Master's Thesis Internship – master Sustainable Business and Innovation

Setting up a repair industry

A study into key lessons to be learned from the success of the automotive repair industry

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Abstract

As the linear economy causes a variety of problems, the Dutch government has set a goal to reach a circular economy by 2050. One of the strategies of reaching a circular economy is extending product lifetime through repair. However, little is known in literature about repair. To add to the base of knowledge regarding repair, the Dutch automotive repair industry, which has been identified by the PBL (2019) as a major circular activity, is studied. The required data was obtained using desk research and interviews. The findings were embedded in the circular economy using the resource loops and R-strategies. Main lessons from the development of the automotive repair industry are that the car manufacturer Ford tried to serve the lower end car market by lowering the price of a car, but found a repair and service infrastructure was needed as well. To this end he made the design of the car repairable, set up a school for mechanics and wrote repair manuals. In 2002 repair information and spare parts were made publicly available in the automotive industry. Upcoming trends can be observed in new business models, including lease, a struggle for in-vehicle data and electric cars. From the development of the automotive repair industry three guidelines for other sectors to develop a repair industry have been formulated in accordance with literature; the product has to be repairable, there needs to be and interest, either by the customer or the manufacturer to prolong the product lifetime, and free competition over the repair and service of a product after it has been sold are required.

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1. Introduction

Debate about the future economic paradigm has been increasing for several decades (Bonviu, 2014). The linear economy model, using a 'take, make, dispose' principle, has been predominant since the rise of the industrial revolution (MacArthur, 2013). Due to the uneven regional distribution of wealth, the industrialised countries have had an abundance of resources and energy, while labour was more scarce. This made the abundant use of resources a viable business model (Sariatly, 2017). With growing demand through the extreme increase in world population and wealth however, resource extraction tripled from 1970 to 2010 (Schandl et al, 2018). The once abundance of resources is turning towards depletion (Sariatly, 2017). These depletions have caused many, highly diverse natural resource crises over the past decades (Rees, 2017). As well as a depletion of resources, four of the nine planetary boundaries have already been crossed (Steffen et al, 2015). Both problems can be considered market failure caused by a linear socioeconomic system (Michelini et al, 2017). To reach a long-term solution and avoid future crises, the socioeconomic system must change from linear to circular (Geissdoerfer et al, 2017).

1.1 The circular economy

The circular economy moves beyond the profit ideology of the linear model and instead proposes an ideology based on societal benefit (MacArthur et al, 2016). To uphold this, the circular economy has three guiding principles (Geissdoerfer et al, 2017; Bocken et al, 2016). First of all, as the name suggests, the economic circles are closed, going from a take, make, waste economy to an economy where the waste becomes the resource for the cycle to start again. As a result, a fully circular economy has no waste and does not extract any resources from the environment. The second principle requires the resource to retain their initial value. If materials downgrade when they are used again, a circular economy will be impossible since a resource can only be used a few times before it must be discarded. If a resource retains its original value however, it can remain in the cycle indefinitely. The last principle requires the use of renewable energy sources in all activity in the cycle so no limited resources are used in the process.

1.2 Reaching circularity

The Dutch government has set a goal to use 50% less primary resources by 2050 and aspires to gain a full circular economy (EZ & IenM, 2016). As a circular economy is preferred over a linear economy (MacArthur, 2013), it is desirable to know the drivers and barriers for reaching a circular economy. Research into the circular economy is still in an early phase and should be brought into the academic world (Elia et al, 2017; Stahel, 2016). One of the strategies for reaching a circular economy is to slow the resource loop by extending product lifetime (Bocken et al, 2016). One of these strategies for extending product lifetime is to repair products (Potting et al, 2017). However, very little is known in literature regarding repair, so an exploratory research into one of the major repair industries adds to the knowledge base about one of the circular economy strategies (PBL, 2019).

1.3 The automotive repair industry

The case study chosen for this thesis is presented in a stocktaking by the PBL of Dutch circular activities; the automotive industry (PBL, 2019). One of the calls for action of this report is to research and learn from common and long-time circular activities, in particular from the 20.000 car repair shops currently present in the Netherlands (PBL, 2019). Needless to say the automotive industry has its fair share of challenges ahead when it comes to sustainability, but the large automotive repair sector is one of the major circular economy activities in the Netherlands (PBL, 2019). Not only are there many car repair shops, parts are often re-used, and second hand cars are commonly accepted with about four times as many second hand cars sold than new bought vehicles (PBL, 2019; CBS, 2020). Repair and

maintenance are largely intertwined in the automotive industry, so from now on the term repair is used to cover both repair and maintenance, unless maintenance is specifically mentioned or the term repair logically only refers to a repair. The research question is formed as follows;

What lessons can be learned from the processes that have led to the success of the automotive repair and maintenance industry?

1.4 Outlook

This thesis first presents the theoretical background needed to answer the research question. In the methodology it is discussed how the data is gathered and analysed. Next, the development of the automotive industry is described, after which the main lessons to its success are distilled from it and the broader context in the circular economy is discussed. These lessons are combined with the literature about repair to set up guidelines for other sectors to get a repair sector using the smartphone industry as an example. Finally, the limitations of the thesis are discussed, a call for future research is given and the paper is concluded.

2. Theory

In this chapter the relevant theoretical background is given. First, the circular economy and several circular economy strategies are discussed. Second, strategies to improve a repair sector are discussed.

2.1 Circular economy

The circular economy aims to minimise waste and resource input (Geissdoerfer et al, 2017). Strategies for attaining a circular economy are discussed in section 2.2. The circular economy changes the economic logic by encouraging sufficiency instead of production (Stahel, 2016). It relies more on labour to repair or recycle products and resources, rather than the natural resource use driven linear economy (Stehel, 2016). The intended goal of the circular economy is to gain environmental sustainability while also creating economic growth (Kirchherr et al, 2017; Korhonen et al, 2018). Herein lies a large portion of the promise of the circular economy, as it has the ability to attract the attention of companies to sustainability, using the potential of large economic benefits (Korhonen et al, 2018).

The circular economy adopts a narrower scope than the concept of sustainability, making it more suitable for implementation by the private sector, but other aspects of sustainability and the behaviour of actors might be overlooked (Geissdoerfer et al, 2017). Research into the circular economy focusses more on environmental performance than on all three dimensions of sustainability (Geissdoerfer et al, 2017). For instance, the social wellbeing is mostly comprised to the creation of jobs (Frey and Stutzer, 2010). The circular economy can however cause social insecurity as jobs or job requirements may change or disappear and companies might go bankrupt (Malhotra and Van Alstyne, 2014).

2.2 Circular economy strategies

In this section the resource loops, and strategies for slowing the resource loops are discussed. In addition the R-strategies are discussed. These strategies are used to analyse how the automotive repair industry performs in the circular economy, rather than as a phenomenon of its own.

2.2.1 Resource loops

Bocken et al (2016) describe three options to turn a linear resource flow into a circular resource loop. The first option is to slow the resource flow, extending product lifetime. The second option is closing the resource flow, eliminating waste by using the waste as a new resource. The third option is narrowing the resource flow, reducing resource use both associated with the product and in

production. An overview is given in figure 1. Bocken et al (2016) name the car as a classic example of design for slowing the resource loop as it is designed for durability, maintenance, and repairability. Figure 2 shows an overview of design strategies to slow the resource loop, as Bocken et al (2016) have presented.

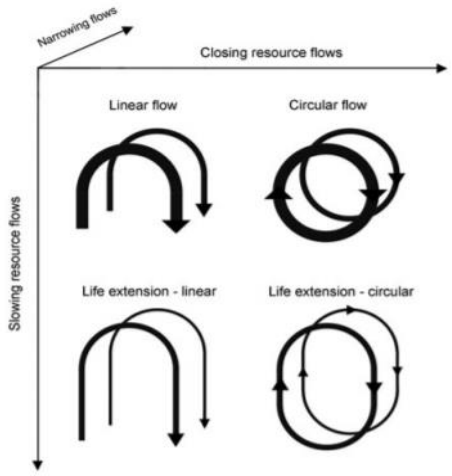


Figure 1: Resource loops (Bocken et al, 2016).

Design strategies to slow loops

Designing long-life products
- Design for attachment and trust
- Design for reliability and durability

Design for product-life extension
- Design for ease of maintenance and repair
- Design for upgradability and adaptability
- Design for standardization and compatibility
- Design for dis- and reassembly

Figure 2: Design strategies to slow the resource loop (Bocken et al, 2016).

2.2.2 R-strategies

Several strategies for reaching a circular economy have been described in literature (PBL, 2019). These strategies attain different levels of circularity and are arranged from most to least circular. Since all strategies attribute to a more circular economy, it is desirable to both attain a larger volume of circular activities and to implement higher ranking circular activities. The PBL (2019) drafted a framework for the R-strategies created from several frameworks found in literature. The framework used by the PBL (2019) is shortly explained below.

R1; Refuse and Rethink
Refuse means consuming less, for example stop eating meat. *Rethink* entails the more intensive use of products or allocating multiple uses to them, for example a Combined Heat Power (CHP) plant.

R2; Reduce
The concept of *reducing* includes both more efficient ways of manufacturing as well as using the product. An example of a more efficient production is electrolyte aluminium ore instead of heating it, while a more efficient use is for example a more fuel-efficient car.

R3; Reuse
Reuse means extending product lifetimes by giving them a new owner, for example second hand shops.

