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Investigating the Potential of Circular Business Models for Automotive Manufacturers in the Future Mobility Market

A Case Study of Volvo Cars Corporation

Master's Thesis in the Master's Programme
Management and Economics of Innovation & Quality and Operations Management

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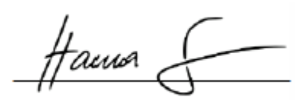

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Abstract

The mobility industry is going through significant changes as the three trends automation, electrification and shared economy is rapidly advancing. These three together are expected to have a big impact on how we consume and utilise mobility in the future. Exactly how, and how fast the changes will be, is still debated but that major changes are happening is agreed upon by most researchers and experts. At the same time the concept of circular economy is gaining attention as environmental concerns are rising. Circular economy aims to decrease the amount of virgin materials used and to extend and close the loops of consumption in comparison to the linear economy of “take-make-use-dispose” which is dominant in today's consumption society.

This thesis investigates what potential the concept of circular economy can have on the future of mobility for automotive manufacturers, using Volvo Cars as a case study. To fulfil the purpose of the thesis, a backcasting method in four steps was conducted. Firstly, five success factors on the future mobility market was identified by interviewing experts and researchers. Secondly, the present state at Volvo Cars was analysed in regards to the success factors found in previous step. Thirdly, a set of seven circular business models was identified and their potential evaluated in regards to the success factors. Lastly, the effort needed to implement these circular business models and their potential was evaluated.

As results it can be seen that circular economy and its business models have a big potential of positively impacting the future of mobility. The uncertainties on exactly how, and how big it would be, is though impossible to say at this stage and a lot of research is yet to be done. The impact is likely to be positive in both economic terms for the company but also for the global and local environment.

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Terminology

Loops	At end-of-use all the material and components are reused, remanufactured or recycled into new products. No waste is generated and all material is being regenerated into new products.
Inner Loops	Prioritisation of re-using material and components further down in the value chain since it takes less energy. Example, it is better to reuse or remanufacture a component than recycle the material and use for new products.
Megacities	Cities that has a high gross domestic product, high population, high population density and with geographical restrictions on their expansions, often built on an island. Examples are Hong Kong, New York and Singapore.
Reverse Supply Chain	The movement of goods from the customer back to the vendor or manufacturer.
Robo-taxis	A mobility service that is provided by a autonomous vehicles without a driver.
Uber	A multinational platform-based mobility provider. Connecting drivers with customers to book rides.
UberBlack	A premium alternative of the normal Uber with more luxurious cars.
UberPool	An alternative to the normal Uber car where you share rides with people that are going along the route that you are planning to a lower price.

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1 Introduction

This section will introduce the background to the project, followed by the purpose and specific research question for the thesis and lastly, the delimitations will be presented.

1.1 Background

The world is facing more and more challenging environmental challenges. In 2015, world leaders agreed upon the ambitious target to limit the temperature warming to 1.5 degrees Celsius (UNFCCC, 2018). Yet we are consuming more and more with a rising economy and a rapidly growing middle class (Kharas, 2017). After the industrial revolution, when mass production and new production methods resulted in products with high availability at a low cost, a staggering growth of industrial activity and an increasingly consuming society has led to high emissions and high generation of solid waste deposited in landfills causing severe problems. This expansion is expected to grow with the increasing population and more people entering the middle class (Lieder & Rashid, 2016). Today we already use the resources of 1,7 earths every year and if everyone would live like the average U.S or Australian citizen, we would need approximately 5 earths to support our lifestyle (WWF, 2017). This is not only causing environmental problems but the resources are also becoming more scarce with higher prices of natural resources leading to an increased pressure on the manufacturing industry (Lieder & Rashid, 2016).

These problems and challenges have arisen mainly because of the fact that the global economy as of today has been dominated by a linear economy, which is defined as converting natural resources into waste through production (Murray, Skene & Haynes, 2017). This type of economy has a negative impact on the environment in two ways: removing natural resources from the environment through unsustainable harvesting and reducing the value of the natural capital through pollution. Hence, the linear economy presents several limitations due to its nature of take-make-use-dispose (Lieder & Rashid, 2016), where goods are made from raw materials and then sold, used by the buyer and finally made into waste. Alterå (2017) explains that the economic success of the linear economy has caused several external costs that does not show in the financial numbers. Today, these negative externalities cannot be ignored and looked upon as side effects but is rather a proof that we are getting closer to the limit of our world's resources.

Due to an increasing awareness of the environment as well as an understanding of how a high-consumption society will affect our future, several steps have been made to improve the resource efficiency of the linear economy (Ellen MacArthur Foundation, 2015b). However, as long as the entire system is based on consumption, with an increased input of materials, rather than on restorative use, substantial losses will occur along the value chain. For example, in Europe the recycling of materials and recovery of energy captures less than 5 % of the total value of raw materials. It has also been shown that the way we use our resources and finished products in today's system is not optimal, where the average car is parked 92 percent of the time, 31 percent of food is wasted and the average office is used 35-50 percent of the time during working hours (Ellen MacArthur Foundation, 2015b).

In addition to the mentioned inefficiencies and the challenges in resource scarcity and pollution, several other trends show that the traditional linear economy is being challenged (Ellen MacArthur Foundation, 2015b). Companies are for example noticing an increased risk in volatile resource prices on the market, discouraging them to invest. Furthermore, the raw materials are in most parts of the world imported which brings a supply risk. These risk together with advances in technology, an increased urbanization and acceptance of alternative business models has caused a new economy to emerge - the circular economy. Lieder and Rashid (2016) explains that the circular economy have arisen as an alternative way of making business since it is considered to be a solution that harmonizes economic growth with environmental protection.

The car industry is no exception, where circular economy has gained traction as a way of ensuring environmental-friendly production and delivery in a constantly growing industry. The automotive industry is namely one of the largest manufacturing sectors in the world, using a large amount of raw materials (Wells, 2013) as well as emitting a large proportion of the total amount of greenhouse gas emissions (26-28% of greenhouse gas emissions come from the transport sector (EEA, 2017; EPA, 2018)). This highlights the importance of finding new ways of both producing and using cars, and the technology to do so is advancing fast. Electric vehicles have become available on the mass market and are expected to grow in numbers and the advancing technology of self-driving vehicles opens up for new ways of using and owning cars.

The increasing need for more environmental-friendly business models together with the rapid technological shifts has hence led to automotive manufacturers testing and researching new ways of doing business to gain both environmental and economic advantage. Volvo Cars aims to be on the forefront of this development and has recently launched a new way of owning cars on subscription, Care by Volvo, made a deal with Uber to sell 24.000 self-driving cars and the Volvo Cars owned car sharing company Sunfleet has during the last years grown their business substantially. These new ways of doing business creates an opportunity to move away from the traditional linear way of selling cars to a more circular. Yet the potential advantage in adopting circular business models in these new business models has still not been fully understood. That is why this thesis aims to start a discussion and be used as a foundation to further investigate the potential in circular business models in the future automotive industry.

