanufacture and which to destroy, an option that directly affects the flow of resources available to remanufacturers. Finally, OEMs often favour the sale of new parts over remanufactured ones, even though remanufacturing is more sustainable.

In the article *Automotive Remanufacturing in the Circular Economy in Europe: Marketing System Challenges* (Kalverkamp & Raabe, 2017), the above-mentioned problems are analysed and addressed, and the authors also propose ideas to improve this situation. First of all, one could aim at strengthening European end-of-life vehicle (ELV) laws to limit exports to non-EU countries. Next, tax incentives would be advisable to promote remanufacturing. Another crucial aspect concerns cooperation between the different actors in the sector. Promoting cooperation between independent remanufacturers, dismantlers and distributors could generate synergies that reduce transaction costs and improve the availability of reusable components. In this respect, the development of common platforms for information exchange and component traceability would be an important step to ensure a more transparent and efficient management of end-of-life vehicles.

2.6 Beyond recycling: the potential of remanufacturing for the circular economy and the market response

Remanufacturing offers benefits mainly on three levels: environmental, economic and social. First and foremost, as mentioned above, remanufacturing spare parts reduces CO_2 emissions, raw material consumption, waste production and energy consumption. According to estimates in *The Value of Remanufactured Engines: Life-Cycle Environmental and Economic Perspectives* (M. Fabbro & Keoleiano, 2008), up to 90% of the raw materials required for the production of new spare parts can be saved through remanufacturing. In a particular context, as described above, where there is a shortage of raw materials, this practice could be of immense value to car manufacturers who are increasingly finding it difficult to supply spare parts to their consumers. Obviously, this also translates into a saving of energy used for production, since the remanufacturing process is quicker and easier than production from scratch, usually this saving is between 55-85% (Lund, 2018). Furthermore, by reducing the extraction and processing of materials, CO_2 emissions are reduced by 80% (Nasr & Thurston, 2006) and waste production is reduced by about 50% (MacArthur , 2020) by avoiding the disposal of components that are still usable. As already mentioned, remanufacturing is a pillar of the EU strategy to achieve climate neutrality by 2050 through the application of policies related to eco-design and material reuse. In addition to the above-mentioned environmental benefits, remanufacturing also brings economic advantages for both companies and consumers. In this respect, companies can reduce production costs and, as a consequence, the price offered to consumers can be reduced by 40% to 80% compared to an equivalent new product. As if this were not enough, through remanufacturing one may also be able to achieve a competitive advantage over those who do not implement this practice, thus being able to enjoy greater power within the market (Rematec, 2017).

For consumers, on the other hand, the purchase of remanufactured parts saves time on top of money, due to shorter waiting times. Indeed, while the availability of new parts decreases remanufactured goods are readily available. Furthermore, through the return of cores to remanufacturers, the problem of disposal of broken parts by consumers is also solved. The positive impact of remanufacturing also extends into the social sphere, contributing to the creation of a fairer and more sustainable production system. This growing sector also has the potential to generate new jobs; today the number of people employed in remanufacturing is estimated at around 190,000. A market study conducted by ERN predicts that with supportive government policies and industrial investment, the remanufacturing industry could grow to EUR 90 billion and employ 255,000 people (ERN, 2024).

Despite all these advantages that remanufacturing brings, its spread is still hampered by consumer perception. Many buyers are still wary of the quality and safety of these types of parts, considering them inferior to new parts. According to a study quoted in the article *Consumer Perception of Remanufactured Automotive Parts and Policy Implications for Transitioning to a Circular Economy in Sweden*, 58.6% of the 320 participants had never heard of remanufactured parts, and 76.4% had never bought any. Furthermore, knowledge of the concept of remanufacturing was very low: only 14.8% of the consumers had direct experience with the use of remanufactured parts.

According to surveys, the negative consumer perception is influenced by various cultural and psychological factors. For example, remanufactured parts are associated with products that tend to last less and with lower quality standards, although this is not true. In addition, risk perception also comes into play, i.e. many customers fear that remanufactured products may have hidden defects. This changes if consumers are informed about remanufacturing processes and quality certifications, in which case they show a greater willingness to purchase due to an increase in confidence in remanufactured products of 30-40%. The influence of price and warranties also plays a crucial role: offering coverage similar to that of new products, e.g. with warranties of 1-2 years, increases trust and encourages the choice of remanufactured components. Some strategies to improve consumer perception may include more effective communication through labels and certifications that guarantee product quality, information campaigns to educate the public on the benefits of remanufacturing, and loyalty programmes to promote the purchase of these products (Leonidas & Mitsutaka, 2019).

Remanufacturing offers a valuable opportunity to integrate environmental, economic and social benefits, facilitating the shift towards a more sustainable economic model. However, in order for it to take hold on a large scale, it is essential to overcome obstacles related to consumer perception and to establish rules and industrial practices favourable to its growth. To ensure its long-term success, it will be crucial to introduce supportive policies, define more precise quality standards and promote greater awareness among consumers.

3. Methodology

3.1 Research Design

This thesis is based on a qualitative research approach, which I consider the most suitable for analysing a continuously evolving branch such as the remanufacturing of spare parts in the automotive industry. Unlike purely quantitative analysis, which aims to measure variables and inevitably generalize results on a large scale, qualitative research has allowed me to explore in depth the motivations, perceptions, and strategies that influence the actors involved in the remanufacturing process.

My investigation focuses on remanufacturing not only from the perspective of remanufacturers but also of other stakeholders. The semi-structured interview format chosen allowed me to tailor the set of questions for each respondent so as to explore specific aspects according to the interviewee's role.

The interviews targeted a selection of professionals holding key roles in the automotive aftermarket, particularly in remanufacturing. Their answers provide complementary viewpoints from remanufacturing companies, consortia, and specialized distribution operators. Since the remanufacturing sector remains underexplored in academic literature, however, the objective of this work is not only to describe existing practices, but also to provide an outlook on future developments. Another reason for choosing the interview format, therefore, was to uncover new perspectives and potential development levers to support a broader and more informed adoption of remanufacturing.