R4; Repair and revision
The lifetime of a product can be extended by *repairing* it once it breaks down, for example a car may be repaired in a garage. *Revision* entails the reuse of still functional parts in a new product, for example using the bricks of a demolished house to build a new house.

R5; Recycle
Recycling is the process of gathering and reusing resources from disposal, for example plastics that get melted down and form the resources for new plastic products.

R6; Recover
The final strategy is the *recovery* of energy from products through incineration or fertilisation.

R1 and R2 are production phase strategies, and require smarter product use and manufacturing aiming to narrow the resource loop. R3 and R4 are use phase strategies that aim to extend the lifetime of products and parts, thereby slowing the resource loop. R5 and R6 are end phase strategies with the goal of regaining as much as possible from discarded products trying to close the resource loop. As stated in the introduction, this thesis targets R4; Repair.

2.3 Repair strategies

MacArthur (2016a) has recommended three ways to empower repair strategies: create a repairable design, make repair information more available and make spare parts more available. These recommendations are used as a literary foundation for the guidelines for other sectors to build a repair industry, where the sectors are aspiring to learn from the development of the automotive repair industry.

Create a repairable design

To be able to conduct a repair, the design of the product should allow for an easy disassembly. This means the assembly should be reversible to the extent that components can be replaced. To this end screws should be used instead of, for example, glue. Especially components that have a limited operational time, such as batteries, should be easily accessible. In addition, components should not be integrated to make the replacement of individual components impossible.

Make repair information more available

Especially for more complex products, a manual or repair information is necessary to conduct a repair. This information should be easy to use and easy to find and could come in the form of a written text or a video. Forums, where users can share their experiences or comment on the repair manuals can help and can be monitored by an online service expert from the manufacturer.

Make spare parts and accessories more available

To repair a product, spare parts are necessary. The manufacturer should make the spare parts available for every interested buyer at a reasonable price. It is important that the responsibility of making the spare parts available lies with the manufacturer, as they have the capacity and resources to produce the spare parts or acquire them from their suppliers. The manufacturers should make the spare parts available for as long as a can be expected of a reasonable product lifetime. So even after the manufacturer has stopped making the product or the particular edition of the product, the spare part required to fix it should be made available.

2.4 Scientific contribution

Research into the concept of circular economy has remained superficial (Korhonen et al, 2018). Sahel (2016) argues more research is needed to convince governments and businesses that the circular economy or a circular business model is feasible. Through analysing the automotive repair industry, this thesis adds to the knowledge base about the circular economy by studying one of the largest and most embedded circular activities in the Netherlands according to the PBL (2019). In addition, the lessons drawn from the development of the automotive repair industry aim to provide a pathway for other sectors to attain a repair industry.

3. Methodology

This study was conducted through qualitative research. The Dutch automotive industry has been identified by the PBL (2019) as an interesting topic to study as it has a remarkably high number of 20.000 repair shops. A single, in depth case study was performed to determine what has led to the

success of the automotive repair industry, where many other repair industries have remained underdeveloped. The automotive industry is also a well-developed industry with a fully developed production and service market. The regulatory system regarding the automotive industry (self-driving cars excluded) is highly developed as well, providing many possible reasons for the success of the circular activities to investigate. For example laws regarding emissions of certain gasses, safety, and the regulatory service checks (APK). Chapter **Fout! Verwijzingsbron niet gevonden. Fout! Verwijzingsbron niet gevonden.** details the methods used to acquire the data used in this study. Chapter **Fout! Verwijzingsbron niet gevonden. Fout! Verwijzingsbron niet gevonden.** discusses how these data were processed.

3.1 Data collection

Data was gathered in two consecutive steps. The first step was desk research, that was followed by an analysis. The second step was to validate the results of this analysis through conducting interviews, so that the gained knowledge could be used to adjust the analysis.

Within the desk research two sources of information were explored. The first was literature written about the automotive industry, as well as about the more general aspects of the sector's system - for example rules and regulation, a life cycle analysis and price. Events or circumstances that forced the industry to change and generic drivers and barriers for circular activities were researched in literature as well. These papers were found by searching Google Scholar. The search terms that were used are; 'automobile repair industry', 'circular economy car repair', 'service industry innovation', 'circular economy strategy; extending product lifetime', 'circular economy strategy use phase' and 'LCA car'. However, not all search terms brought useful results. Search terms that did not yield useful results are; 'car repair', 'car repair shop', 'car repair businesses'.

The second source of information was news articles were collected through LexisNexis, an application that gathers news articles. The search term 'garage' the Dutch word for car repair shop, did not yield useful results as the results could not be narrowed down to the intended domain of Dutch car repair without using the word 'reparatie', which generated a selection of the results found with the search term 'auto reparatie'. Several other search settings and search terms yielded no usable results. However, with the search term 'auto reparatie' the Dutch word for car repair, and a branch restriction 'automotive services' the results were found. With duplicate stories turned off, a total of 218 newspaper articles were found, though not all articles were relevant.

After analysing the articles and drawing preliminary conclusions a total of 6 interviews have been conducted with experts of the automotive aftermarket, averaging 40 minutes of recorded interview. An overview of the interviewed organisations is given in table 1. The interviews were semi-structured using the analytical questions as guidelines. This format was chosen to provide structure to the topics that need to be discussed, but did give the interviewee freedom to talk about what they wanted to talk about, and freedom in the manner of expression (Drever, 1995). The interview guide was set up when the desk research step was nearly completed to allow the researcher to ask specific questions that could verify the results found in the desk research.

Interview number	Type of organisation	Interviewee position in the organisation
1	Bank	Sector manager mobility
2	Automotive branch organisation	Sector manager aftermarket
3	Automotive aftermarket magazine	Chief editor

4	Automotive aftermarket branch organisation	Head of press
5	Car importer	Manager lease and business aftersales
6	Automotive recycling organisation	Two business developers

Table 1: Overview of the interviews.

3.2 Data analysis

The interviews were recorded and transcribed. After the transcription they were processed through coding. The coding was conducted with the qualitative data analysing software "NVivo" in which the data was broken into components, line by line. The components were labelled, capturing the essence of the phrase or story used. A few examples are;

'*The success of the automotive repair industry comes from trying to make the aftermarket competitive'.*

'*If the producers of consumer electronics were to make their products repairable and provide the spare parts, an enormous repair sector will arise straight away*'

'*Cars get repaired because of their long technical and economic write-off time*'

The information gained in the interviews was used to verify and supplement the findings from the desk research. Both the desk research and the interviews were used to reconstruct the development of the automotive repair industry. The following chapter discusses the most important processes in the development of the automotive repair industry. Key actors were identified, then the results were embedded in the broader circular economy concept using the R-strategies and resource loops. From the results guidelines were drawn up for other sectors to get an effective repair industry. These guidelines were then tested on the smartphone industry.

4. The development of the automotive repair industry

In this chapter the main changes in the automotive industry are discussed that led to the wide adoption of maintenance activities. First, the start of the automotive industry in the USA is described as the European market at the time was distorted by World War 1 and the political unrest that followed, disturbing the free market function. Second, the competition in the Dutch automotive aftermarket after World War 2 is discussed as the scope of this thesis is the Dutch automotive repair industry. Third, the current situation of the Dutch automotive repair industry is described. It concludes with the currently observed trends that could shape the future of the automotive repair industry.

4.1 The start of mass production

When commercial sales of the automobile started in the USA around 1900, it was a product only the wealthy could afford, mostly used for sports or parading, not transport (Geels, 2005). Manufacturers and mechanics thus focussed on increasing performance instead of lowering cost of production or maintenance (McIntyre, 2000; Geels, 2005). This changed when Henry Ford began his famous mass production of the model T car, more than halving its price between 1909 and 1916, making the car available to a much larger market (Williams et al, 1992). At that time, cars needed frequent adjustments and repairs. The cost of these services was however exorbitantly high with very low quality because cars were far from modular and lacked replacement parts (Flink, 1970). Additionally, mechanics took this lack of standardisation and customer awareness to exploit their customers,

charging high prices or charging for repairs never conducted. Furthermore, the service sector had not been expanded as fast as the sales had, forming a gap in service supply (McIntyre, 2000).

Creating a repair sector
In 1913 Ford officials feared the market share they aimed to serve by lowering the price of a car would still not be achievable due to the highly expensive and poor quality service (McIntyre, 2000). The intended new customer group thus forced Ford to set up a repair and maintenance system. Regarding this topic, it was stated in interview 3 (2020):

"*Cars get repaired because of their long technical and economic write-off time.*"

To increase their customer base by improving repairs, from 1913 onwards Ford undertook action on several fronts according to McIntyre (2000). The repairs were standardised both in procedure and time needed for the repair. The design of the car was made more modular and spare parts were produced in the factories. Ford also set up a school for mechanics and urged the dealers to create a division of labour as well as use specialised tools (Thompson, 1954). A quote from interview 3 (2020) supports design as a major factor which formed the automotive repair sector:

"*To remain successful in the repair industry several things are required. First and foremost repairability; the car needs to be repairable."*

While most of the larger dealers accepted the changes and provided decent services, not all the dealers cooperated. As the majority of dealers was very small, most changes were resisted as service still was only a minor part of their revenue so they neither had the capability and resources, nor the economic benefits for standardizing repairs or creating a division of labour (McIntyre, 2000). Even though Ford executives were horrified by the practices of small independent car repair shops, the small shops flourished as they provided acceptable repairs for acceptable prices. The small shops profited from the repairable design and availability of spare parts enough to get acceptable repairs for car owners (McIntyre, 2000). So even though Ford's strategy of increasing the quality of all repair shops did not turn out as planned, the lack of a service system was successfully removed as a major bottleneck for the burgeoning of the car. The diffusion of the car and the expansion of the automotive service sector continued up to Second World War (McIntyre, 2000).