1.2 Purpose and Research Questions

With this background the objective of the thesis is to create a broader understanding about the potential of circular economy within the automotive industry. The aim is that the results of the study can be used as a foundation for future discussions and research within circular economy in the automotive industry. To reach the aim of the thesis, the following research question were identified:

- ***What is the potential with adopting circular business models for automotive manufacturers in the future mobility market?***

In order to answer this question two sub research questions were developed. Firstly, the matter of how mobility will develop and what the future of mobility will consist of was addressed. This was done by analysing success factors on the future mobility market by answering the following question:

a) *What will be important success factors on the future mobility market?*

Secondly, circular business models needed to be understood and then analysed in order to estimate their capability to help automotive manufacturers meet the success factors on the future mobility market. This was done by answering the second sub research questions:

b) *Which circular business models have the potential to impact these success factors on the future mobility market and then in what way?*

To help answer these questions, a case object was used in the thesis. The case object was Volvo Cars Corporation (hereafter Volvo Cars), an automotive manufacturer on the present mobility market, which was investigated in regards to both its current operations and its future development.

1.3 Delimitations

The thesis was delimited to investigating the potential of circular business models in the mega city market in 2030. The reason for focusing on mega cities is particularly due to the fact that the need for change in these areas are high, where an increased urbanisation and continuously increasing pollution and congestion are causing problems. This means that the change in the mobility market will most likely occur in these areas first, making it interesting to investigate these areas in a first stage. The choice to focus on the future, and especially 2030, is that it is a substantially long timeframe that allows people to think outside their everyday work but yet not too far away meaning that we can create a more reliable vision of what will have happened. These delimitations were done in dialogue with stakeholders at Volvo Cars as well as with external researchers.

2 Theoretical framework

In the following section, the theoretical framework for the thesis will be presented. First, the concept of circular economy will be explained and a definition presented. Thereafter, the trends of mobility will be explained and its implication on the way we move in urban areas. Lastly, the method of backcasting will be presented.

2.1 Circular Economy

The exact time for the origin of the concept of circular economy has been widely debated over the years. The broader concept was mentioned as early as 1848 by Hofman, the first President of the Royal Society of Chemistry, who stated "*...in an ideal chemical factory there is, strictly speaking, no waste but only products. The better a real factory makes use of its waste, the closer it gets to its ideal, the bigger is the profit"* (Murray et al., 2017). However, the first time it was mentioned as "circular economy" in literature was during the 1980s. Around this time, the concept of closed-looped economy was also first introduced. These two concepts have as of today partly come together as one, since the common denominator in most meanings of circular economy is the concept of cyclical closed-loop system. Hence, circular economy is also known as closed-loop economy (Murray et al., 2017). Murray et al. (2017) further explains that a circular economy has zero net effect on the environment and rather restores damage that has been made when acquiring natural resources. Circularity also includes that as little waste as possible is generated during the entire life-cycle of a product or service. The three principles of reduce, reuse and recycle can be seen as a basis for circular economy, where the goal is to close all material flows in the economic system (Lieder & Rashid, 2016).

In addition, Alterå (2017) states that the circular economy can be seen as an economy that works within the boundaries of the earth and its resources. It can be said to be an economy were waste is not created but resources rather kept in the natural cycle, where it can be brought back into nature in a sustainable way. Key things that differ the circular economy from the linear is that consumers are seen as users and the focus is on value cycles and not value chains. Ellen MacArthur Foundation (2015b) continues this definition by explaining that the circular economy is characterized by a restorative and regenerative mind-set, where the aim is to increase and retain the utility and value of each step of the technical and biological value cycles.

Stahel (2016) further gives an explanation of the difference between the two types of economies, with regards to the ownership. The author explains that in the linear economy natural resources are being processed and turned into finished products by adding value. These products are then sold and at this point the ownership and responsibility for the waste is passed onto the buyer, who decides what to do with the waste – recycle, reuse or discard. In the circular economy the processing of materials and reprocessing of goods is aimed at generating jobs, save energy and reduce waste with the objective of creating and maximizing the value at each point of a product's life. The ownership retains with the manufacturer, who have the responsibility for the products and materials throughout the life-cycle where the focus is on solutions rather than products.

2.1.1 Definition of Circular Economy

Circular economy has, as described above, become a trending topic in the recent years. This can be shown by the fact that over 100 articles were published on the topic in 2016, compared to 30 articles in 2014 (Kirchherr, Reike & Hekkert, 2017). The recent hype in the area and the fact that it has emerged in a short period of time has led to a variety of definitions, where no common definition has been agreed upon. Kirchherr et al. (2017) reviewed 148 articles of which 114 presented a definition of circular economy. The lack of a common definition is evident since in these 114 articles it occurred 95 different definitions. The one that is most commonly used is the one that Ellen MacArthur Foundation (2013b, p.7) uses, which is used in 11 of the 114 articles and reads:

> *"[Circular economy] an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models."*

Especially there is a focus on the fact that circular economy is a system that is designed to be restorative and regenerative. Since Ellen MacArthur Foundation (2013b) presented their definition in 2012 this concept has been used in 47% of the definitions examined by Kirchherr et al. (2017). The EU Waste Framework Directive uses a framework called 4R (Reduce, Reuse, Recycle and Recover) of these the first three (Reduce, Reuse and Recycle) are the most used of the articles examined by Kirchherr et al. (2017). The lack of a common definition makes it harder to define what is included and excluded from circular economy. In this thesis the definition provided by Ellen MacArthur Foundation (2013b) and the three principles of *reduce, reuse* and *recycle* will thus be used as a foundation of what is included in the term circular economy.

2.1.2 Circular Business Models

A business model is defined by Osterwalder and Pigneur (2010, p.14) as “the rationale of how an organization creates, delivers, and captures value”. The business model should consist of the following four elements: value proposition, supply chain (called infrastructure management in some articles (Sommer, 2012)), customer interface and financial model according to a screening of articles about business models made by Boons & Lüdeke-Freund (2013). These elements can then be further divided into the business model canvas, as defined by Osterwalder and Pigneur (2010). The business model canvas consists of nine building blocks and visualises and captures the means of how a company intends to make money and is therefore a useful tool (Osterwalder & Pigneur, 2010).

Sustainable business models have in recent years gained attraction both from companies and researchers with the growing interest of sustainable economy. Bocken, Short, Rana & Evans (2014) argues that it is necessary for companies to adopt sustainable business models in order to embed sustainability into the business purpose and process to achieve long term social and environmental sustainability. The need for a change in how companies capture value is due to the fact that eco-efficiency and eco-design is not sufficient. This since a decrease in resources used is offset by an increasing consumption, due to a growing population and increasing world economy (Bocken et al., 2014). A sustainable business model has more than just an economic bottom line as it incorporates a triple bottom line including economic, environmental and societal measures; also referred to as people, planet and profit (Bocken et al., 2014). The business model canvas that Osterwalder and Pigneur (2010) presented has been altered to consider sustainable measures as well. Joyce and Paquin (2016) presented the triple layered business model canvas which is an alteration of Osterwalder and Pigneur’s traditional business model canvas. The triple layered business model canvas incorporates three dimension and describes how companies can create both economic, environmental and social value, as with the triple bottom line.

One way of creating a sustainable business model is by implementing the circular economy concept on the way the company make business, which is then called circular business models. Linder and Williander (2015) define circular business models as business models which have the conceptual logic for value creation based on utilizing economic value retained in products after use in the production of new offerings. Another definition provided by Nußholz (2017, p.12) is as follows:

> *“A circular business model is how a company creates, captures, and delivers value with the value creation logic designed to improve resource efficiency through contributing to extending useful life of products and parts (e.g., through long-life design, repair and remanufacturing) and closing material loops.”*

Common for these definitions is that they both see a circular business model as one that aims to decrease the utilization of virgin materials by substituting primary material input with secondary production, extending average lifetime of products and recycle materials (Nußholz, 2017). A circular business model is not only a way of decreasing the environmental impact but also a possibility to create new business opportunities, both in the traditional forward supply chain but also in the reverse supply chain that is needed to close loops (Valkokari & Antikainen, 2016). Linder and Williander (2015) states that circular business models can radically increase the resource productivity with higher profitability. It is though challenging to implement circular business models as it is a radical change to the linear business model traditionally used by most manufacturing companies. The value chains become more complex and this makes it harder to validate circular business models than linear business models (Linder & Williander, 2015).