Participants were selected based on their diverse skills and experiences, yet all are directly involved in the remanufacturing sector. The choice focused on professionals whose participation could provide qualified and diversified insights on a strategic, operational and predictive level.

3.2 Qualitative Research

For the accurate analysis of the material collected through semi-structured interviews, a qualitative approach was adopted to identify and interpret meaningful patterns within the data. This method proved particularly suitable for exploring the complexity of perceptions, experiences, and opinions expressed. The analysis followed several steps, beginning with familiarization with the data through full transcription and repeated reading of the interviews. This was crucial to acquire full understanding of the content and grasp the variety of nuances present in the responses.

To reinforce and contextualize the findings from the interviews, the analysis was complemented by a case study on Bosch eXchange, an industrial remanufacturing programme promoted by Bosch. This case was selected as it exemplifies a virtuous model in addressing key challenges. Bosch has established an integrated logistics network for the collection and selection of cores, introduced rigorous quality standards and functional testing for each remanufactured component, and built a communication system based on transparency and trust, offering warranties equivalent to those of new parts. Furthermore, the company has effectively interpreted European directives on the circular economy, positioning itself as a leader in the sector. The integration of insights from the interviews with the Bosch eXchange case study enabled a connection between qualitative evidence and experiences on the field, illustrating how some of the systemic barriers currently present on the Italian market can be overcome. This combined approach strengthened the validity of the results and made it possible to formulate more robust recommendations, both from a theoretical and practical perspective.

3.3 Data Collection

Data collection was carried out through semi-structured interviews, chosen for their flexibility and ability to generate in-depth qualitative insights into complex and underexplored topics, such as the remanufacturing of spare parts in the automotive sector. Interviewees were selected using purposive sampling, taking into account their direct experience and professional position within the automotive aftermarket supply chain. The selection of participants followed a criterion of relevance and role diversification, including remanufacturers, consortium operators, distributors, and professionals involved in logistics and spare parts marketing. All interviewees had a direct connection to the sector under investigation and operational knowledge of the related issues. The selection of the interview partners was made from pre-existing personal contacts. The acquaintance with the professionals involved fostered a climate of trust and informality which facilitated an open dialogue,

and encouraged the emergence of authentic and detailed accounts. The interviews were conducted online via video call to overcome logistical barriers related to the geographic dispersion of the participants. Each session lasted between 20 and 50 minutes. The semi-structured format enabled the use of a common interview guide to maintain consistency across conversations, while also allowing for the in-depth exploration of specific aspects as they emerged, according to the profile and expertise of the interviewee. All interviews were recorded with the consent of the interview partners and subsequently transcribed in full to enable a rigorous thematic analysis of the content.

3.4 Interview Protocol

To ensure consistent and comparable data collection, a semi-structured interview protocol was developed to guide the conversation along a shared thematic pathway, while maintaining a degree of flexibility. The interview was structured into sections reflecting the key areas of interest in the research, including: the perception of remanufactured parts on the Italian market; customer understanding of differences compared to new parts; the role of regulations and certifications; logistics and core supply chain management; environmental and economic benefits of remanufacturing; operational challenges; and future prospects in relation to the electric transition. The questions were drafted to be clear and encourage open and reflective responses. While adhering to a common outline, the interviews allowed for spontaneous elaboration, so as to adapt the conversation to the specific competencies and experience of each interviewee. The protocol also included exploratory questions on innovative aspects of remanufacturing, such as the use of digital technologies and the potential technical upgrading of components during the remanufacturing process. This approach enabled the collection of rich, contextualized qualitative data, capable of capturing the complexity of the remanufacturing practice from multiple professional perspectives, and thus contributed to the construction of a nuanced and multi-faceted view.

INTERVIEWEE'S ROLE	INTERVIEW DURATION	COMPANY SECTOR
CEO & FOUNDER	30 MINUTES	SPARE PARTS REMANUFACTURING
CEO & FOUNDER	40 MINUTES	SPARE PARTS REMANUFACTURING
CONSORTIUM DIRECTOR	35 MINUTES	CONSORTIUM OF SPARE PARTS DISTRIBUTORS
DIRECTOR SERVICE E AFTERSALES	50 MINUTES	AUTOMOBILE SALES
SOLE ADMINISTRATOR	35 MINUTES	AUTOMOTIVE PUBLISHER
JOURNALIST	30 MINUTES	AUTOMOTIVE PUBLISHER
SALES AGENT	45 MINUTES	SPARE PARTS SALES

The table summarizes the interviewees' profiles, offering a diverse overview of the automotive and remanufactured parts sector.

4. Findings

In this chapter, the main findings emerging from the analysis of interviews conducted with professionals in the automotive remanufacturing sector are presented. Through the thematic analysis approach, a series of recurring sub-themes were identified, offering a detailed insight into the perceptions, operational challenges, cultural dynamics, and prospects of remanufacturing. Each section of the chapter is dedicated to one of these sub-themes, illustrating how the collected experiences and opinions contribute to addressing the research question and outlining the challenges and opportunities for the broader adoption of remanufacturing in the Italian context.

4.1 The perception of remanufactured parts: a cultural and communicative barrier to the spread of remanufacturing

One of the main barriers to the spread of remanufacturing identified in the interviews is the still highly ambivalent perception of remanufactured parts, both among industry professionals and end consumers. In the past, remanufactured parts, often referred to as "refurbished", were viewed almost exclusively as a cost-saving alternative. Today, although a significant evolution is underway, this shift struggles to gain ground among consumers. Initially, remanufacturing was widespread primarily for high-turnover mechanical components (such as alternators, starters, and steering racks), which were offered as low-cost alternatives, often at the expense of perceived quality. The market has historically shown a preference for new, even if non-original, parts, considered more reliable than remanufactured components and competitive given the small price difference. However, the widespread integration of electronics in vehicles has transformed this scenario. Remanufacturing now requires highly specialized technical skills. This has led to a significant qualitative improvement in the sector, marked by the emergence of highly professionalized firms operating according to rigorous and standardized procedures. The added value of remanufactured components now lies not only in economic convenience but in the ability to restore the full functionality of a complex part, with reliability levels comparable to, and sometimes exceeding, those of new products.