4.2 A competitive Dutch automotive aftermarket

Moving on to the Netherlands after the Second World War, in chapter **Fout! Verwijzingsbron niet gevonden. Fout! Verwijzingsbron niet gevonden.** the situation of anti-competitiveness is described. In chapter **Fout! Verwijzingsbron niet gevonden. Fout! Verwijzingsbron niet gevonden.** measures taken to mitigate the danger of cars are discussed. In chapter **Fout! Verwijzingsbron niet gevonden. Fout! Verwijzingsbron niet gevonden.** the reasons to introduce competition is discussed, as well as an explanation how competition is stimulated, while in chapter **Fout! Verwijzingsbron niet gevonden. Fout! Verwijzingsbron niet gevonden.** the effects of the competition are shown. In chapter 4.2.5 End-of-life phase regulations for car wrecks are discussed.

4.2.1 Overcoming anti-competitive regulations

After the Second World War an agreement was made by European countries to limit competition in order to stimulate the European economy, depleted by the Second World War (De Plecker, 2012). For the automotive sector these limitations included areas of operations for dealers, in which dealers were controlled by a single manufacturer with very limited competition between them called 'exclusive distribution' (De Plecker, 2012). This meant brand dealers could only sell one brand, could only sell in a restricted area and could only repair and maintain their own brand. Independent repair shops were allowed to conduct business and could purchase spare parts from manufacturers and brand dealers,

but had to pay extreme prices, as the brand dealers held a monopoly on the parts, but competed with the independent repairs shops that required the parts from them (Van der Vegt, 2013).

Although the limited competition meant the manufacturers could ask higher prices, it also prevented them from increasing their market share. In 1963 BMW appealed to get an exemption on these limitations, which was approved in 1973 (De Plecker, 2012). BMW's reasoning was simple; they estimated that the potential profits they could attain through competition in areas currently assigned to other brands were greater than the profits they made from the limited competition in fewer regions (De Plecker, 2012). Shortly after, all European car manufacturers followed the example of BMW and appealed for an exception on the limitations. This makes sense as their market power was compromised by the exception BMW got. As the situation became legally unretainable in 1985 the first Block Exemption Regulation (BER) was passed for the whole automotive sector to get an exception on the limitation to competition (De Plecker, 2012). Notably, the BER is valid for about 10 years, after which it needs to be updated, which has happened ever since.

The BER allowed for both selective and exclusive distribution, allowing the dealer to choose between these two options (Faull & Nikpay, 2007). In case of exclusive distribution the BER provided some protection to the brand dealers as it was forbidden for manufacturers to make price agreements or to force the brand dealer to have a minimum price or maximum discount (De Plecker, 2012). This allowed brand exclusive dealers to compete with selective dealers. In return for these concessions, the manufacturers now had more options to expand their market share. Even though the original BER did not change the repair industry that much, a future update of the BER, discussed in section 4.2.4, did.

4.2.2 Car safety

At the same time another social issue became more prominent; the safety of cars. To improve car safety two policies have been implemented in the Netherlands: The Type Approval Regulation (TAR) and the APK. Though introduced in 1958, the TAR has been updated since and aims to increase vehicle safety and make trade easier (Pace, 2019). The TAR is a mandatory certification for the EU forcing manufacturers to deliver products that meet certain requirements (Pace, 2019). As the risks involved in car safety are high, their production has stricter requirements aiming to uphold a certain quality and have a regulated end-of-life phase (CBI, 2020). For example, cars have to be 95% recycled and should reduce hazardous substances released in the end-of-life stage of cars by prohibiting the use of amongst others lead, mercury and cadmium (ARN, 2017; CBI, 2020). The law to reduce waste from end-of-life cars was first introduced in 2000 and was made particularly to reduce hazardous waste leakage to the environment from wrecks (Eur-Lex, 2021). Secondly, in 1985 a mandatory regulatory service check (APK) was introduced in the Netherlands to improve vehicle safety (RAI, 2020a).

4.2.3 Consumer choice

To diminish safety risks from malfunctioning cars, the APK needs to be performed. Due to the high financial burden of a car on a household, the government does not want a monopoly to form on a mandatory service (Interview 2, 2020; Interview 3, 2020). So the government decided that all repair shops should be able to perform these APK's and conduct necessary repairs. As a result of this drive for safety, the APK has legally forced the maintenance sector to grow. As the mechanics in repair shops had the most experience in maintaining the car and were able to conduct a repair, if a part did not meet the standard of the APK, they took on the role of performing the APK. Repair shops do need to get a certificate from the government and mechanics performing the APK need to have completed an education to be allowed to perform the APK (Interview 4, 2020). The APK changed the repair industry as providing maintenance became increasingly important. To safely conduct the APK and make repairs, all repair shops must have access to the Repair and Maintenance Information (RMI) and have access to spare parts (EC, 2020).

4.2.4 The BER and TAR

In 2002 a European law passed which opened the market diminishing this monopoly and provided a more level playing field with the revision of the BER. Dealers could now sell more than one brand, the selling areas were dismantled and the aftermarket was more opened as spare parts had to be sold at standard prices and access to technical information was made easier and standardised (Jongsma, 2002; Buters, 2002). This law would partly come into effect in 2003 and partly in 2005 to give the current regime time to adapt. This update of the BER was more radical, caused more resistance and had perhaps a bigger impact on the sector than the introduction of the BER did in 1985 (De Jong, 2002). The BER of 2002 was introduced by European commissioner Mario Monti, at the time responsible for competition (Jongsma, 2002). The BER was introduced as consumers were harmed by the lack of competition as repair at a brand dealer was up to 50% more expensive than repair at an independent repair shop and cars were needlessly expensive due to the restriction in operating areas of brand dealers (Peeperkorn, 2000; Botman, 2001). A wide variety of stakeholders lobbied for a competitive aftermarket including: motoring consumers, the leasing and rental industry, test equipment and diagnostic tool manufacturers, parts wholesalers, data publishers as well as independent and authorised repairers (Lobbyfacts, 2020). As it was stated in Interview 2 (2020), competition was assured in the aftermarket:

"*The availability of spare parts and technical information has led to a successful automotive repair industry.*"

The current BER, regulation 461/2010, ensures the availability and a fair price of spare parts and equipment, access to technical information, and an obligatory continuation of the guarantee if the car is repaired or maintained at every repair shop, even if it is not connected to the dealers' network of the car manufacturer (Figiefa, 2010). This BER is valid until 2023 when a new BER will be put into effect (Figiefa, 2010). This update is necessary as for the last few years car manufacturers have been moving aggressively into the repair industry, trying to put independent repair shops out of business by restricting access to vehicle-generated data (Breitschwerdt et al, 2017). The new BER will most likely entail the problem of restricted access to vehicle-generated date as well as telematics (Interview 2, 2020; Interview 3, 2020). In short, the BER aims to remove any competition limiting factors in the automotive aftermarket, providing full market function in the automotive repair industry.

The TAR has two important clauses for the automotive repair industry; a certificate of conformity and the public availability of the Repair and Maintenance Information (RMI) which was introduced in 2007 (Interview 2, 2020). The certificate of conformity upholds the quality of the product to which it has been approved in the TAR and ensures a customer has the right to expect a certain performance for a certain amount of time for the product they bought (EUR-Lex, 2020). A well-known example of non-conformity is the Diesel gate scandal, where the car got a certain type approval, but did not meet the specs under which it was approved. A functioning RMI is required for the car to be approved, which is publicly released upon approval. The easy and clear access to the RMI is described by the European Commission as; 'key to guaranteeing free competition on the vehicle aftermarket' (EC, 2020).

4.2.5 End-of-life phase

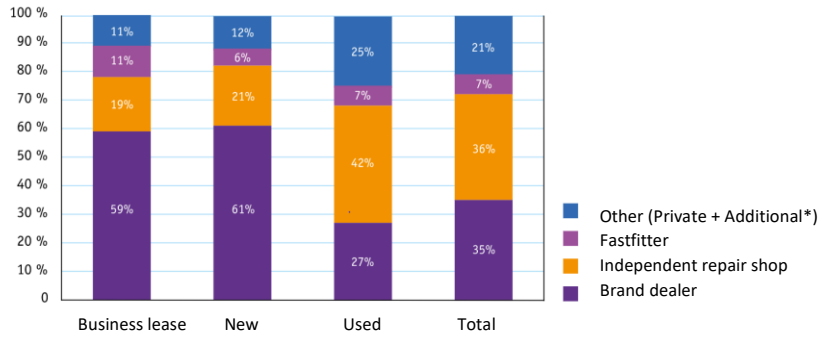
In the Netherlands Auto Recycling Nederland (ARN) works together with a majority of recycling companies, attaining a weight recycling rate of 98,5% while 95% is legally required (ARN, 2020). This legal requirement lies with the company selling the product. To help achieve this obligation, ARN registers the wrecks and the achieved recycling percentage (Interview 6, 2020). Auto Recycling Netherlands (ARN) was founded in 1995 by BOVAG (repair shops), RAI (import), Stiba (part revisioning) and FOCWA (damage repair), all major branch organisations from the automotive aftermarket (ARN, 2020). Of this 98.5% a large portion is revised, strengthening the repair industry through providing

cheaper spare parts (ARN, 2017). The revision of parts is preferred because of two reasons (Interview 6, 2020): The parts can be sold making it the economically preferable option, but the revised parts also count as fully recycled, making it easier to reach the required 95% (Interview 6, 2020). The full process of recycling is: First parts are revised, then the wreck is shredded, and finally ARN has developed the post shredder technology (PST) to help reach the set goals by recovering as much energy and materials as possible (ARN, 2017; ARN, 2020).