2.1.3 Circular Economy in the Car Industry

The automotive industry and car production has since it first started been part of a traditional linear economy where material is taken and used to produce cars which after they break down are scrapped. The car industry is the largest manufacturing sector in the world and therefore a major consumer of raw materials, accounting for 16 % of global steel use, 30 % of aluminium, 5 % of plastic, 85 % of magnesium die casting and significant amount of other materials (Wells, 2013). This together with the fact that in present time 12 million light-weight vehicles are taken out of use each year (Saidani, Yannou, Leroy, & Cluzel, 2017), makes the recycling of the parts and materials in the car after end-of-life very important. However, only a small portion of the material in cars is recycled back into the car and the rest is instead down-cycled to less technical applications or thrown away (Wells, 2013). An example of a valuable material that is not taken care of properly is gold, where the entire amount in scrapped cars each year, estimated to 20 tonnes, are going to waste instead of being recycled (Huisman et al., 2017).

The automotive industry is therefore not in the forefront when it comes to circular solutions and transitioning to a more sustainable way of producing and using its products. However, Stahel (2016) explains that business models of new, flexible urban mobility solutions are changing the fundamentals of the linear economy and therefore the entire automotive industry. The competitive advantage is no longer based on features such as ownership, fashion and emotion, which in turn makes car manufacturer's current capabilities less important. Their strength in mass production, ground-breaking technology for combustion engines and gearboxes as well as high class supply chains is not sufficient to be able to compete with these new business models in mobility.

Furthermore, Koerner (2017) states that the consumers' needs and wishes are changing, where they are looking for more efficient and longer lasting cars in order for them to save cost. This trend is further driving the transition from a linear to a circular economy in the automotive industry. This transition is today making companies more aware of how they design their cars to be able to retrieve material at end-of-life. The author also mean that car manufacturers might have to rethink their entire business model from producing and selling products to rather becoming collaborators and deliverers of services.

2.2 The Future of Mobility in Urban Areas

Modern technology will most likely change the way we move around in the city and possibly the way we live. Today 55% of the world population lives in urban areas and the number is expected to increase to 66% by 2050 (Thomopoulos & Givoni, 2015). This also increases the importance of how people move in cities. The technology on the mobility market is under fast development and is expected to continue to change the way we move. This section aims to describe some of the trends that scientist see going forward in the area of urban mobility and what implications these will have on the cities that more and more people live in.

2.2.1 Development in the Mobility Area

There are a lot of trends and the technical development is moving rapidly in the mobility sector. This section will focus on the three areas: automation, shared economy and electrification, which are seen as major trends by researchers (Sprei, 2018).

2.2.1.1 Automation

The technical development of autonomous vehicles started already in 1926 with the first radio controlled car but really gained momentum after Mercedes Benz introduced a vision guided robotic van in 1980 (Bimbraw, 2015). The technology from 1980 is similar to the one used in today's cars and has led the development of adaptive cruise control, lane parking and steering assist, which is present in many modern cars today (Bimbraw, 2015). The development has been significant especially in the last decades which has led car manufacturers to make bold statements including that no one will die in a new Volvo by 2020 or that Nissan will produce a number of driverless cars in 2020 (Bampton, Campbell, & Heyns, 2016). A lot has already happened, Tesla have their Autopilot installed in all Model S cars and Delphi Automotive did a trip from coast to coast in the U.S. where the car drove 99% of the trip by itself (Bampton et al., 2016).

The National Highway Traffic Safety Administration has divided the technology into a continuum of different levels of automation which is commonly used. The five levels are based on the amount of human interaction and are described below:

- *Level 0: The human driver is in complete control of all functions of the car.*
- *Level 1: One function is automated.*
- *Level 2: More than one function is automated at the same time (e.g., steering and acceleration), but the driver must remain constantly attentive.*
- *Level 3: The driving functions are sufficiently automated that the driver can safely engage in other activities.*
- *Level 4: The car can drive itself without a human driver* (Anderson et al., 2016).

In recent years, companies outside of the classic automotive industry have started their own development of autonomous cars (Bampton et al., 2016). Google's manufacturing of self-driving cars started its development in 2009. The cars, under the new name Waymo, are currently being tested and have already logged over 6,5 million kilometres on common roads. They are now launching their first program with real test riders (Waymo, 2018). More traditional car manufacturers are also aiming at providing level 4 autonomous cars. Volvo Cars has for example started testing autonomous driving on certain roads around Gothenburg (Volvo Cars, 2018).

The first commercial autonomous vehicles are planned to be ready on the market from 2020. The transition to being only autonomous vehicles on the roads is thus expected to take time and they will most likely coexist with traditional vehicles for quite some time. If the adoption speed of autonomous vehicles will follow the pattern of the adoption of other smart vehicle technologies, 50% of all sold vehicles and 40% of all travel with vehicles will be done in autonomous vehicles by 2040 (Bagloee, Tavana, Asadi & Oliver, 2016). This rather rapid development puts high demand on the infrastructure and legislation since it still exists many challenges and uncertainties that need to be resolved (Bagloee et al., 2016).

If successfully implemented, this technology could be very beneficial for many parts of the society. Safety, decrease of congestions, availability of mobility for everyone and reduced need for parking space are just some of the benefits. Fagnant and Kockelman (2015) calculate that the economic benefit for the US could be as much as $27 billion annually by reducing the cost of crashes, congestions and many other factors. This results in a saving of $2000 per sold autonomous vehicle (Bagloee et al., 2016).

2.2.1.2 Shared Economy

Sharing economy is not a new modern invention, rather it is something that mankind has been doing in all ages (Frenken & Schor, 2017). The amount of sharing has rather decreased in recent time. The family car has been replaced by individual cars as well as the family TV where family members each have their own screen to look at (Belk, 2007). The novelty that has become a buzzword among economists in recent year is rather the new form of sharing where you share assets outside of your immediate proximity. This new form of sharing is what Schor (2014) calls “Stranger sharing”. Sharing economy can be divided into many forms of sharing and the one that is most commonly used in the case of car is referred to as access based consumption (Benoit, Baker, Bolton, Gruber & Kandampully, 2017) or also called access based services (Bardhi & Eckhardt, 2012). The definition widely used for access based services is market-mediated transactions that provide customers with temporarily limited access to goods in return for an access fee, while the legal ownership remains with the service provider (Bardhi & Eckhardt, 2012; Schaefers, Lawson & Kukar-Kinney, 2016).

Customers’ desire to own resources has decreased, while instead focus on gaining access through networks, aided by modern technology, has increased in popularity (Bardhi & Eckhardt, 2012; Moeller & Wittkowski, 2010). This trend of access-based consumption has the potential to be beneficial both for customers and suppliers but threatens companies who rely solely on classic transactional business models (Moeller & Wittkowski, 2010). Access-based consumption lets the customer use the benefits from the resource during a limited time period without transferring the ownership and therefore the risks involved with such ownership. Schaefers et al. (2016) found that the bigger financial, performance and social risks that are involved in owning a product the more likely it is that customers prefer to use access-based services. Here cars can be argued to have a high risk in all three parameters due to relatively large investments, a risk of bad performance and break down and that the car is seen as a social symbol with a rapid development of new trends. Another risk discussed by Schaefers et al. (2016) is the risk of insufficient capacity usage. This is the case with private cars as they are parked 92 percent of the time and therefore their capacity is not nearly optimally used (Ellen MacArthur Foundation, 2015a).