"Unfortunately, there is still a lot of confusion between refurbished and remanufactured. The first simply means making the product work again, while the second involves identifying and resolving the root cause of the failure to prevent it from recurring."

Despite this progress, the perception of remanufactured remains fragile, fragmented and often distorted. The interviews highlight a profound terminological confusion that still hinders market understanding: terms such as *remanufactured*, *reconditioned* and *second-hand* are frequently

misused, compromising the possibility of clearly communicating the technical and industrial value of remanufacturing. The main objections raised by consumers relate to perceived quality: “Is it second-hand?”, “How long will it work?”, “What if it breaks again?”. In common parlance, there is still a widespread belief that a remanufactured component is simply a repaired item or, worse, an item salvaged from waste. This misconception fuels a sort of “cultural distrust” towards remanufactured parts that limits their adoption. In fact, a remanufactured component satisfies the same technical specifications of a new product, confirmed by rigorous testing and checks that guarantee reliability, safety and durability. A broad and coordinated cultural effort is therefore needed to explain more clearly what is really meant by *industrial remanufacturing*. To this end trade associations can play an important role, promoting greater awareness throughout the supply chain, helping to build a common language and spread a more mature, transparent and sustainability-oriented technical culture. Lacking terminological clarity is compounded by the want of coordinated communication. In Italy the supply chain has no common information strategy to educate end consumers and train repairers on how to explain remanufactured products. Dissemination initiatives remain too isolated and are often left to individual actors, such as specialized publishers or dedicated TV programmes, without broader institutional or regulatory support. The absence of a common language and clear regulatory references continues to marginalize remanufacturing on the aftermarket, often confining it to specific product categories or cases when new parts are unavailable.

The Bosch case study offers a compelling example of how an effective communication strategy can help reshape public perception. In its campaign, remanufactured components are portrayed amidst nature, accompanied by the slogan “Take part in protecting the environment”. The initiative is a clear and strategic attempt to bridge the gap between the actual value of remanufactured products and their public image. As confirmed in the interviews, communication plays a decisive role not only in informing customers, but in reshaping the collective understanding of remanufacturing by emphasizing the connected aspects of environmental sustainability, technical quality, and industrial reliability.

Figure 10: Bosch Exchange Advertising Campaign

The perception of remanufactured parts constitutes a major constraint on the development of remanufacturing in Italy. Although advanced technical competencies and highly qualified enterprises exist, they are not yet adequately supported by a regulatory, cultural, and communicative system capable of sustaining and leading the transformation.

4.2 New and remanufactured spare parts: a difference still poorly understood

Another central aspect that emerged from the interviews is the persistent difficulty on market to grasp the real differences between new and remanufactured parts. This misunderstanding on the part of both end consumers and some professionals, is one of the main barriers to a widespread adoption of remanufacturing. A number of interviewees noted that the only difference perceived by most drivers is still primarily related to price. Remanufactured parts, when considered at all, are seen solely as a cheaper alternative to new ones, with little to no appreciation for their technical, environmental, or functional value.

This narrow view reduces remanufactured components to a mere "cost-saving choice," overlooking the fact that, when processed according to professional standards, these parts can achieve performance levels equal to or even better than new components. In fact, remanufacturing is not limited to restoring functionality; it can also serve as an opportunity to improve the component by addressing the original design flaws that caused its failure. This is particularly evident in cases where all wear-prone elements are replaced while the structural components unaffected by time are retained, thereby reducing the use of new resources without compromising reliability. If properly communicated, the quality of such interventions can inspire trust even in end customers. For this to occur, however, consumers have to be guided through a process of understanding. interview partners say: *"Customers understand the value of a remanufactured part when clearly told what is behind it: the traceability of the process, the tests, the certifications, the warranty. Without effective communication, remanufacturing is perceived as a second-rate option."*

The difference between a new and a remanufactured part is not immediately visible; it requires explanation of what happens "behind the scenes," including all technical steps involved in remanufacturing—from diagnosis to replacement, testing, and certification. In the absence of such communication, remanufactured parts continue to be viewed as inferior or as "fallback options," rather than as qualitatively valid and sustainable alternatives. As a matter of fact, automakers have long relied on remanufactured parts, offering officially refurbished product lines, often with the same warranties as new ones. Similarly in high-risk sectors such as aerospace the use of remanufactured components is standard practice provided that the process is traceable and certified. This reinforces the notion that the value of a component is not determined by its "newness," but by the rigor of the process through which it has been remanufactured.

"It's a practice that is not only efficient but entirely consistent with what happens in other technologically advanced sectors. Even automakers offer remanufactured parts, and in the aviation

world, the use of second-hand or remanufactured components is commonly accepted, as long as they are certified. So, if we fly safely with them in the sky, why shouldn't we use them in cars?"

It is clear that younger and more expert operators, who are more familiar with digital technologies, are more open to remanufactured parts than less informed drivers and garage owners who do not actively promote them. Without clear, shared, and technically grounded communication, remanufactured parts will remain appreciated only by a niche audience, and will fail to be established as a true systemic alternative. From a technical and functional perspective, the difference between a new and a remanufactured part is increasingly negligible, provided that the remanufacturing process follows rigorous and traceable standards. Today, the real gap lies in perception, driven by a lack of communication, entrenched cultural stereotypes, and a generally opaque market offering. Bridging this gap means not only educating consumers but also holding supply chain operators accountable, so that they become true advocates for a qualified and sustainable reuse culture. One of the clearest proposals that emerged from the interviews is the introduction of a standardized visual communication system that clearly identifies the remanufacturing process as certified, traceable, and professional. A label, QR code, or dedicated packaging that are easily identifiable by the average consumer could play a decisive role in restoring the dignity and perceived value of remanufactured parts. Without a strong and unified signal, the entire sector risks remaining trapped in a self-referential technical narrative, unable to translate its strengths into widespread trust and collective awareness.