4.3 Consequences on the Dutch automotive sector

The automotive aftermarket has become a large sector, as in 2018 the total branch revenue for repair and maintenance was 3.7 billion Euro in the Netherlands (RAI, 2020). In addition there are close to 20.000 car repair shops according to the PBL (2019), so employment is generated as well. As a result of the BER, brand dealers have been struggling from 2009 onwards as they began to lose their monopolistic market power (Trommelen, 2010). Another consequence of the BER update is that independent repair shops no longer have to buy spare parts from brand dealers causing the latter a loss of revenue up to 30% (Van der Vegt, 2013). To fill the gap of providing spare parts to independent repair shops, part distributors, or part acquiring collaborations of independent repair shops, emerged (Van der Vegt, 2013). Even though brand dealers could still supply independent repair shops with spare parts, they have lost their monopolistic position over the spare parts and must now compete. As manufacturers produce only a portion of the parts themselves, the part distributors can, in compliance with the new BER, acquire the spare parts from part manufacturers, passing over the car manufacturers (Interview 3, 2020).

Independent repair shops profited at the cost of brand dealers. This shift in market power is mainly due to the update of the BER in 2002 and the financial crisis which left customers to postpone buying a new car (Thieleman, 2009). The reduction in car sales due to the financial crisis has forced dealers and independent repair shops to rely much more on repair and maintenance (Interview 2, 2020). The repair and maintenance market is slowly shrinking due to the technological advancements of cars (Interview 2, 2020). This situation left independent repair shops to do relatively well, while brand dealers continue to struggle. Independent car repair shops are important for increasing vehicle age as they repair older vehicles compared to brand dealers, as can be seen in figure 3 (BOVAGRAI, 2020). This is because independent repair shops have an interest in conducting repairs on a vehicle, whereas brand dealers have an interest in selling new cars (Interview 2, 2020). The independent car companies in general are considered cheaper and will be preferred if the guarantee on a new car has run out (ANWB, 2020).



* Under additional fall the categories: 'Car window repair shop', 'Car damage repair shop', 'Abroad', 'Roadside assistance', 'Additional', and 'I don't know'.

Figure 3; Passenger car type and type of repair shop (BOVAGRAI, 2020).

Brand dealers hardly earn anything from selling cars anymore. Instead they use the newly sold cars to attain a customer base for repair and maintenance in their shop where they do earn money from (Interview 2, 2020; Interview 4, 2020). As a result of this shift in the market, manufacturers now move aggressively into the aftermarket as they fear to loose an important part of their business (Breitschwerdt et al, 2017). Brand dealers earn most of their profit from repairs, car manufacturers urge their dealers to conduct repairs to uphold a reputation and earn money from the spare parts and part manufacturers have become dependent on supplying spare parts as well (Interview 2, 2020; Interview 3, 2020). The financial dependency of part manufacturers, car manufacturers and brand dealers shows that it has fully integrated into the automotive industry (Interview 3, 2020). Geels (2005) also identified the maintenance network as a key aspect of the automotive industry. This dependency on the repair sector was first observed in section 4.2 when Ford executives observed the need for a service industry to retain customers and has remained a driving presence.

The consumption pattern of the Dutch households has changed. While the spending on transportation, including cars, remained about the same between 2000 and 2019, the total expenditure of households increased over 60% (CBS, 2020b). Relatively, the expenditures on cars have thus fallen drastically. This change shows a shift in the social esteem of the car and might explain why cars are aging rapidly (Interview 1, 2020). As new cars have less social esteem, fewer new cars are bought, in turn stimulating the repair sector. In addition to the changing social esteem of a car, the leisure activities of the population have changed and shifted in value too (Interview 1, 2020). People used to repair their own cars and bikes, but nowadays they value their leisure time over the cost of a repair. In addition, cars are getting increasingly complex, making the repair of a car even more undesirable for the customer to do themselves. These changes have also contributed to the growth of the repair sector.

4.4 Upcoming trends in the automotive repair industry

As the car is a complex product, much skill and knowledge is required to conduct repairs, making larger repair shop chains more suitable to stay technologically up-to-date (Interview 4, 2020). An example of the increasing complexity is that the APK inspects defects on electronic systems, such as the starting motor, radio, lighting, or air conditioning, from 2010 onwards (Noordhollands Dagblad, 2007).

More than half of new cars in The Netherlands are now sold to lease companies (Interview 1, 2020). A lease company buys cars at a great discount from the manufacturers and rents them for a certain amount of time. After this rental period, often 3-5 years, the cars are sold as occasions (Interview 1, 2020; Interview 5, 2020). These occasions are often sold abroad as there is a mismatch between customer desires of new, often larger cars and subsidised electric vehicles (EV's), and the desires of the occasion market, which is mostly interested in smaller cars (Interview 3, 2020; Interview 5, 2020). This mismatch causes much export of EV's and import of gasoline cars. If the government intends to stimulate a cleaner car fleet, this issue will have to be addressed. Leasing companies also have contracts with repair shops, causing a less competitive aftermarket and a stronger lock-in (Interview 1, 2020).

The electric car has significantly fewer moving parts and is much more robust, requiring less maintenance (Interview 3, 2020; Interview 4, 2020). The electrification of the car fleet will reduce the working hours in repair shops and cause a shake out. The autonomous car has the potential to intensify the use of cars. If made fully autonomous, the repair sector will become almost fully a maintenance sector as very few accidents will occur (Interview 1, 2020).

Wall (2017) describes an increasing struggle between car manufacturers and other stakeholders into who owns the data generated by a car. The car manufacturers want to own all data and exclude others from using it to gain a competitive advantage and profit off the exclusive rights of that data, whether

aggregated or individual data about the car. Whereas car companies argue they are protecting their intellectual property rights, other stakeholders argue this is anti-competitive. The negotiations of the new BER are already ongoing and the availability of vehicle data and telematics will be one of the major points of debate, as the manufacturers want to take full and exclusive ownership of the data, creating an unfair advantage for their own dealer network (Interview 2, 2020; Interview 3, 2020). While the manufacturers argue that safety can not be assured if anyone can access the data, several lobby organisations and initiatives are active to ensure a competitive aftermarket including the Right to Repair Campaign and the Alliance for the Freedom of Car Repair (Lobbyfacts, 2020; DAPD, 2020).

Another upcoming trend is car sharing, either through Mobility as a Service (MaaS) or through sharing platforms. MaaS will shift the balance of the repair industry as MaaS companies will have contracts with repair companies instead of the customer picking out a repair shop of their choosing (Interview 1, 2020). If the manufacturers change their business model to provide a mobility service instead of selling a car, they will also internalise the repair industry (Interview 1, 2020). The car sharing companies will have a strong incentive to keep their vehicles operational for as long as possible. An example of the potential this holds is the scooter sharing service, Felix, which got parking permits for guaranteeing that their electric scooters would stay in service for at least fifteen years, providing a strong incentive to repair (Interview 2, 2020). Similar deals could become the future for cars, and would greatly increase the stimulant to maintain a longer product lifetime. An overview of the development of the automotive repair industry is given in figure 4.

Figure 4: Overview of the development of automotive repair industry.

4.5 Main actors

To give the reader an overview of the main actors in the automotive repair industry this section describes both the actors and their roles in contributing to the repair sector.

Manufacturer

The manufacturers have a dual role in the automotive repair industry. On one side the manufacturers, Ford in particular, have set up the repair sector as they rely on it to keep the car affordable. On the other side the manufacturers also try to exert pressure on the repair industry by withholding technical information, overpricing spare parts, and shielding in-vehicle data, trying to monopolise the repair and maintenance of the car.

Car owner/Customer

Through limited budget or by choice, the customer decides how much they are willing to spend on a car. At the start of the mass production the average customer could not afford a new car every time a part of the car broke down. To that extent the customers forced Ford to set up a repair industry. The current trend is that customers spend less on a car, more often opting for a repair rather than getting a new car. This has led to an increase in vehicle lifetime.

Public sentiment

The update of the BER resulted partially from the introduction of the APK. In turn, the APK was introduced as public sentiment no longer accepted the high number of fatalities in traffic accidents. Besides the introduction of the APK a wide variety of safety measures, including alterations to the design of the car, have been legally forced. A similar shift in public opinion toward the environment has led to subsidies for electric cars, thus stimulating their diffusion.

Independent repair shops

While large scale repairs have been set up by the manufacturer, the independent repairs shops made it competitive by providing acceptable repairs for acceptable prices. As opposed to manufacturers, independent repair shops have no incentive to let their customer buy a new product. Their incentive is to conduct as many repairs as possible and to retain customers by conducting successful and cheap repairs as well as keeping the product repairable for as long as possible.