The amount of shared cars has also increased with car sharing companies such as Sunfleet, Drive Now, Car2Go and many others that are establishing themselves in cities around the world. The car sharing business has grown rapidly in the last couple of years and this expansion is expected to continue. Global Market Insights (2018) forecasts that the car sharing business will grow with an annual rate of 35% until 2024 making the number of members in car sharing programs over 30 million in 2024. This forecasted rapid growth is also projected by both Boston Consulting Group (Bert, Collie, Gerrits &

Xu, 2016) and McKinsey & Company (Grosse-Ophoff, Hausler, Heineke and Möller 2017), indicating that major business analysts believe in a rapid increase of the shared car market.

2.2.1.3 Electrification

The amount of vehicles around the world is expected to grow to 1,7 billion in 2035 (Bauer, Hofer, Althaus, Del Duce & Simons, 2015) compared to almost 1,3 billion vehicles in 2015 (Statista, 2018). This high and continuously increasing amount of vehicles increases the importance of how these are powered and where the energy comes from. In the EU, the transportation sector is responsible for 26% of the greenhouse gas emissions (EEA, 2017) and in the US for 28% (EPA, 2018). This highlights the importance of finding alternatives to the traditional combustion engine that has dominated the vehicle market since its introduction in 1885 (Chau, 2009). Policymakers are tightening the regulations in relation to greenhouse gas emissions by making greater demands (Faria, Moura, Delgado & De Almeida, 2012). This is especially evident in big urban areas where the low air quality has led to major cities starting to ban diesel cars. For example, Mexico City and Paris has committed to remove all diesel cars before 2025 (C40, 2018). This is one step in reducing the 7 million premature deaths that the World Health Organisation (2016) said was caused by bad air quality in 2012. The problems with pollution together with an increasing urbanisation has increased the need of finding new alternative ways of powering vehicles. Hence, the regulations are likely to get even stricter (Helms, Pehnt, Lambrecht & Liebich, 2010).

Electric vehicles are a technology that has been recognised as one of the most viable alternatives to reduce the greenhouse gases and dependency of oil. Electric vehicles can either be a combination of a combustion engine and an electric motor, today called hybrids, or be pure electric vehicles with big batteries storing the energy and emitting no tailpipe emissions. In this section only the pure electric vehicles will be discussed. The effectiveness of these electric vehicles to reduce the overall greenhouse gases has been discussed among researchers. The tailpipe emissions from electric vehicles are zero which is good, particularly in urban areas, to decrease the local pollution. However, the overall life cycle impact and the potential of mass producing electric vehicles has been debated (Bauer et al., 2015). This due to the many parameters that has to be included in a life cycle greenhouse gas assessment of the vehicle such as how the electricity is produced, how effective the production of the vehicle and its batteries is and how it is taken care of at end of life.

However, most scientist (Bauer et al., 2015; Faria et al., 2012; Helms et al., 2010; Ma, Balthasar, Tait, Riera-Palou & Harrison, 2012) conclude that the life cycle greenhouse gas emissions have the potential to be significantly lower for electric vehicles. It thus depends on the circumstances previously discussed and especially on the way the electricity is produced and how efficient the battery production is. A car that is powered by electricity from coal and is produced with virgin materials does not have to be better than an effective combustion vehicle. With the reduction of cost and enhanced technology of renewable energy that has been, and is likely to continue, the opportunity to charge your car with renewable energy will increase (IRENA, 2018). The battery technology has also become better and cheaper. The increase in demand and competition and the decrease in price will most likely put pressure on manufacturers to increase the effectiveness and the reuse of batteries which could decrease the amount of energy needed to produce them (Curry, 2017). It is though still problematic to produce the amount of batteries needed to electrify all cars since they rely on relatively scarce metals and the production volume that would be needed is far from covered by today's battery production (Väyrynen & Salminen, 2012).

The technological advancement, reduction of price and increased environmental awareness has led to an increase in electrical vehicles sold. In 2016 the global market increased by 40% from previous year by selling more than 750 000 electric vehicles (IEA, 2017). Tax reductions, access to special fast lanes and dedicated parking spots has most likely boosted these numbers and can be seen as a signal that policymakers are pushing for modern technology. IEA (2017) projects that the electric vehicle stock will be 56 million in 2030, 28 times the stock 2016. This trend has led to not only make dedicated electric vehicle manufacturers like Tesla ramp up their production but also traditional car manufacturers to focus on electrification (IEA, 2017). Volvo Cars has declared that every car they sell will have some form of electric motor from 2019 and onwards (Volvo Cars, 2017).

2.2.2 Impact on Urban Mobility

Mobility in cities is already a big problem, and it will not decrease with the increased urbanisation. In 2014 congestion costs reached approximately 1 % of the total GDP in the US as well as in the EU and in Asian countries it is estimated to be around 2-5% of GDP (Dia, 2017). The emissions from transport is also as previously discussed a big problem, both for the global environment and the local health in cities. The transports are only expected to increase with a growing demand for personal mobility. Global travel and the amount of global motorised vehicles is expected to double until 2050 (Dia, 2017). If the development continues as today, urban dwellers will spend three times as much time in traffic jams as they spend today, making it 106 hours per year (Spickermann, Grienitz, & Von Der Gracht, 2014). These figures highlight the need of new technologies and new ways of moving around, especially in urban areas where the problem is worst. The amount of individual mobility will continue to increase with an increased living standard, more individual lifestyles and everyday life becoming more and more hectic (Alessandrini, Campagna, Site, Filippi & Persia, 2015).

The change of urban mobility could take two different directions, either incremental or revolutionary development (Cascetta, 2014). Incremental change is what has been going on during the last couple of decades in the urban mobility sector, where the same modes of transportation (eg. private cars, railways) have been altered with incremental improvements and increased efficiency (Cascetta, 2014). On the other hand, a revolution is defined by Gilbert and Perl as a ‘‘substantial change in a society’s transport activity – moving people or freight or both – that occurs in less than 25 years” (Cascetta, 2014). Cascetta (2014) exemplifies this with the introduction of the private car in the US during the early 1900’s, which has dominated the mobility in the US since then. The new technologies previously discussed could potentially lead to a similar revolutionary change in urban mobility in the future.