4.3 The role of communication in promoting remanufactured products

As previously mentioned, communication remains a significant barrier to the widespread adoption of remanufactured spare parts. Despite being supported by solid technical foundations, remanufacturing is still a poorly understood and underappreciated domain, often hindered by fragmented, unstructured communication that rarely aims to raise awareness. The absence of a clear, coherent, and shared narrative across the supply chain prevents both consumers and many industry operators from fully grasping the value of this solution.

The interviews highlight that effective communication depends very much on to the credibility of its sources. Industry-specific publications, for instance, have long played a vital role in delivering up-to-date, verified information to professionals. The timeliness and reliability of this content are considered essential for companies to make sound strategic decisions, anticipate trends, and respond proactively to market changes. Articles, investigations, technical features, and special issues on remanufacturing serve as valuable sources of information guiding the choices of manufacturers, distributors, and garages. One of the key challenges that communication must tackle more assertively is the perceived quality of remanufactured products:

When choosing spare parts, remanufactured goods are often seen as the third option, after original and equivalent parts. Ultimately, it still comes down to product quality and price. The latter remains the main factor for about 70% of customers. In case of an accident, if the driver is at fault, they'll install any reliable part that costs the least. If they're not at fault, they'll choose the original part (i.e. the more expensive one), since the insurance company is paying.

In a market in which the main concern is the reliability of the spare part, especially when it comes to safety-critical components such as the steering or braking system, it is essential to associate the quality of the product not only with the technical process but also with the brand of the remanufacturer. Well-known and market-recognised names, such as Brembo, are perceived as a guarantee of reliability, also in the field of remanufacturing. This shows the relevance of corporate reputation in supporting trust in the remanufactured product: quality and the manufacturer's name give a significant impulse to overcome mistrust, especially in contexts where safety is a decisive factor. Uncertainty is not limited to end consumers. Several testimonies revealed that even among repairers, there is often a lack of operational convenience. The core return process tends to be more bureaucratically cumbersome than simply discarding a part as waste. In the absence of a streamlined supply chain and concrete economic incentives, such as recycling bonuses or more advantageous pricing policies, remanufacturing remains unattractive. The same holds true for dismantlers, who may

find it more profitable to sell cores as raw materials rather than invest time and resources in disassembling and reintegrating them into the remanufacturing loop.

Another issue stems from the disconnect in communication priorities across different levels of the supply chain. While multinational corporations often highlight the environmental benefits of remanufacturing, for many small businesses and end users, these remain abstract topics with limited relevance in daily purchasing decisions. According to many operators, the real decision-making factors are reliability, price, and ease of management, particularly with regard to the core return process, which is still perceived as too bureaucratic and costly. A further problem lies in the lack of commercial transparency. According to some interviewees, many car repairers continue to offer spare parts using the list price of new, even when aftermarket or remanufactured parts are involved. At most, a marginal discount is applied, such as 10%, which can only rise to 30% if the spare part is labelled as “second-hand”. This behaviour contributes to further confusing consumers, who are left sailing among the entries of a simplified and often erroneous classification of spare parts with just three categories: original, competitive and second-hand. The consequence is a general loss of confidence and a reduced propensity to make an informed purchase. It is essential to strengthen awareness and education efforts targeting both professionals and the general public. Some stakeholders, particularly publishers and event organizers, have already taken significant steps: reportages, informational articles, round tables, and conferences focused on remanufacturing. These are valuable tools for promoting broader awareness. However, such actions remain too isolated and lack coordination at the national level. To truly enhance the value of remanufactured parts, it is not enough to improve their technical performance. What is needed is a strong, unified communication strategy based on transparency, certified quality, and tangible sustainability capable of reaching the entire supply chain, all the way to the end consumer.

4.4 Without cores, no remanufacturing: the strategic value of reverse logistics

To initiate remanufacturing activities, it is essential to have cores to work on. In most cases, finding cores is the first obstacle that must be overcome.

"Remanufacturing, above all, means having a base to work on. We call it the core."

Unlike traditional logistics, which manages the distribution of finished products to the consumer, reverse logistics handles the return flow of used or defective components, known as *cores*, from customers to collection, evaluation, and remanufacturing centres. This process is far from straightforward: the main challenge lies in establishing a stable and reliable supply network for used parts, which is necessary to ensure the economic and operational sustainability of remanufacturing: *"The most complicated task is sourcing the parts to be remanufactured: it's not easy to create a supply basin, as the awareness not to scrap potentially reusable parts is still lacking, especially among garages."* This lack of awareness among garages and dealers often leads to automatic scrapping of parts that could otherwise be remanufactured. In many cases, used parts are discarded as waste rather than being reintroduced into the industrial circuit. Some manufacturers try to patch this gap by introducing incentive mechanisms, such as requiring the return of a faulty component when purchasing a new one otherwise imposing a significant surcharge. This model works well for complex and expensive units like engines and gearboxes but is still rarely applied for lower-value components. A well-structured reverse logistics system must include component traceability, an efficient network for collection and transportation, inspection procedures to identify which items are truly suitable for remanufacturing, and a digital management system to monitor their condition. Investing in this segment not only improves the efficiency of the circular production process but also provides an opportunity to create value from goods that would otherwise be treated as waste. In this respect, reverse logistics is as a strategic lever for a true transition to the circular economy in the automotive sector.

According to the interviewees, some of the most adopted solutions include partnerships with national and international carriers, selected on the base of the customer's location to ensure timely collection. In some cases, companies build their own internal logistics networks to better control and speed up operations. Another model, especially common among large enterprises, involves completely outsourcing returns management to specialized service providers. These providers handle the collection and processing of cores independently, streamlining the entire process for repairers.

An example of the latter method is *Bosch eXchange*, a remanufacturing programme offered by Bosch that relies on a highly specialized system to solve core sourcing challenges. Bosch works with CoremanNet (Core Management Network), a global logistics network operating in over

20 countries that manages used components through an integrated system. CoremanNet goes beyond simple collection: it takes care of classification, traceability, and technical evaluation of cores, offering a concrete solution to the lack of efficient reverse logistics.