Branch organisation

The BER was introduced and updated in 2002 partially due to lobby efforts. The branch organisations are still lobbying to maintain a competitive aftermarket, and without them it would be harder for policymakers to determine what could be a potential barrier to the free market function of the repair industry.

Government

It is the role of the government to write policy to create a level playing field and to enforce manufacturers to follow the regulations. Should a manufacturer overprice their spare parts, it is up to the government to rectify this limitation of free market function.

5. Analysis

In this chapter the automotive repair industry is viewed in the broader perspective of the circular economy. First the most important processes in the development of the automotive industry are described. Next, the circular results of the automotive repair industry are discussed, and finally, other R-strategies and the resource loops are examined.

5.1 Important processes

In this section the two main processes in the development of the automotive repair industry are discussed. The sections below include for both processes what they contain, what led to them, and what change they brought about.

5.1.1 Serving a new customer group

Given the expensiveness of the car, Fords wish to make the car available for the average American could not be achieved with simply halving the initial costs of the car. The costs and quality of service had to improve as well, because a broken car, even when bought for half the price it used to cost, was still too expensive for the average American. To set up a repair sector Ford undertook a great effort. The design of the car was made modular, a school for mechanics was set up and repair manuals were drafted for the repair shops. Even in the current day and age there is significant dependency of chain partners on the repair industry. This dependency even goes so far that brand dealers make most of their profit through conducting repairs and manufacturers generate much revenue through the sales of spare parts.

5.1.2 Competition and safety

To make cars safer the APK was introduced. However, a regulatory check without sufficient customer choice was problematic for such an expensive product. To attain consumer choice and have APK's of sufficient quality it was decided all repair shops should be able to conduct repairs and APK's with all materials and information they required. The repair of a complex product such as a car requires spare parts, technical information and diagnostic equipment were publicly available at a reasonable price, legally captured in the BER update of 2002. One of the key attributes that set the automotive industry apart from other industries is competition in the aftermarket (Interview 2, 2020; Interview 3, 2020). In other words; the automotive industry has free market function of sold products.

5.2 Circular result in the Netherlands

To analyse how the automotive repair industry affected the reduction in resource use, several statistics of cars use are discussed. First the number and age of cars in the Netherlands from 2000 to 2020 is depicted to determine whether product lifetime is indeed increasing. Then the general development of product lifetime in the Netherlands is compared to the product lifetime of the cars. Thirdly, to determine if it is still desirable to increase vehicle lifetime, even if more efficient cars are available, an LCA study is discussed. Finally the product use intensity is discussed.

Figure 5 depicts the number of passenger cars of a certain age class present on the Dutch roads from 2000 onwards, as presented by Statline (2020) . The total number of passenger cars increased from 6.340.000 in 2000 to 8.680.000 in 2020 in a relative linear fashion by 37%. The number of passenger cars younger than 1 year slowly declined from about 600.000 in 2000 to about 430.000 in 2020. While the downward trend is significant on its own with about a 30% decline, when compared to the total number of vehicles the relative decline is even higher; going from a share of 9.5% in 2000 to 5% in 2020 almost halving its share. This means that for the same functionality of cars only half the cars had to be produced because of the increase in vehicle age. According to Den Hollander et al (2017) increasing product lifespan is most effective in preserving resources.

Car fleet; Type, age class, January 1st.
Subject; Passenger cars.

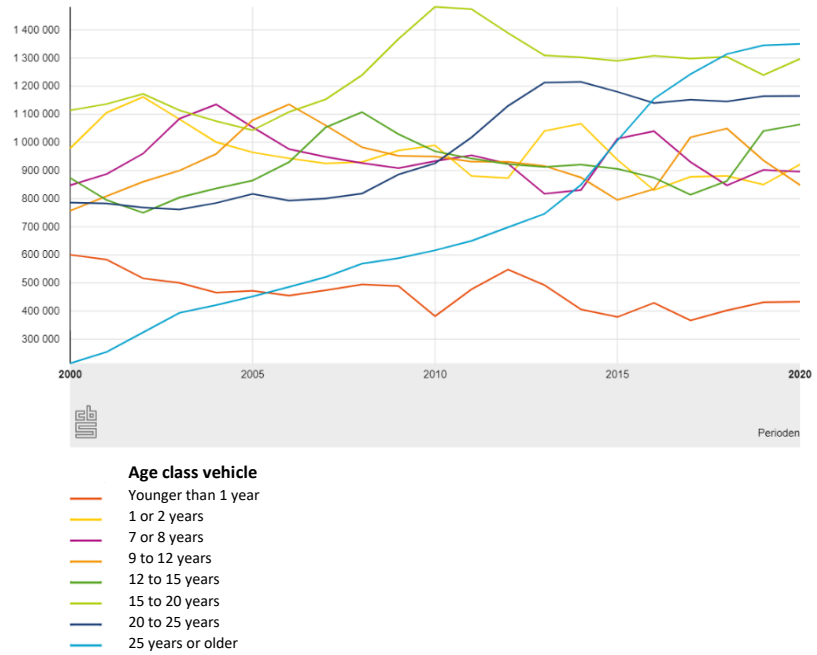


Figure 5; Number of passenger cars in a certain age group from 2000-2020 (StatLine, 2020).

Comparing the development of the age of passenger cars to other products allows to determine if the increase in vehicle age is a specific development of the automotive industry or simply a consequence of a general increase in product lifetime. Bakker et al (2014) concluded that from 2000 to 2005 the average product lifetime decreased for almost all products, sometimes be even more than 10% in the Netherlands. She found that despite improving efficiency the most beneficial strategy for reducing emissions would be a significant lifetime expansion. Similar studies for LED TV's, laptops, and mobile phones showed the same results. The decrease of the average product lifetime makes the drastic increase of vehicle age all the more significant.

Danilecki (2017) conducted an LCA about the car. In particular they compared the VW Golf mk5 and the VW Golf mk6. The new model consumed on average 0.4l/100 km less than its predecessor, resulting in a reduction of 133 KG CO2 each year according to their assumed data. However, as the car costs about 2800 kg CO2 equivalent, it takes about 21 years for the marginal abatement to surpass the production phase. The potential of reducing the weight of the car by 60 kg, reduced the pay-back period with 4 years to 17 years. See figure 6. Even though this improvement is hypothetical and considered a best practice, the pay-back period is still less than the European average lifetime of a car and about the average lifetime of a car in the Netherlands (CBS, 2017). With an increase in emissions during production relative to the emissions of the use phase, emission pay back periods for more efficient usage become even longer (Danilecki, 2017). It can thus be concluded that even as cars are getting more environmentally friendly, both in production and in use, an extension of their average lifetime is preferable as is concurred by the authors. The impact of the electric car is discussed in section 5.3.3.

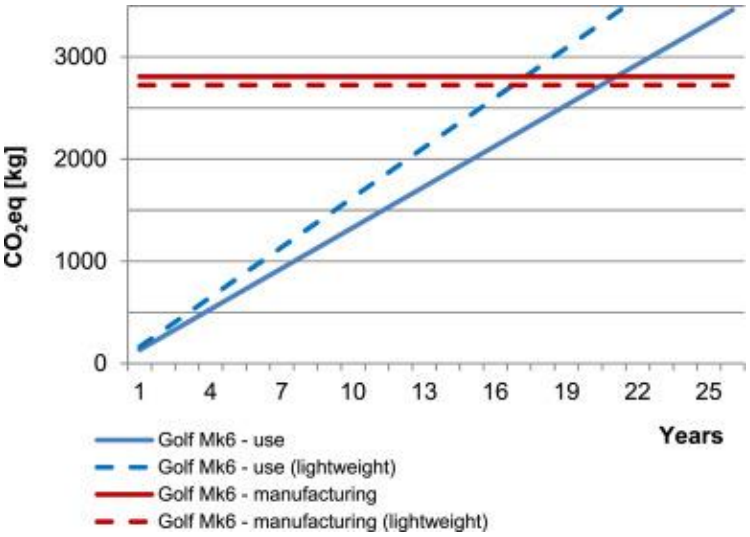


Figure 6; The pay-back period of abatement.

Between 2000 and 2020 the total kilometres driven increased by about 20%, while the average kilometre driven per car decreased by about 6% (CBS, 2020a). Younger vehicles are also used much more on average than older vehicles. Cars aged 0-5 years are used on average by 80% more than 15-20 year old cars, with the age groups 5-10 and 10-15 showing usage in between the other two groups. Cars older than 25 years are much less used; with less than 40% usage compared to cars aged 15-20 (CBS, 2020a). As the total of kilometres driven increases (CBS, 2020b), the explanation for the decrease in kilometres driven per car is not a reduction of vehicle use, but a decrease in product use intensity. This decrease in product use intensity is not desirable for attaining a circular economy as more vehicles are needed per kilometre travelled.

5.3 R-strategies

To broaden the perspective on the automotive sector, an overview of the other R-strategies in the automotive sector is given. Since the R-strategies do not operate in solitude, but influence the repair sector, it is important to provide the reader an insight into them as well.