How fast, and how extensive the change will be, is thus discussed among researchers and the forecasts are still uncertain. If combining the three previously mentioned technologies it could open up totally new possibilities. Shared autonomous electric vehicles (SAEV) could change the way we move in cities (Sprei, 2018). They could also lead to an increased amount of travelling due to the reduction of cost of between $0,18 and $0,34 per mile in a SAEV in comparison to today's cars (Fagnant & Kockelman, 2014). The amount of cars needed would also be reduced as one SAEV could cover for 11 privately owned cars in urban areas (Fagnant & Kockelman, 2014). The greenhouse gas emissions could in such a system be reduced if the production of electricity became more renewable and the SAEVs were combined with public transportation and active travel such as walking and biking (Sprei, 2018). If SAEVs were effectively deployed it would make private ownership of cars obsolete and decrease the amount of cars and trucks in the world by 70% (Arbib & Seba, 2017). Arbib and Seba (2017) has the most aggressive forecasts expecting that 95% of the travelled miles in the U.S. will be in some form of SAEV or what they call Transport as a Solution in 2030. This due to the enormous economic benefits both for the individual and the society that this type of mobility could provide (Arbib & Seba, 2017). Others thus have more pessimistic forecasts such as BCG (Collie, Rose, Choraria & Wegscheider, 2017) expecting that 25% of the travelled miles in the US will be in SAEV’s by 2030 as well as Bansal and Kockelman (2017) making both a pessimistic forecast of 25% and an optimistic of 88% level 4 autonomous vehicles in the US, with the time-frame on 2045 instead of 2030. Thus the uncertainties and how fast this transition will go is still to be discovered.

Spickermann et al. (2014) took another approach in their research and conducted a study of the desired future of urban mobility in 2030 with a range of different stakeholders in German urban areas. It concluded that a multimodular solution where public and private mobility is seamlessly incorporated in a smart mobility system is what stakeholders from urban areas would prefer. This type of system could work with SAEV cars connecting to a public transport system and providing the citizens with a multimodular solution. Sprei (2018) argues that these public transports will have to be significantly cheaper than the SAEVs to attract customers and this can be hard due to the possibility of making SAEV solutions very cheap.

As described, there are many possible outcomes for mobility in the future. Technical advancements open up for new solutions but it is still a long way to go and many uncertainties and challenges has to be overcome before a mobility revolution could happen. What can be concluded is thus that the field of mobility is changing and that both the opportunities and challenges are big for the future.

2.2.3 Scenario Analysis

A method commonly used when discussing the future of mobility is a scenario analysis. VTI (Kristoffersson, Pernestål Brenden & Mattsson, 2017). conducted a scenario analysis for the impact of autonomous mobility in Sweden. They choose to investigate two parameters: how much shared economy is adopted and how ambitious and strong the infrastructure politics and institutions are. This resulted in four more or less promising visions of the future where a high adoption of sharing economy and strong political promotions could lead to a state where “sharing is the new black” as they explain it. Another forecast made by Townsend (2014) investigates the four scenarios of:

- Growth where current key conditions are preserved and the growth comes from present trends
- Collapse when disruptive innovation and some critical systems of today fail. In this example low cost robo-taxis are rapidly growing and outmanoeuvring traditional cars.
- Constraint when the growth in the future is constrained by a lack of resources and environmental concerns
- Transformation is when disruptive innovation is growing rapidly and allowing for new solutions to gain big market share rapidly.

Which way the development takes is highly relevant for all actors on the market in order to stay relevant.

Volvo Cars has also made an internal scenario analysis which is not public. In this they use the same method as VTI (Kristoffersson et al., 2017) but on their axis they instead have amount of regulations and technical development. This allows for four future scenarios which vary in what way we are able to move around and how the mobility market will evolve.

2.3 Backcasting

Backcasting was originally developed in the 1970s within the energy field to identify and analyse energy futures that could not be analysed using traditional energy forecasting (Robinson, Burch, Talwar, O'Shea, & Walsh, 2011; Vergragt & Quist, 2011). However, since the first introduction backcasting has been extended to include sustainability and during the last decade the approach have gradually gained popularity and is now applied widely (Vergragt & Quist, 2011). Backcasting can be seen as a contrary to forecasting where future scenarios or conditions instead are envisioned before considering which steps that needs to be taken to get there (Holmberg & Robert, 2000). The method has been defined as "generating a desirable future, and then looking backwards from that future to the present in order to strategize and to plan how it could be achieved" (Vergragt & Quist, 2011, p. 747). This means that backcasting aims at developing a future vision but also at developing pathways on how to reach these visions. Holmberg and Robert (2000) further explains that, in the context of sustainable development, backcasting starts the planning based on requirements that needs to be met for society to be successfully sustainable and then links today with tomorrow by answering the questions on what shall be done to get there.

According to Dreborg (1996) backcasting is useful when the problem that is studied is complex, thus affecting many sectors and levels of society, there is need for a major change, when present dominant trends are part of the problem and the problem is mainly a matter of externalities. This is due to the nature of backcasting, where the focus is on the problem to be solved and not on the present conditions and trends, which enables consideration of a broad scope of solutions and widens the perspectives of the actors involved. These conditions make backcasting suitable to achieve major changes at many levels of society instead of solely making incremental changes.

Vergragt and Quist (2011) further explains that backcasting is especially well suited for sustainability issues because of its normative nature. With an increasing popularity of sustainability, backcasting has therefore gradually regained popularity and the method has become widely applied over the last couple of decades. Holmberg and Robert (2000) mean that backcasting can handle the complexity of environmental issues in a systematic way which brings clear advantages. The method can also help to foresee changes in the market and therefore identify business opportunities as well as risks and understand how to avoid them. This means that backcasting increases the chances for a strong economic performance. Another advantage backcasting brings is within innovation since the method helps to avoid lock-ins and encourages managers to think outside the box (Alänge & Holmberg, 2014).

Backcasting should be performed based on a set of principles that are general to help the coordination of different sectors of society and business and at the same time cover all relevant sustainability aspects (Holmberg & Robert, 2000). It is not desirable nor possible to specify the future state in detail, instead thinking in broad terms is advised in backcasting as it opens up the mind to new options (Holmberg, 1998). According to Quist and Vergragt (2006) it is also important to include a broad range of different stakeholders including actors from governments, companies, public interest groups and knowledge bodies to bring about system innovation. The involvement should be present both when defining the problem as well as when developing shared visions and future solutions. In addition, it is of great importance to encourage the stakeholders or expert to distance themselves from present constraints without losing their own expertise and experience (Vergragt & Quist, 2011).

Furthermore, Holmberg and Robert (2000) argues that it is important that the scope is wide enough and the time horizon long enough when using backcasting. Vergragt and Quist (2011) means that the time horizon should be realistic in the sense that it should be easily envisioned. It should however also be far enough into the future to make disruption and significant changes possible to occur.

2.3.1 Participatory Backcasting

The nature of backcasting, to extrapolate desired futures back into the present, means that it is important for the processes to be iterative and interactive to reach a successful result. This, in turn, implies that the method is benefited by continuous feedback between future visions and present actions as well as a high stakeholder involvement, where a shared future vision is developed together. These new insights led to a shift in the approach in the 1990, especially in the Netherlands, Sweden and Canada, where backcasting became more participatory in its nature (Quist & Vergragt, 2006; Vergragt & Quist, 2011).

In the participatory backcasting, also called second generation backcasting, a broad stakeholder involvement is used, instead of experts as in the traditional approach, to envision the future state. Robinson et al. (2011) mean that in participatory backcasting the analysis focus on the preferred futures of the participants instead of externally supplied targets or goals. This allows the stakeholders to contribute with their views and learn the consequences and trade-offs with their own preferences of the future. One positive outcome of participatory backcasting is therefore an increased social learning of the participants which facilitates change. However, the ability to review and compare external targets is lost in this shift.

One important issue in backcasting is therefore to decide who should develop the future vision, if it should be done by experts or rather be left to stakeholders and citizens as in participatory backcasting. Experts are usually bound by their knowledge which is based on the present whereas stakeholders represent interest and values for today, meaning that both groups have a hard time disengaging from the present. In this sense, the difference between the two groups is not that great but it actually makes a great difference on the result if the future visions are developed by stakeholders or experts (Vergragt & Quist, 2011).