The platform was developed in the early 2000s by Motorservice, with the aim of simplifying return management and streamlining the remanufacturing process. Officially launched in 2003, CoremanNet enables digital registration of returns, including component codes and pictures, and tracks their entire journey. In Europe, the service includes 12 strategically located collection centres, from which components are shipped to the central warehouse in Göttingen, Germany, for initial inspection. This system ensures transparency, speed, and efficiency across the entire supply chain.

The return process includes several stages:

- Back in Box: the customer returns the core in the packaging of the remanufactured part, following CoremanNet's instructions. The component must be complete and in acceptable condition for evaluation.
- Collection and Evaluation: the returned part is analysed at the Göttingen centre, assigned a CBN (Core Before New) code, and assessed for remanufacturing suitability.
- Credit: if the core meets requirements, the customer is credited the agreed sum and a detailed return report.

This advanced system is a best practice in reverse logistics for the automotive sector, combining operational efficiency with sustainability. The approach adopted by Bosch helps to engage the entire supply chain, ensuring a continuous and controlled flow of components and effectively applying the principles of the circular economy.

4.5 Regulatory vacuum: the absence of legislation on remanufacturing

The regulatory framework governing remanufactured spare parts in the automotive sector at both national and EU level currently appears fragmented and insufficient. In Italy, a comprehensive and dedicated set of regulations is entirely lacking. One example mentioned by an interviewee is the Block Exemption Regulation (BER), also known as the "Monti Law," which governs the use of equivalent parts for warranty repairs. However, it makes no reference to remanufactured components. This regulatory gap generates uncertainty, leaving sector operators without clear legal guidelines and forcing them to operate in a context of subjective interpretations and often burdensome bureaucratic constraints. The challenges are not restricted to the national level. At the European level, remanufacturing has yet to receive the regulatory attention it deserves, although related topics are beginning to emerge in the political debate. Currently, there is discussion on reforming the rules governing the end-of-life treatment of vehicles, aiming at a more sustainable management of the over six million vehicles decommissioned in Europe each year. Among the proposals are the requirement to design vehicles for easier disassembly and reuse of components, and the mandate to include a minimum percentage of recycled plastic in new vehicles. However, many of these ideas are seen as impractical by industry insiders, mainly due to the absence of clear and applicable criteria for defining which components may be recovered and resold. Some European countries have adopted more concrete and structured measures. A notable example is France, where it is mandatory to offer customers a remanufactured alternative in all repair quotations when available. This measure has helped increase awareness among both consumers and professionals, promoting a stronger culture of remanufacturing. In Italy, instead, the absence of structured legislation slows down the growth of the branch and limits its potential.

4.6 No standards, but not without rigor: the regulatory challenge of remanufacturing

Another significant gap in the current regulatory framework is the absence of uniform quality standards, which forces companies to find independent solutions. Automotive components must comply with strict and certified quality requirements so nothing can be left to chance: "*We are dealing with critical components for driving safety; we cannot allow inefficient parts on the road".*

Many companies refer to ISO 9001 to ensure traceability, transparency, and compliance with production processes. However, this standard provides only a general management framework and does not address the technical specificities of the remanufacturing process, which would instead require dedicated regulatory criteria and certified methodologies. To address this gap, some companies have developed independent and innovative solutions. One practical response has been the adoption of a three-phase remanufacturing process: an initial selection of cores to exclude parts unsuitable for processing, reworking according to consolidated technical protocols, and rigorous final quality checks on the remanufactured component. In the absence of adequate testing equipment available on the market, one of the companies interviewed reported designing and building in-house high-precision testing instruments to verify efficiency and safety before reintroducing components onto the market. This approach reflects the high level of specialization achieved by certain industrial players and underscores their need to fill the regulatory void with internal rigor. Another response to the lack of shared standards is the strengthening of customer relations through comprehensive technical service. Some companies operating in B2B offer continuous assistance that spans the pre-sale phase, including diagnosis of the failure and spare part selection, to post-sale support, guaranteeing 12 months of commercial coverage and technical assistance in case of malfunctioning. These measures build customer trust, partially compensating for the lack of formal institutional recognition of remanufactured product quality.

In the absence of official standards, companies are relying on voluntary initiatives, structured internal processes, and self-developed engineering solutions. This approach not only protects the end user but also represents a first step toward the future definition of common criteria and specific certifications needed for the full recognition of remanufacturing as a reliable, transparent, and sustainable industrial process.

4.7 Distribution channels for remanufactured parts: opportunities and access barriers

A considerable challenge highlighted in the interviews is the positioning of remanufactured parts on the market. These components are predominantly distributed through independent channels, mainly aftermarket distributors not affiliated with original equipment manufacturers. This segment is currently the primary commercial outlet for remanufacturers, thanks to its greater flexibility and

openness to alternative products that match original parts in quality and functionality. Several independent distributors actively promote remanufactured parts, considering them equivalent in performance to new ones and, in many cases, more cost-effective.

However, achieving a stable presence within sales networks and becoming fully integrated into the commercial strategies of large distributors remains complex. Access to official catalogues of major industry players is often hindered by economic and relational barriers. Listing a remanufactured product line requires significant investment in marketing, sales force training, and technical support. These are resources that not all manufacturers can provide independently. Another obstacle is the difficulty for small and medium-sized remanufacturing businesses to build a direct sales network capable of ensuring widespread market coverage and close contact with end customers. Creating a dedicated commercial team would entail high costs, often unsustainable for companies in a sector still marked by narrow margins. One alternative, as mentioned in several interviews, is the formation of strategic partnerships with local distributors or consortia, which could serve as an effective pathway to increase the market penetration of remanufactured products.