5.3.1 Recycling and revision

The revision of parts strengthens the repair industry through providing cheaper spare parts (ARN, 2017). The availability of cheap spare parts might stimulate the second hand market as well, because maintenance will be cheaper as spare parts are cheaper through revision. Older vehicles can require older spare parts to match, for example the colour of paint changes over time. These older spare parts are hard to reproduce and can best be required through revision. It can thus be concluded that a strict required recycling rate stimulates the prolonging of vehicle lifetime besides the intended goals of simply recycling materials. The demand for parts helps set stricter recycling regulations as the recycling rate is much higher when parts are revised (Interview 6, 2020). There thus seems to be a positive reinforcing effect between these R-strategies. As the burden of reaching the required 95% recycling rate lies with the brand dealers and manufacturers, they rely on ARN to fulfil and document this requirement. Parts are however increasingly sealed together and fabrics mixed in a way they become non-recyclable (Interview 6, 2020). An example of this is the increasing difference in plastics used in a single component, making recycling difficult. If the car becomes too hard to recycle however, the manufacturers cannot attain the required 95% recycling rate, so they have a strong incentive to keep their design recyclable (Interview 6, 2020).

The high recycling rate of cars has several factors (Interview 6, 2020). The car is very large and consists largely of well recyclable steel. Another important factor lies with the tax a consumer has to pay for

owning the car until it is sold to a demolition company. This way the customer has a strong incentive to bring their unused product to a demolition point from where it can be recycled. This process also helps with keeping an orderly documentation of the product, which is very uncommon for consumer products. Finally the strict law of 95% weight recycling ensures the recycling potential is reached.

5.3.2 Reuse

Not only has the automotive industry become successful in recycling, revising and repair, the second hand market is extremely big as well with four times the amount of cars sold second hand than first hand each year, as can be seen in figure 7 (CBS, 2020). Cars often have a second or third life, stimulated by a well-functioning repair industry and increasingly by part-revision (Interview 3, 2020). As repairs become cheaper, a second hand car becomes more interesting to a customer because older vehicles need more repairs and a lower cost of repair lowers the maintenance costs especially of older vehicles. The argumentation goes the other way around as well in that the reselling of cars will require more repairs to be conducted. There is thus a positive reinforcing effect between reuse and repair and between repair and recycling through the revision of parts (Interview 5, 2020; Interview 6, 2020).

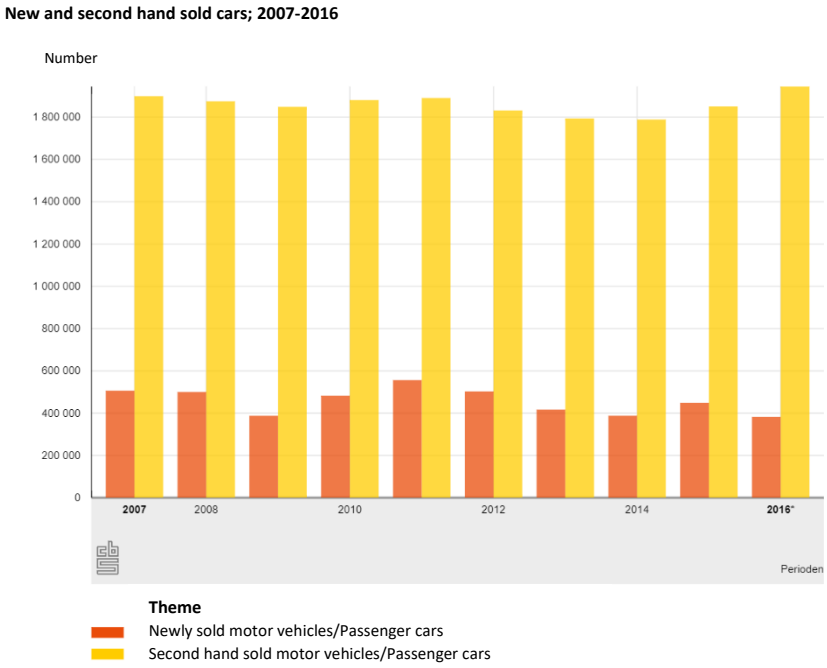


Figure 7; Number of passenger cars in a certain age group from 2000-2020 (StatLine, 2020).

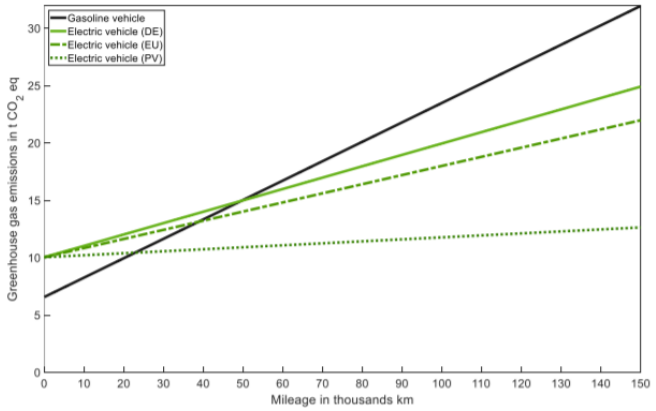
5.3.3 Reduce

There are three main options to reduce emission in the use phase; a more efficient conventional car, the electric car, or cleaner fuel (Interview 2, 2020). Manufacturers have a major interest in the first two as it allows them to sell more of their product, while a cleaner fuel allows the current car fleet to reduce emissions without a new product (Interview 2, 2020). Even though the efficiency is still low, it provides an alternative to the electric car which has environmental problems of its own for example with the battery. Additionally the electric car has significantly fewer moving parts requiring fewer maintenance and repairs (Interview 1, 2020; Interview 2, 2020; Interview 3, 2020). The electrification of the car fleet will reduce the working hours in repair shops and cause a shake out (Interview 1, 2020; Interview 2, 2020; Interview 3, 2020).

The past years, a large portion of the subsidised electric vehicles were sold abroad after the leasing contract of about four years, selling both the environmental gains and the granted subsidy to a foreign

nation (Interview 1, 2020; Interview 3, 2020; Interview 5, 2020). The average leasing contract lasts about 4 years, after which the subsidised electric vehicles enter the second hand market. However, without subsidy the electric vehicles are too expensive and are sold abroad (Interview 1, 2020; Interview 5, 2020). Given the fact that cars are driven 12.8 km/year on average in the Netherlands (CBS, 2020a), it takes over 120.000 kilometres or approximately 8 years for the new electric vehicle to pay back the carbon investment for the production of a new electric vehicle compared to driving an already manufactured gasoline car as can be seen in figure 8 (Regett et al, 2019). Additional regulation is thus required to gain a positive carbon payback period from subsidizing electric vehicles. The use of more efficient combustion engine vehicle has a carbon payback period of 17 years in the case of Danilecki (2017) as is described in 5.2.

Despite the current success in extending the product lifetime of cars, regulations aiming to extend product lifetime of vehicles are however still lacking. The TAR could, for example, further specify and require a long term design. Also subsidy for new cleaner vehicles such as EV's could be granted only if the vehicle remains in use for at least a certain amount of time, in the range of 15 or 20 years (Interview 2, 2020). Another option to increase the time a consumer uses the car could be found in a requirement of a minimum amount of years the consumer has to own the car when the consumer applies for a charging pole or parking space. The scooter sharing company Felix was able to get parking places in Amsterdam by promising a use of at least 15 years of their scooters, thus having an incentive to increase the time they use a scooter (Interview 2, 2020).



Climate impact of a gasoline and a battery electric compact-class vehicle as a function of mileage and charging electricity (DE: German electricity mix, EU: European electricity mix, PV: photovoltaics)

Figure 8: Carbon payback period for electric vehicles (Regett et al, 2019).

5.3.4 Rethink

The autonomous car has the potential to intensify the use of cars significantly as it holds the potential to become a public transportation means driving itself from one customer to the next. If made fully autonomous, the repair sector will become almost fully a maintenance sector as almost no accidents should occur (Interview 1, 2020). However, manufacturers are reluctant to produce an autonomous car as the issue of accountability has not yet been solved (Interview 3, 2020). As discussed in chapter 4.4, MaaS and car-sharing are upcoming trends. The intensification of car usage is good for the environment, but does cause a significant reduction in repair and maintenance work. As higher R-strategies are preferred, this is a positive trend.

5.4 Resource loops

Bocken et al (2016) attributes the successful slowing of the resource loop of the automotive industry to its high initial costs, leading to a change in design. While this might be true, the single motive of high initial costs seems incomplete. For example, it fails to explain why bikes are often repaired and mobile phones are not, even though the purchase price is similar. It also does not fully explain why a customer spends on average as much on repairs and maintenance as on buying a car (Interview 3, 2020), while for most other products this is not the case. MacArthur (2013) claims that the linear economy is the result of an unbalance between labour and capital caused by colonialism where capital, or resources, are cheap and labour is expensive. The loss of value of resources is a good explanation for the shortening of product lifetime of most products as found by Bakker et al (2014). The combination of the claims by Bocken et al (2016) and MacArthur (2013) might provide an explanation of the success of the car repair industry. The car is, compared to the labour of repairing it, very expensive in terms of capital which might explain the success of its repair industry. While, as the rest of this research shows, it is not the only factor attributing to its success, it could well be the underlying factor that drove the automotive sector to develop a successful repair industry while other industries did not. These conditions caused customers to force Ford into setting up an adequate repair industry, because buying a new car was simply too expensive and deterred customers from buying a car in the first place. In case of the car the ecological and economical product lifetimes are closer together than in most products. The relative high cost of capital can thus be seen as a driver that pushed towards the success of the automotive repair industry.