2.3.2 Principles and Processes of Backcasting

In search of a system thinking within sustainability, scientist came together in the process called "The Natural Step" to define four non-overlapping principles that they all could agree upon regarding sustainability (Holmberg, 1998). The defined principles, also called system conditions, state that in order for a society to be sustainable, nature's functions and diversity must not systematically be:

- *Subject to increasing concentrations of substances extracted from the earth's crust*
- *Subject to increasing concentrations of substances produced by society*
- *Impoverished by over-harvesting of other forms of ecosystem manipulation*
- *Resources must be used fairly and efficiently in order to meet basic human needs worldwide*

These principles are commonly used together with a backcasting method for strategic planning in sustainability (Holmberg, 1998). Alänge and Holmberg (2014) explains that the backcasting approach is the most common way to introduce these system conditions into organizations. This since it enables organizations to analyse their own position compared to future demands of a sustainable society. Furthermore, the principles are timeless since they are applicable both in the long and short term, which ensures that decisions are made in a long-term context even if they deal with today's activities (Alänge & Holmberg, 2014).

Holmberg (1998) has defined four steps for the process of backcasting. The first step aims at defining a set of criteria for a future sustainable society and then discussing them. The criteria are often based on the principles described above. The principles are however mostly used as a guidance for the discussion about the future sustainability, where the goal is to gain a better understanding about what the demands for future sustainability will mean for the organization.

The second step involves analysing the current activities and competencies of the organisation in regards to the criteria from the first step. In the third step, the future desirable situation is envisioned and discussed, where the goal is to free the mind from the current situation and open up for new future solutions and possibilities. Here, the criteria from the first step as well as the analysis of the current situation from the third step could be used as a help to develop this future situation. The future situation should preferably not be specified too much in detail since this might hinder finding and discussing new options. In this step it is also often useful to look into the future and discuss the role the organization might take in the assumed future situation. Thereafter, the results from this step is used in the fourth step, where strategies to move from the current situation to the future goal situation are identified. In this step, the low-hanging fruits as well as solutions that are harder to implement can often be identified to find the appropriate pathway to transition from today's situation to the desirable future. The four steps developed by Holmberg (1998) could therefore be summarized to:

1. *Define criteria for future situation*
2. *Analyse current activities and competencies*
3. *Envision future situation and evaluate new solutions*
4. *Identify transition pathway*

The four steps are visualised in Figure 2.1 below.

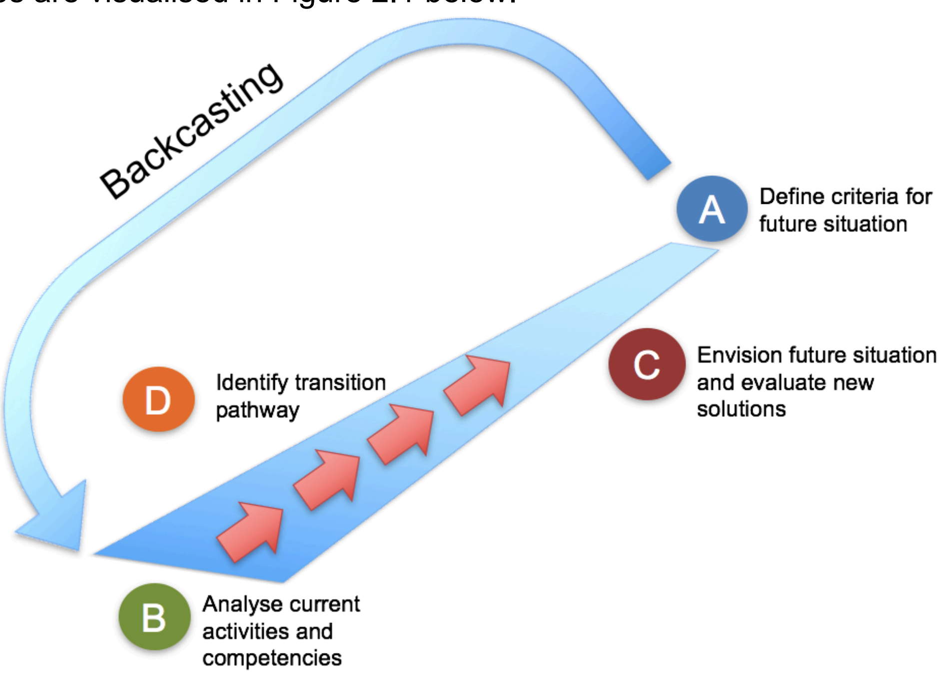

Figure 2.1 Visualisation of the Backcasting method

3 Methodology

The following chapter will describe the methodology of the project, where the research strategy will be presented followed by an introduction to backcasting that will be used as a method for the thesis. Thereafter, the method for each consecutive step of the thesis and their respective data collection will be presented. Lastly, the quality of research and eventual ethical issues will be addressed.

3.1 Research Strategy

Research strategy can be divided into two different types: quantitative and qualitative, where quantitative is used when the data in the project needs to be measurable and qualitative is better for a project that aims at understanding incentives and beliefs (Bryman & Bell, 2015). Furthermore, a research project can either be using an inductive or deductive approach, where an inductive approach will build a basis for future studies in the same area while deductive rather uses information that already exist within the area to test hypotheses. The research strategy of this thesis will be of qualitative and inductive character. This due to its exploratory nature and focus on building a better understanding around the area of circular economy for the automotive industry.

3.2 Method and Data Collection of the Four Steps

The method that will be used to answer the research questions in the thesis is backcasting, described in chapter 2.3. The exact steps of the method differ between the different frameworks that have been developed. In this thesis, the four steps described by Holmberg (1998) were used as a basis and adapted to match the research question and aim of the thesis, leading to the four steps below:

A. *Define factors for success in a future mega-city mobility market*
B. *Analyse the current state in regards to the defined factors*
C. *Identify new circular business models and evaluate their potential in regards to the success factors*
D. *Suggest a prioritisation of the business models in regards to the effort needed to implement them and their potential benefits*

As mentioned in chapter 2.3, backcasting is well suited to use for complex problems which affects many sectors and levels of society (Dreborg, 1996). This is hence one of the reasons for using backcasting for this thesis. The future of mobility is very uncertain and its development will affect many sectors worldwide. How to adapt to this development will therefore also be a very complex problem for many actors. Another reason for using backcasting as the method for this thesis is its sustainability focus, which is a big concern in the transport and mobility sector. Backcasting is said to be useful when there is need of a major change and when present trends constitutes part of the problem at hand (Dreborg, 1996). This is the case in the mobility industry right now as an increasing population and extensive car usage is causing congestion and air pollution around the world.

In the following sections, each step of the backcasting method and its respective methodology and data collection will be presented and explained further.

3.2.1 Step A

In the first step of the thesis, the aim was to create a vision of what will be important to be successful on the mega city mobility market in 2030. As mentioned in chapter 2.3*,* the time horizon when conducting a backcasting should be long enough to enable disruption and significant changes but still not as far into the future that it is hard to envision it (Vergragt & Quist, 2011). Since the mobility industry is rapidly changing, disruption will happen faster than in other industries. Twelve years into the future, 2030, will therefore be far enough for significant changes to occur in the industry but still a future that is possible for actors to envision.