4.8 Industrial remanufacturing: between sustainable opportunities and market challenges

Unlike rebuilt components, which require new production from virgin raw materials, remanufactured parts begin with an existing base, the core, on which inspection, replacement of worn elements, and functional testing are performed. This enables substantial resource savings, avoiding the costs and environmental impact associated with material extraction, industrial transformation, and new production. Industry studies have shown that the remanufacturing process can reduce CO_2 emissions by up to 90% compared to manufacturing a new component. The economic advantages are also clear: remanufactured parts typically cost about 50% less than their new equivalents, allowing customers to spend less without compromising performance. Additionally, reusing cores reduces the amount of waste and disposal sites, promoting a responsible end-of-life vehicle management approach. Many materials found in end-of-life vehicles such as steel, aluminium, plastic, and precious metals from catalytic converters can be recovered, reused, and reintegrated into the production cycle, thereby contributing to a truly circular economy. Beyond environmental and economic benefits, industrial remanufacturing also positively impacts human capital and technical expertise. The process requires advanced skills in mechanics, electronics, and diagnostics. These skills are often undervalued or at risk of disappearing. Remanufacturing helps preserve and pass on this know-how throughout the supply chain, generating a valuable knowledge spillover that supports the industrial continuity of the sector. In this sense, remanufacturing is not only a sustainable option but also a means of

enhancing Italy's specialized technical competencies. Additional strategic and financial advantages of remanufacturing emerge when considering ESG. In an era where Environmental, Social, and Governance criteria are increasingly influencing the evaluation of enterprises, remanufacturing contributes to improved brand reputation and compliance with environmental objectives. Companies adopting sustainable practices gain easier access to credit, benefit from better financial ratings, and enjoy lower debt servicing costs. Operationally, a more readily available stock of parts helps reduce vehicle downtime, streamline customer service, and lower support-related expenses such as replacement car provisioning.

Nonetheless, challenges remain. The primary obstacle is market unpredictability, which does not always favour sustainable products. Price, perceived quality, and the commercial strength of traditional channels still significantly shape sales dynamics. Irregular core availability, lack of regulatory standards, and distribution complexities all make the spread of remanufacturing difficult. Despite these barriers, its if environmental, economic, technical, and cultural potential remains vast. The task now is to support these benefits with appropriate policies and a deep cultural shift in both the market and consumers.

4.9 The future of remanufacturing in the era of electric mobility

The reflections emerging from the interviews portray a complex and somewhat contradictory picture of the future of spare parts remanufacturing. On the one hand, the transition to electric vehicles is perceived by some as a potential threat, expected to drastically reduce the range of traditionally remanufacturable components, such as gearboxes, pistons, turbochargers, and injectors. On the other hand, it is recognized as a unique opportunity to redefine the technical and strategic scope of remanufacturing. The future of remanufacturing, therefore, is not in question in terms of relevance, but in terms of direction: what is changing is not the necessity to remanufacture, but rather the nature of what is being remanufactured and the skills required. Electric vehicles, although devoid of internal combustion engines, contain an increasing number of advanced electronic components such as control units, inverters, sensors, electric motors, and onboard modules. Their remanufacturing will require a profound conversion of current skills and infrastructures. Batteries, in particular, emerge as a central element: they are the most expensive, delicate, technically vital and geopolitically critical component. The materials needed for battery production, such as lithium, cobalt, and rare earth elements, are sourced from politically unstable regions, and their refinement imposes a very high environmental cost. In this context, battery remanufacturing is not just a sustainable option, but a strategic priority capable of reducing dependence on imports, lowering costs, and mitigating the environmental impact of electric mobility. Currently, the infrastructure needed to support battery remanufacturing is largely insufficient. Facilities capable of effectively working on batteries are still rare and are often mistaken

for disposal plants. The difference is substantial: the former replace defective or degraded modules and rebalance the system to restore efficiency; the latter dismantle the battery to recover raw materials, resulting in a significant loss of industrial value. Establishing a structured network of specialized remanufacturing centres is thus one of the most urgent and complex challenges to address. Beyond technical aspects, broader considerations also emerged. Some operators expressed scepticism about the actual achievement of sustainability goals in the short to medium term, viewing the electric transition more as an aspiration than an actual process, particularly in Italy, where implementation lags behind other European countries. Remanufacturing also plays a crucial role in terms of industrial resilience: it offers a concrete solution for maintaining operational continuity and economic accessibility during an uncertain and fragmented transition phase.

Many interviewees noted that the role of institutions is still marked by ambiguity and a lack of clarity. A portion of the sector is concerned about the possibility that change will be driven solely by top-down regulations such as mandatory electric vehicle targets rather than actual market demand. The fear is that political decisions may undermine the economic sustainability of remanufacturing if not supported by a coherent industrial vision. Instead, a shared strategy between the public and private sectors is needed, one that can enhance existing know-how and support companies in transitioning toward new forms of remanufacturing through targeted incentives, technical training, and infrastructure investment. Despite uncertainties, a strong common awareness emerges: the ability to remanufacture will provide a competitive advantage, now more than ever. Those who succeed in evolving, acquiring new competencies, developing certified processes, and gaining market trust will be the key players in a sector destined not only to survive but to play a pivotal role in the circular economy of the future automotive industry. For this scenario to materialise, technical, regulatory, and cultural gaps must be addressed, which are now slowing down the transition to remanufacturing. Remanufacturing holds all the potential to be a concrete and strategic industrial response to change, but it requires an ecosystem that recognizes it, supports it, and helps it evolve.