As explained in section 5.2 the resource loop of the automotive industry has slowed in the Netherlands. The resource loop has also been closed to a large extent as 98.5% of the weight of a car is recycled (Interview 6, 2020). The car is however an energy-consuming product. The electrification of the car fleet does help reduce the energy consumption in the use phase and narrow the resource loop (Regett et al, 2019). However, an electrification of the car fleet requires new cars, in turn accelerating the resource loop. Additionally, the recycling of the battery of an electric car is not yet optimal, making the resource loop more open (Interview 6, 2020). The different resource loop strategies thus seem to conflict in the automotive industry as is also indicated by Bocken et al (2016).

5.5 Overview of key factors

In this section an overview of the key factors for the success of the automotive repair industry is given. Chapter 4 concluded with an overview of the key processes in the development of the automotive repair industry. In this section not only processes but other factors such as product characteristics, for example, are included as well.

High product price

The car is and always has been a very expensive product. Due to the high price the majority of the customer base is not able to afford a new car every few years. The expensiveness of the car is unique as no other consumer good is in the same price range. To still serve a large customer base, the choice was made to increase the lifetime of the car by setting up a repair infrastructure and designing a repairable product. This allowed the manufacturers to increase their customer base, while providing customers with the affordable option of repairing the car instead of buying a new one.

Repairable product

The car has a modular design. The drive shaft alone has about 1400 parts, of which 300 moving parts (Interview 3, 2020). These parts are to an extend easy to replace individually, without replacing an entire section such as the engine, of the car. The modularity of the car allows for repairs to be both possible and a preferable option to replacing the entire car or an entire section of the car. In addition,

the car is a very heavy product containing much materials, especially steel. Replacing one part instead of all the material in a car is logically a preferable option.

Legislation
For the automotive industry some unique legislation is in place. The BER only applies to the automotive industry, forcing manufacturers to make spare parts and diagnostic equipment available at a normal price. Due to the repairable design there are spare parts to make available. Other necessities for conducting repairs, such as access to in-vehicle data, are likely to be added in the next update of the BER. The TAR for vehicles includes a section requiring public access to repair and maintenance information. This means vehicles only get a type approval, and thus the right to be sold in the EU, if the information for their repair and maintenance is publicly available. The end-of-life phase of the car is also well regulated. Tax need to be paid until the car is sold at a demolition company. Additionally, manufacturers need to prove that the cars they sell are for at least 95% recycled.

Parts infrastructure
Of the recycled cars parts are revised. This helps to reach the required 95% recycle rate, but provides the repair industry with cheaper spare parts as well, stimulating the repair industry. Cars consist of many parts due to their repairable design, of which most are produced by part manufacturers, but also many by the manufacturers self. Since the 2002 BER update, part distributors have taken over the role from brand dealers of providing independent repair shops with spare parts.

Product value chain dependency
Brand dealers, part producers, part distributors and even manufacturers have become dependent on the repair industry. Brand dealers earn most of their profit in the repair shop part of their business. Even manufacturers urge dealers to conduct repairs as they earn through the sales of spare parts, while at the same time rely on proper maintenance and repairs to uphold a certain quality and reliability.

Social value
The car has become less of a status symbol over the years. It has become increasingly socially acceptable to drive an older car. This trend makes customers more willing to repair an older vehicle instead of buying another one. Additionally, leisure time activities have changed. People used to conduct simple repairs themselves, but in combination with the increasing complexity of the car, customers bring their car to a repair shop for almost any fix, in turn stimulating a repair sector.

Safety requirement
Public opinion towards the safety of cars has changed over the years. Many requirements to the car have been set, such as the seat belt or hands free calling. One of the regulations the drive for safer cars produced was the APK, a regulatory safety check. This obligation fell into the domain of the mechanics of the repair shops and have provided a great boost. As the government did not want monopoly to form on a mandatory service check on such an expensive consumer good, the decision was made to pursue competition in the aftermarket by updating the BER.

6. Guidelines for other sectors

Three main lessons, that other sectors could use to set up a repair industry, can be learned from the development of the automotive repair industry. These lessons are stated and argued in this chapter and highlight specific examples from the smartphone industry. According to the PBL (2019) there are 600 repair shops for consumer electronics compared to almost 20.000 repair shops for cars in the Netherlands, while the PBL (2019) estimates more repair shops for consumer electronics could lead to a much longer product lifetime. To this end the smartphone industry is chosen to serve as an example

case. To attain a proper indication of the sector, the common practice is compared against the best practice, which is deemed to be Fairphone (Ifixit, 2020; Fairphone, 2020).

6.1 Product repairability

The importance of design, together with access to repair information and spare parts is also stressed in literature (MacArthur, 2016a; King et al, 2006; Matsumoto et al, 2016). In the automotive industry the car has are *repairable*, modular design. If the design of consumer electronics was made to be repairable and spare parts and RMI were provided, a large repair sector would soon follow (Interview 3, 2020). This is in fact exactly what the EU has planned in their 'Right to repair' for large household appliances, smartphones and computers. The law would force the manufacturers of these products to apply a repairable design and provide spare parts (Peltier, 2020). Even though very little research is available about the repair industry, the EU's 'right to repair' campaign does focus on attaining a repairable product and a competitive aftermarket, even claiming 80% of a product's environmental impact is determined in the design phase (EU, 2020). In chapter 2 indicators of a repairable design by MacArthur (2016a) are stated follows.

To be able to conduct a repair, the design of the product should allow for an easy disassembly. This means the assembly should be reversible to the extent that components can be replaced. To this end screws should be used instead of, for example glue. Especially components that have a limited operational time, such as batteries, should be easily accessible. In addition, components should not be integrated to make the replacement of individual components impossible.

Smartphones

To assess the product repairability of smartphones, the website *Ifixit* about repair is used. In particular an analysis grading the repairability of many smartphones (Ifixit, 2020) and an article about practices manufacturers use to keep their phones unrepairable (Gordon, 2019). The repairability of smartphones is currently at a low level because of the following problems.

- Manufacturers place 'Warranty void if removed' stickers on the phone, which is illegal, but unenforced. These stickers dissuade customers from repairing their phones.
- Rare screws are used, that require special screwdrivers. The iPhone 7 plus even needing 4 different types of screwdriver, including very rare ones such as a pentalobe or tri-point screwdriver, to disassemble.
- Glue is often used instead of screws, making a repair unnecessarily difficult.
- Glass is used often on the front as well as the back, increasing the risk of damage.
- The display is often mounted in a manner that requires the display, LCD and glass to be replaced together if one of them breaks. Other components are often soldered together as well.
- Some phones are designed to be very fragile if they are tried to be opened.
- Battery disassembly is often made unnecessarily difficult through design, glue or soldering.

6.2 Enable requirements for third parties to conducting repairs

Without competition, the manufacturer has a monopoly on the repair of a product once it has been sold. This monopoly has two negative effects for a repair industry. First, the manufacturer can charge a monopolistic high price as there is no free market function. Second, as the manufacturer has an incentive to sell a new product to the customer, he will push the customer in the direction of buying a new product, leading to a reduced product lifetime (Kissling et al, 2013). The automotive industry has a competitive aftermarket though *Legislation, Parts infrastructure* and *Safety requirement*. Some European Union commissioners have proposed to make spare parts and technical information publicly available for home appliances and consumer electronics (Peltier, 2020). The action of making repair

information, spare parts and accessories more available by MacArthur (2016a) is given in the chapter 2 as:

Especially for more complex products, a manual or repair information is necessary to conduct a repair. This information should be easy to use and easy to find and could come in the form of a written text or a video. Forums where users can share their experiences or comment on the repair manuals can help and can be monitored by an online service expert from the manufacturer. To repair a product, spare parts are necessary. The manufacturer should make the spare parts available for every interested buyer at a reasonable price. It is important the responsibility of making the spare parts available lies with the manufacturer, as they have the capacity and resources to produce the spare parts or acquire them from their suppliers. The manufacturers should make the spare parts available for as long as a can be expected of a reasonable product lifetime. So even after the manufacturer has stopped making the product or the particular edition of the product, the spare part required to fix it should be made available.

As discussed in chapter 2, the availability of spare parts and the availability of repair information are two separate recommendations to empower repair by MacArthur (2016a). However, both aspects aim for a common goal, the capability of third parties to conduct a repair. Whether it is the customer or an independent repair shop, it is important the manufacturer is not the only one able to conduct a repair. For a modern product such as a smartphone, more requirements may be needed in order for a third party to conduct a repair. This thesis proposes the addition of tools, data and software needed to conduct the repair as requirements (Interview 2, 2020). Other requirements such as diagnostic equipment or access to the power grid to fix for example an electrical grid or a PV-panel could be relevant as well. To include all possible requirements it makes sense to adopt the broader vision of providing all, that is needed for third parties to conduct repairs, rather than listing individual requirements (Interview 2, 2020).

Smartphones

Manufacturers of smartphones often refuse to sell official replacement parts to third parties, or restrict the use of such parts, using software to prevent full functionality (Gordon, 2019). The right to repair campaign also describes a lack of repair information and a lack of spare parts at normal price (Mikolajczak, 2020). FairPhone has made their phone modular, with readily available spare parts at a normal price and easy to find online repair manuals (Fairphone, 2019). There is no healthy competition in the smartphone aftermarket because of the following problems, which leads to conclude there is no functional competition in the smartphone aftermarket.