The data in this step was collected by conducting 13 qualitative, semi-structured interviews. The interviewees were stakeholders at different positions at Volvo Cars as well as outside the company. As mentioned in the chapter 2.3*,* it is important to include a broad range of stakeholder when defining the problem and envisioning the future (Quist & Vergragt, 2006; Robinson et al., 2011), which is why a big spread of stakeholders were contacted in this first step.

At Volvo Cars the interviewees were chosen on the ground that they all worked in different areas but in some way worked with the future and how Volvo Cars were to tackle that future. Outside Volvo Cars three different categories of people were interviewed: researchers within the field of mobility, policymakers in governmental organisations around mobility and infrastructure and lastly industry consultants working with the future of mobility. Out of eight sent requests to stakeholders at Volvo Cars, six agreed upon an interview. For stakeholders outside of Volvo Cars seven out of 49 requests for an interview were positively answered. This lower answer ratio is probably due to a lack of connection to these recipients. A list of the interviews conducted is shown below in Table 3.1, where the department for the stakeholders at Volvo Cars is presented and the role as well as organisation for the external stakeholder is presented.

Table 3.1 List of interviewees for Step A

Volvo Cars interviewees	External interviewees
Role and department	**Role and organisation**
Product Strategy	Strategist - Strategic Development, Trafikverket
Environment and Fluid dynamics	Vice President, Macron Chair, Electric Mobility Canada
Care by Volvo	Senior Research Manager within Future of Mobility, Deloitte
Strategy and Business development	Assistant Professor in Transport, Chalmers
Corporate Innovation	Director of 3 Revolutions Future of Mobility Program, UC Davis Senior research engineer in Transportation, Georgia Tech
Volvo Cars Mobility	Principal Investigator of Design for Autonomous Mobility, TUMCreate
	Program Director, Drive Sweden

Firstly, the main question “What do you envision will be the success factors of the leading mobility providers in the megacity-market in 2030?” was sent in advance to the interviewees via e-mail to give them the chance to think the question through before the interview. The question was here broken down into four categories: economic success factors, environmental success factors, value proposition success factors and other success factors to prepare the interviewees in what areas the questions would be asked. The form that was sent to the interviewees as well as an interview guideline can be found in Appendix A.

The interviews were conducted mainly via phone except for some interviews with Volvo Cars employees that were conducted through a personal meeting and each interview took 30-60 minutes. During the interview, the interviewees was asked to answer the main question within the four categories mentioned above, where follow-up and clarifying questions were asked when going through each of the categories. These were complemented by a few general questions regarding the interviewee and their work.

From each interview key success factors were compiled immediately after the interview in every category using the form in Appendix A. For each interviewee, the success factors they had mentioned were judged as either normally mentioned or highlighted. A highlighted success factor was either if the interviewee mentioned it several times during the interview or if they specifically said it to be more important than the other success factors. When this had been done for all interviewees, the different success factors from the 13 interviews were summarized. Here the success factors that were the same or similar from the different interviews was grouped and named, resulting in a number of common success factors. These success factors were thereafter graded with one point for the ones that were judged as normal mention and two points for each highlighted mention. These points were then summarized and the highest scored and hence the most commonly discussed success factors were chosen to be used for further analysis in the subsequent steps.

3.2.2 Step B

The aim of this step was to map the current operations at Volvo Cars in order to evaluate which resources and competencies that meet the success factors defined in step A. This was done in order to create an understanding of what is needed for automotive manufacturers to reach future goals and demands. The data collection was done by conducting seven qualitative, unstructured interviews with employees at Volvo Cars from different business segments, both from their more traditional business segments of producing and selling cars but also from more innovative and forward thinking positions and business segments. A list of employees interviewed and their position is presented below in Table 3.2. Most of the employees were the same as the ones interviewed in Step A.

Table 3.2. List of interviewees for Step B

Position	Department
CEO	Sunfleet
Vice president	Product Strategy
Global program director	Care by Volvo
Manager	Strategy and Business Development
Manager	Volvo Cars Mobility
Director	Corporate Innovation
Senior Strategic Advisor Environment	Environment and Fluid Dynamics

The interviewees were asked about how Volvo Cars and their respective department work today, what their focus is and how they look at the future development of Volvo Cars and their department. Above this, a workshop was also conducted with three of the seven interviewees (from the departments Corporate Innovation, Strategy and Business

Development and Environmental and Fluid Dynamics) where the findings from Step A was used as a foundation. During the workshop, a discussion was held about how well Volvo Cars meets each of the identified success factors today both generally and in comparison to competitors from the automotive industry.

3.2.3 Step C

In this step, the aim was to identify circular business models and estimate the potential of each of them in regards to the success factors defined in step A. Firstly, a scan of existing reports within circular economy was done. From this scan, and after discussion with an environmental strategist at Volvo Cars, three frameworks were chosen on the basis that they were relevant for this thesis. Two of the frameworks were chosen since they occurred frequently in reports regarding circular business models. The third framework that was used was chosen on the basis that it was the only one that focused on the automotive industry. Thereafter, the three frameworks were compared and could be summarized into four main areas in circular economy. From these four areas, seven circular business models for the future mobility vehicle were developed together with the environmental strategist at Volvo Cars.

The seven circular business models were combined with the previously identified success factors from Step A into a framework for estimation of the potential, visualised in Table 3.3 below. This framework was used to analyse each circular business model in regards to the five success factors, where an estimation of each business model's potential to meet each success factor was carried out. This estimation was done through conducting a workshop with three Volvo Cars' employees (from the departments corporate innovation, strategy and business development and environment and fluid dynamics). These participants were chosen in order to get many parts of the organisations perspective on the matter yet keep to a small group to get a good discussion. Smaller groups are recommended when the participants have a lot to say and the matter discussed is complex as in this case (Bryman & Bell, 2015. In this workshop, the participants were asked to estimate the potential of each circular business model for each success factor on a scale from -1 to 2, where -1=negative impact, 0=zero impact, 1=low positive impact and 2=high positive impact. The amount of steps of the scale was chosen to be kept to only four because of the uncertainty of the estimations, where more steps would not have given a more reliable result.

Table 3.3. Framework for potential estimation

Impact of circular business models		Success factors			
		Success factor 1	Success factor 2	Success factor 3	Etc.
Circular business models	Circular business model 1				
	Circular business model 2				
	Circular business model 3				
	Circular business model 4				
	Etc.				

During the workshop, every participant first assessed the impact individually by filling out the boxes in the framework, shown in Table 3.3 above. Thereafter, these results were compared and discussed using examples from companies, both in the automotive industry and other industries, that has succeeded within one or several areas of circular economy. From this discussion an overall estimation of the potential of each circular business model in regards to each success factor could be agreed upon.

The reason for having solely employees at Volvo Cars participate in this workshop was to engage in a participatory backcasting, where stakeholder's involvement is chosen over expert's since this enables the development of a shared future vision that is agreed upon by the stakeholders themselves (Robinson et al., 2011). This allows the stakeholders in the organisation to learn the consequences and trade-offs of their own preferences and can therefore facilitate change throughout the organisation. The choice to exclude external stakeholders was also to enable an open discussion that was not constrained by confidentiality as topics regarding future company strategy is likely to be highly confidential.

3.2.4 Step D

The aim of the last step was to compare the potential of the circular business models identified in step C with the effort needed to implement them at automotive manufacturers in general and Volvo Cars in particular. The potential of each success factor was taken from the results in step C and then discussed how they can be beneficially combined.