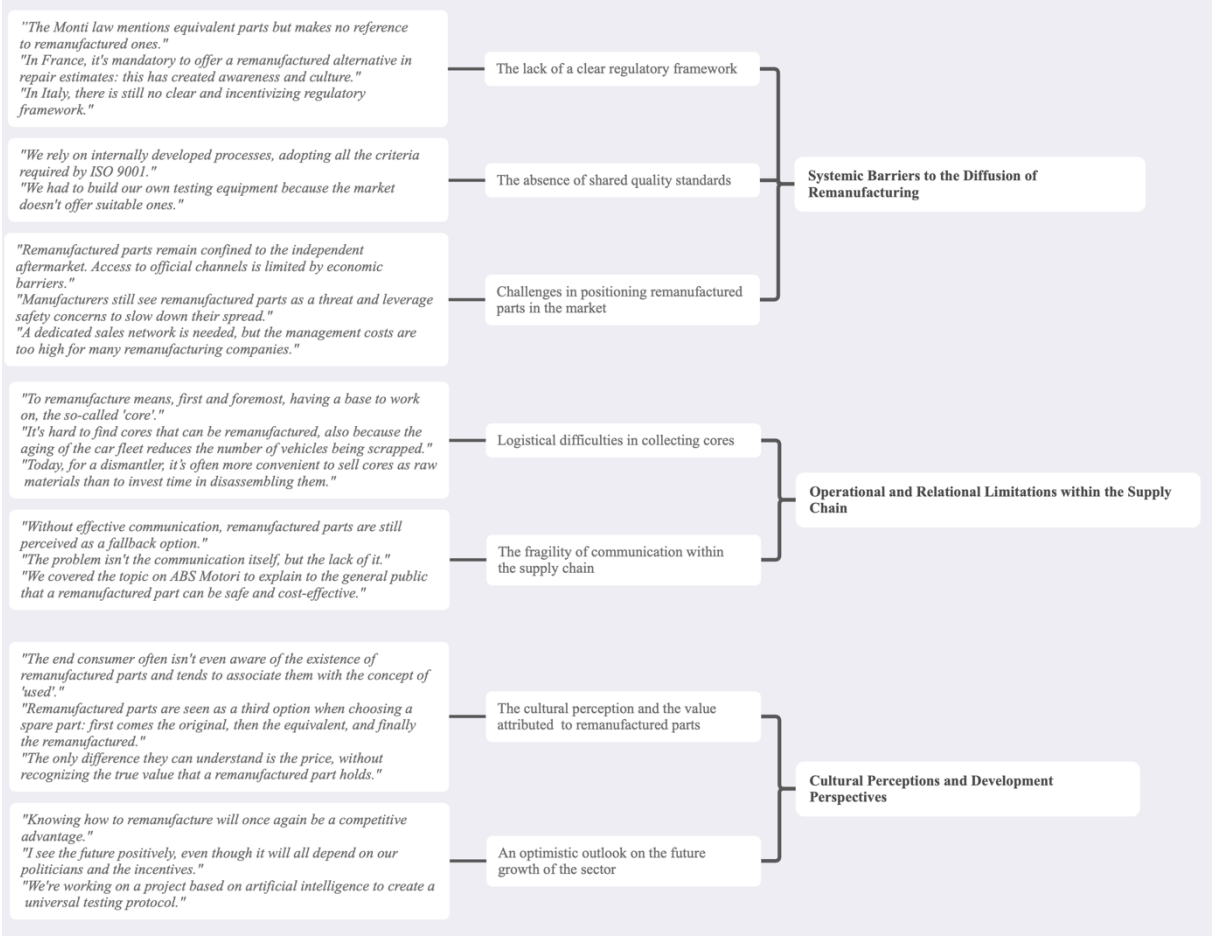

Figure 11 presents the Gioia Table, which synthesizes the key thematic clusters derived from the interviews, emphasizing the main barriers and opportunities associated with remanufacturing in the automotive sector.

5. Discussion and Conclusion

This analysis was set out to study the internal dynamics of the spare parts remanufacturing sector highlighting major difficulties and opportunities especially in the Italian context. Through a qualitative methodology based on interviews administered to key figures in the sector it was possible to obtain a series of significant results. First, the strategic value of remanufacturing as a driver of sustainability and competitiveness of the entire sector emerged. As stated by several interviewees, not only does remanufacturing allow a significant reduction of waste generation and the environmental impact of the production cycle, but it also provides a concrete opportunity for economic valorisation of components otherwise destined for disposal. On the aftermarket, where the main logic is that of disposable goods, the possibility to give new life to a product provides a sustainable and affordable alternative without sacrificing quality. One of the main obstacles that emerged from the interviews concerns the still highly ambivalent perception of remanufactured parts by both operators and end consumers. Confusion between the terms “used,” “reconditioned” and “remanufactured” fuels a cultural distrust that limits the widespread adoption of remanufacturing. A clear and shared narrative shift is needed to educate the consumer and empower the supply chain. Alongside this potential, strong structural deficits emerge that limit the success of remanufactured parts. The lack of clear and uniform regulations at the EU and national levels is a major brake. The absence of a unique definition of “remanufactured spare part” creates confusion among operators but especially among end consumers, who followingly tend to choose new spare parts. These deficits go to the detriment of remanufacturing companies because they shake confidence in remanufactured products. This is compounded by poor support to the industry in form of dedicated incentives, information campaigns and recognition of remanufacturing from a circular economy perspective. The legislative vacuum results in operational uncertainty for companies in the sector. The absence of common standards forces companies to independently define their own quality protocols, sometimes relying on generic standards such as ISO 9001. To make up for this, some companies have developed in-house testing tools and advanced after-sales services, testifying to the high level of specialization they have achieved. From an industrial perspective, many respondents stressed the importance of investment in technological innovation and training of human resources. The quality of the remanufacturing process depends on the availability of appropriate equipment, traceability of materials, and the specialization of the operators involved. Regeneration cannot be improvised: it is a process that requires rigorous standards, quality control and advanced technical skills. The dissemination of best practices and sharing of know-how is crucial to the success of the industry. A critical factor is reverse logistics: the difficulty in sourcing cores is the first practical obstacle to