- Repair information is not provided by the manufacturer. Repair information is very limited altogether, but especially easily accessible online platforms are missing.
- Manufacturers do not collaborate with repair platforms.
- Manufacturers try to shield or overprice spare parts.
- No large scale initiatives for the revision of parts have been found.
- Smartphones require up to four different rare screwdrivers to disassemble.

6.3 Interest in prolonging product lifetime

In order to have a repair sector, either the manufacturer or the consumer needs to have an interest in prolonging product lifetime (Adams et al, 2017). Most companies make money through selling a product, so the more products they sell, the more profit they make (Interview 2, 2020). The manufacturers thus have an interest to keep product lifetime at a level where they sell the maximum amount of products. The optimal product lifetime is thus often a lot shorter than the technical or ecological optimal product lifetime. The most famous example of which is the planned obsolescence

of the lightbulb (Krajewski, 2014). Manufacturers and customers in the automotive industry have an interest in prolonging product lifetime through the *High product price, Product value chain dependency* and changing *Social value*.

As discussed in section 5.2 the interest to prolong product lifetime has decreased for most products. Several options exist to bring the environmental and economical product lifetimes closer together or cause manufacturers or customers to have an interest in prolonging the lifetime of their products:

- A business model where other revenue streams besides the sales of new products have a key role (Interview 1, 2020; Interview 2, 2020; Interview 3, 2020). Product as a Service (PaaS) is a well-known business model where a manufacturer does not sell a product but provides a service to the customer. An example is that Signify has the option to pay for light instead of the lightbulb. In this case the consumer has a stronger incentive to turn the light off and Signify has an incentive to make the lightbulb last longer as they have to pay, should the lightbulb be replaced. The central idea behind PaaS is that the consumer doesn't need a lightbulb, they need light.
- Changing the tax system may also play a role in prolonging the lifetime of products. For example tax could be removed from spare parts, the labour of repair, or from second hand products. By removing tax, repair becomes cheaper and can more easily compete with a new product (Stahel, 2016).
- The certificate of conformity upholds the quality of the product to which it has been approved in the TAR and ensures a customer has the right to expect a certain performance for a certain amount of time for the product they bought (EUR-Lex, 2020). Increasing the legal minimum product lifetime might help stimulate manufacturers to compete over product lifetime. Alternatively a minimum usage period can be demanded as a condition for receiving subsidy or a reduction of VAT (Interview 2, 2020).

Smartphones

Phones are either sold as a product, or sold together with a bundle for data with most phones in the latter payment construction being paid off in two years (Independer, 2020). Through combining the phone and the bundle, the phone is essentially written off in two years. The only PaaS system found was by Fairphone (Fischer et al, 2018).

Phone manufacturers try to shorten the lifetime of their products by making repairs needlessly difficult as is described in the previous section. They also falsely tell customers that repairs either can not be done or are too expensive and buying a new phone is the preferable option (Gordon, 2019). An example of the deliberate shortening of product lifetime is the Batterygate scandal of Apple as they were forced to admit they deliberately slowed down older models of the iPhone (Graham, 2020). Another obstacle is that batteries for smartphones are designed to operate properly for only about a year (Villas-Boas, 2015).

Phones also lose an incredible amount of value in their first year, up to 75%, and most phones have lost 80% of their value after two years (Wild, 2018). Fairphone is an exception aiming for five years of product use instead of the market average of two years (Fairphone, 2020). The lifespan of phones is however increasing as they become more expensive and the new versions are deemed insignificant by customers according to IDC and Morgan Stanley (Wild, 2018). This argumentation shows that the economical lifetime slowly increases as the phones get more expensive. In addition, the technological advancement rate of phones is slowing down, making new phones less desirable compared to slightly older phones.

By adding 'Warranty void if removed' stickers to the phones, manufacturers create a false impression the customers lose their right to a functioning phone if a repair beyond that sticker is conducted (Gordon, 2019). Through the law of conformity the customer however has a right to a minimum amount of time they can expect their phone to perform up to a certain standard (EUR-Lex, 2020). The EU is currently looking into possible changes regarding warranties to increase product lifetime (EC, 2020). Through the stickers and the two year pay-off period, the manufacturers try to make their customers believe they don't have this right. Fairphone encourages the use of their phone for five years instead of the market trend of two years, though their warranty also only lasts two years (Fairphone, 2020). In addition Fairphone states that the most sustainable phone is the one you already have (Fairphone, 2019). Concluding, most smartphone manufacturers have an interest in shortening product lifetime of smartphones instead of prolonging it.

7. Conclusion and discussion

In this chapter the paper is concluded and the research question is answered. In addition the scientific and societal implications are discussed. Finally, limitations of the research and suggestions for further research are given.

7.1 Conclusion

The aim of this research was to identify the key lessons to be learned from the success of the automotive repair industry. The chosen method to achieve this goal was to do desk research into relevant scientific papers, branch organisations, newspaper articles about car repair of the past 30 years, and general information about the automotive industry such as the development of the age of passenger cars and legislation regarding automobiles. To confirm and to add to the conclusions drawn from the analysis, interviews with experts from the automotive aftermarket have been conducted to add to the validity and completeness of the findings.

This thesis has contributed to the limited knowledge base about the circular economy strategy repair by studying one of the major repair industries. The results show the car is such an expensive commodity that buying a new one if it breaks is not possible for the vast majority of the population. Lack of a repair industry or a short product lifetime would prevent customers from buying a car. Manufacturers thus have a strong incentive to keep the product lifetime acceptable for the customer, stimulating a repair sector. This process was strengthened in recent years by a changing consumption pattern in Dutch households, decreasing spending on transportation and parts. These conditions were followed by EU regulation in the form of the BER and TAR, forcing manufacturers to make spare parts and technical information publicly available. These regulations were driven by a public demand for safer cars, leading to the mandatory maintenance check (APK) and customer choice. As the result of this regime, many product chain partners have become dependent on the repair and maintenance industry and would go bankrupt without it. Though the manufacturers have an interest in maintaining a repair sector and a relatively long product lifetime, their primary business model is still to sell as many products as possible resulting in sub-optimal product lifetime. Between 2000 and 2019 the total number of cars increased by 30%, but this increase is for 88% due to an increase in vehicle age. In the same time period the percentage of cars younger than 1 year decreased from 10% to 5%. A clear slowing of the resource loop can thus be observed.

The interdependency between the different R-strategies in the automotive sector have been mentioned, but an extensive analysis is not within the scope of this research. There are however positive reinforcing effects found between the R-strategies Recycle, Revise, Repair and Reuse. The

strategies Reduce and Rethink in the form of the electric car and the autonomous car would be disastrous for the automotive repair sector due to a significant decline in repair and maintenance work. A trade-off between closing or narrowing the resource loop with electric cars, and slowing the resource loop with repair and reuse can be observed. Though electric vehicles produce less carbon dioxide in the use phase, building a new car, especially and electric car, consumes much carbon dioxide. The suggestion for policy makers is to write policy to balance between an optimal vehicle lifetime for current combustion engine vehicles and new electric vehicles in order to reach the set goal of attaining a fully circular economy by 2050 (EZ & IenM, 2016).

The main principles that were distilled from studying the success of the automotive industry are largely in line with the key requirements for enabling repair pointed out by MacArthur (2016a). The 'Repairable design' was found as a standalone aspect in both MacArthur (2016a) and this thesis, whereas the 'Availability of spare parts' and 'Availability of repair information' by MacArthur (2016a) has been bundled in this thesis to the broader 'Enable requirements for third parties to conduct repairs'. This study however proposes 'Interest in prolonging product lifetime' as an addition to the recommendations of MacArthur (2016a) for getting a better repair industry. The additions to the recommendations of MacArthur add to the base of knowledge about repair which could in turn be further researched and refined.

To reach a circular economy by 2050, as is the goal of the Dutch government (EZ & IenM, 2016), the slowing of the resource loop by extension of product lifetime is an important objective. Three lessons, described in the previous paragraph, for attaining a repair sector have been formulated from examining the development of the automotive repair industry. With these guidelines from one of the major success cases for extending product lifetime, policy makers could pursue new strategies in order to stimulate a repair industry in other sectors.

7.2 Limitations

A limitation is the setting in which the research takes place. The automotive sector started over a hundred years ago, so the reconstruction of that time-period had to rely on secondary sources, making information about the start indirect. Given the size and complexity of the subject, some aspects might have been overlooked. To give validity to the finding and reduce bias however, interviews have been conducted. Due to the coronavirus lockdown, these interviews were unfortunately not held in person, possibly affecting the quality of the interview. The rebound effect has not been taken into account in this study. The rebound effect of a well-functioning repair industry could however be huge since Ford created and stimulated the repair industry to diffuse the car. The environmental costs of conducting the repairs have also not been taken into account as this paper focussed on finding the drivers of the automotive repair sector rather than researching the environmental consequences of having a repair sector.

7.3 Further research

Research into the relation between capital and labour for achieving a successful repair industry is recommended. Future research could also focus on the effects policy would have on exempting tax on labour costs for conducting repairs, as this would also stimulate local employment opportunities. Further research could be conducted to determine possible interdependencies between the different R-strategies. The effects of the Right to repair law (EU, 2020) would be interesting to study and could be used to confirm or adjust the findings in this paper. In time further research is recommended into the effects, successes and barriers of the Right to repair law.

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