remanufacturing. Some companies have introduced incentivized return mechanisms or rely on specialized platforms to ensure effective recovery. Without organized and digitized systems, many potentially remanufacturable components end up being prematurely scrapped. One of the most discussed topics is the perception of consumers, who still show a certain mistrust towards remanufactured parts, which are often wrongly associated with second-rate or low-quality products. This impression is mainly caused by a lack of correct information and ineffective communication by operators. There is a clear need for a cultural change through targeted information campaigns and the promotion of certification of regenerative processes to ensure transparency, safety and reliability of products. A proposal to bridge this gap was to introduce forms of standardised visual communication, for example labels or QR codes, to certify remanufacturing processes. An effective, transparent and coordinated communication strategy could improve trust and make remanufactured products more competitive. Particularly revealing were the data that emerged on environmental aspects. As could be expected, remanufacturing enables a drastic reduction in waste and emissions associated with the production of spare parts from scratch. International studies cited in this work estimate that the remanufacturing of a single component can reduce its carbon footprint by up to 80% compared to the production of a new component. This is particularly significant if one considers that this benefit is combined with a lower consumption of critical raw materials, the supply of which is increasingly expensive and geopolitically sensitive. Many interviewees noted an increased interest of garages and distributors in remanufactured products, especially in a period marked by high inflation and an increasing focus on value for money on the part of motorists. In terms of price, remanufactured parts are up to 50% cheaper than new ones, without compromising on quality, provided they are remanufactured according to strict technical standards. Furthermore, remanufacturing improves the rating of companies on the ESG and reputational front, opening up concrete financial opportunities. The role of distribution should not be underestimated: remanufactured parts are widespread in independent channels, but struggle to enter the official circuits due to economic and logistical barriers. From this perspective, strategic partnerships and local consortia could encourage development.

Remanufacturing cannot be tackled in isolation by individual companies but needs a joint commitment of all actors in the sector using networks, consortia, integrated supply chains. The role of institutions is crucial: a comparison between the Italian and French models shows how targeted regulatory policies and the obligation to offer regenerated products in quotations can accelerate the cultural and industrial transition. This work highlights how the sector is in a phase of profound transformation, which other than problematic is rather to be seen as a concrete opportunity for the development of new potential. The remanufacturing of automotive parts is confirmed as a strategic area for the ecological transition and economic efficiency, but it needs a more favourable regulatory,

cultural and industrial context. In the age of electric mobility, it will be able to take on an even more central role, provided it keeps pace with evolutions and gets ready to remanufacture control units, inverters and above all batteries. This will require the adoption of more complex processes, the training of new skills and the construction of dedicated plants. The challenge is also geopolitical: the best to master the necessary rearrangement will become the protagonists of the circular mobility of the future. Only in this way will it be possible to fully appreciate the work of the many Italian companies that are already implementing a new concept of circular mobility with vision and competence.

5.1 Reflections on the future of remanufacturing in the automotive sector

The data and implementation examples cited in this work show the great potential of remanufacturing in the automotive sector. Remanufacturing is not simply a way of saving resources and lowering costs but is emerging as a real game changer in terms of design, production, usage and disposal of car components. The idea of a future in which the "design for remanufacturing" is the norm, meaning that products will be conceived to be disassembled, remanufactured and reintroduced onto the market, is spreading in the world of industry and will bring about a real revolution. In this scenario, the adoption of a modular design logic, which facilitates the replacement and reuse of individual components, will be a key element in ensuring the efficiency of remanufacturing processes. The product will no longer be conceived as a single unit destined for scrapping at the end of its life, but as a modular system, easily upgradable over time, with tangible benefits in terms of sustainability and longevity. If this were to materialise, there would be major consequences for the entire industry: supply chains, industrial processes, but above all, the business models of companies would change. The way these companies operate would change radically: they would no longer limit themselves to selling new components and managing service until the end of their life cycle but would instead have to start thinking in terms products with multiple life cycles, considering remanufacturing as a part of the value chain. This evolution would also entail a rethinking of business performance metrics, no longer only sales volumes would be evaluated, but also the ability to extend product life, reduce life cycle costs and optimise resources. Remanufacturing could thus contribute to the creation of new success indicators related to circularity, resilience and environmental responsibility. The automotive sector is increasingly moving towards remanufacturing. The necessary conditions for the development of remanufacturing already exist, but cultural barriers severely limit its spread. If these could be overcome, remanufactured parts could become the norm and no longer a second or third choice. A crucial step will be the creation of collaborative supply chains, efficiently connecting

manufacturers, remanufacturers, distributors and garages. Cooperation between these actors will foster data exchange, component traceability and the adoption of common standards, creating a mature and interconnected ecosystem. To ensure this, consortia already exist whose function is to coordinate, support and develop companies in the sector. Remanufacturing can become a key lever not only for environmental protection, but also for the competitiveness of companies. In today's global context, where raw materials are becoming more and more expensive and scarce, and where consumers are increasingly aware of sustainability, offering high-quality remanufactured products is certainly a real advantage. It is no coincidence that many leading companies are already investing in it, some OEMs are starting to develop in-house remanufacturing programmes or collaborate with specialised partners to include reman products in their official offers, as stated in the previous chapter. This change is also stimulated by external factors such as increasing regulatory pressure on environmental issues, the push towards low-emission production models and the increasing role of ESG criteria in company evaluations. It is easy to see how remanufacturing is no longer just an opportunity, but a concrete response to new compliance and reputation requirements. It is clear that there is still a long way to go, and there are many challenges to be met: from standardising processes, to overcoming regulatory barriers, to the need to spread a different culture, both among industry players and end customers. The ideas gathered during my work indicate that something is changing. The interviews conducted, the practices observed, the experiences shared, show a sector ready to make a quantum leap. Remanufacturing is no longer seen as a "fallback" alternative, but as a concrete and modern option, capable of responding to the needs of a changing world.

The future of remanufacturing in the automotive sector will depend on how companies, but above all consumers, will be able to cope with this phase of change. A joint effort will be required in which institutions create an appropriate regulatory framework; companies invest with courage and vision; distribution and service networks equip themselves to manage the flow of remanufacturable components, and consumers are put in a position to make informed choices. The world of professional training will also play a fundamental role, and it will be necessary to update technical and professional curricula to include specific skills on remanufacturing, from electronics to diagnostics, including sustainability and life cycle analysis. Only in this way will it be possible to form a new generation of professionals capable of strengthening and innovating the sector. If the above conditions are met, in my opinion remanufacturing can become more than an important part of the automotive sector, in fact one of its most solid pillars, and perhaps inspire other manufacturing sectors grappling with similar environmental, technological and economic challenges.

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