The effort needed was analysed by researching what Volvo Cars does today in regards to the circular business models. At Volvo Cars this was done by reviewing Volvo Cars' business today with internal documents about their business models. This was complemented by analysing the data that we had got from the seven interviews that is listed in Table 3.2 when asking them about their current work and how Volvo Cars works today. Then during the previously mentioned workshop, the three participants were asked the question "*How far is Volvo Cars from achieving these circular business models today?",* going through them one by one. The answers from the workshop responses together with the analysis from the interviews were compiled. These results were sent to the supervisor at Volvo Cars to confirm that it was correct and that no confidential information was exposed.

3.3 Quality of Research

To ensure the quality of research it can be examined by testing it in three different areas: reliability, replication and validity (Bryman & Bell, 2015). In this section these will be gone through, motivated and discussed for the conducted research. To start with reliability, Yin (2006) describes it as if another set of researchers conducted the same research, with the same case, they would come up with the same result. This can be argued to be true in some extent for this research as the steps for the backcasting can be followed and the same conclusions should be found. However, the industry for this research is changing fast and the future is very uncertain. If the research was conducted again after a period of time, the circumstances and people's perception could therefore greatly have changed. This is problematic as the relation to the question asked is likely to change over time, giving the research a lower reliability (Bryman & Bell, 2015). In addition, the results are in some part constrained by confidentiality which makes it harder to come up with the same results if not given the same access to information about Volvo Cars.

The matter of replicability is highly relevant in business research even though studies are not commonly repeated (Bryman & Bell, 2015). The study conducted at Volvo Cars could be repeated for any other car manufacturer or case company in a similar situation. All the conducted steps are explained and able to follow. The broad topic and the aim to be used as a foundation for future research and discussion however leaves more room for the researcher to interpret the questions and method as they feel suitable, decreasing the replicability as it to some extent is dependent on the researcher and not only on the method.

For the last aspect, validity, it is recommended to investigate the external validity for this sort of research (Bryman & Bell, 2015). Internal validity is only relevant when investigating causal relationships, if x leads to y (Yin, 2006) which is not the case in this research. When it comes external validity, hence if the research can be generalised beyond the specific case studied (Bryman & Bell, 2015), it is assumed that this research can be generalised for other automotive manufacturers in some of the steps. However, for the steps concerning the current situation, step B, and how big effort needed to implement the circular business models, in step D, the research is only focusing on the case object Volvo Cars and therefore not guaranteed to be the same for other companies. However, during the discussions with employees and experts in the automotive industry it was believed that most automotive companies are rather similar which increases the external validity. Due to that a participatory backcasting approach was selected for step C, as described in chapter 3.2.3, the external validity also decreases. This due to that only relevant stakeholders within the firm were interviewed in this step. For a better external validity, it would have been better to avoid participatory backcasting as more external stakeholders, not tied to the case object, then would be incorporated.

3.3.1 Ethical issues

According to Bryman and Bell (2015), there are four main areas of ethical issues: harm to participants, lack of informed consent, invasion of privacy and deception. Firstly, harm to participant has been avoided in this thesis by not discussing personal matters nor addressing the participants by their names in this report. This makes sure that no participant will be held responsible for their contribution to this study. The report was also sent to the case object Volvo Cars, to make sure that no confidential information was mentioned in the report.

Secondly, lack of informed consent has not been an issue since all participant in this study was informed about the project and their respective contribution to the research in advance. The same goes for invasion of privacy since the participants could choose not to answer questions they felt uncomfortable with. Lastly, deception was avoided through giving the participants a description about the study without concealing any information.

4 Results

In this section, the results from the four steps of backcasting will be presented and analysed consecutively.

4.1 Step A

Step A was done in order to create a vision of the future mobility market and identify success factors that will be important to achieve for an actor on this market. In this chapter, the results from the 13 conducted interviews regarding future success factors will therefore be presented and analysed.

4.1.1 Results

After summarizing and grouping the answers from the conducted interviews, 13 success factors was identified within the four categories. Three success factors are economic, two environmental, six value proposition and two other. These success factors are shown in Table 4.1 below, where the amount of times each success factor was mentioned (M) as well as the points they were scored (P) is presented. In Appendix B, a breakdown of each success factor and its points can be found, where a division of internal and external stakeholders' success factors as well as highlighted and normally mentioned success factors is presented.

Table 4.1. Scores of the identified success factors

Economic			Environmental			Value Proposition			Other		
Low total cost per km	M	10	Low/no local pollution	M	11	Flexible offering	M	11	Efficient urban land use	M	6
	P	16		P	16		P	16		P	8
High value --> High utilisation	M	4	Environmentally friendly as order winner	M	5	Easy and convenient offering	M	8	Data management	M	3
	P	6		P	6		P	11		P	5
New form of tax	M	5				Services outside mobility	M	6			
	P	6					P	7			
						Multimodality	M	5			
							P	6			
						Personal space	M	3			
							P	5			
						Safety and trust	M	6			
							P	6			

The success factors that were chosen for further analysis were the five highest scored. As shown in Table 4.1, these are: Low total cost per km, Low/no local pollution, Flexible offering, Easy and convenient offering and Efficient urban land use. The three first were mentioned by almost all of the 13 interviewees as well as highlighted by several of them as important success factors. These were all scored with 16 points. The last two was not mentioned by as many interviewees but they scored high points due to the fact that some of the interviewees highlighted them during their interviews, giving them 11 and 8 points respectively.

Between some of the success factors, similarities could be found. This in combination with the fact that not all could be chosen for further analysis mean that some of the success factors are incorporated into the five chosen ones. In these cases, the success factor that is incorporated will be presented and explained in the analysis of the respective success factor below.

4.1.2 Analysis

The interviewers agreed widely upon some success factors but mostly on the fact that the future is very uncertain and that it is hard to predict what will happen within mobility. The technologies of electrified, automated vehicles that could be beneficially shared has the potential to disrupt the whole mobility business with an uncertain outcome. In this uncertain future some success factors though seemed to be relatively common among the interviewees and these will be analysed beneath. The analysis conducted on these success factors is done in regards to the car industry and is therefore slightly adapted to this type of mobility service.

4.1.2.1 Low Total Cost per Kilometre

All except three of the interviewees mentioned the importance of being good at keeping the costs low per kilometre in the future mobility market. This due to that mobility will more and more be bought as a service where the operator no longer is a private person but rather a mobility provider. These mobility providers are more enlightened customers and will hence have a bigger knowledge in the total cost over a lifetime and prioritize solutions that offer a low cost per kilometre higher than what private car customers do today. Some interviewees also discussed the potential of car manufacturers to retain the ownership over the vehicle and then sell a functioning vehicle as a service. This means that every extra kilometre in an already produced vehicle would increase the benefits. When vehicles are bought as services instead they will also be utilised much more and therefore drive longer distances during a shorter time period putting a higher demand for durability to extend the lifetime and hence lower the cost per kilometre. The success factor High value → High utilization is incorporated into this success factor. This is due to the fact that an increased cost for producing vehicles in the future with all the modern technology will increase the incentives to utilise them more optimally to make it affordable to travel in them.

The success factor has been narrowed down to only include the total cost for a vehicle per kilometre and not consider the price that each specific customer is paying per kilometre. The price will reasonably follow the pattern of the cost but in this project the discussion has been limited to the cost, since this is the important thing for car manufacturers to keep to a minimum in the future according to the interviewees. This to be able to compete and make a profit in the changing market.

4.1.2.2 Low/no Local Pollution

Almost all of the interviewees also mentioned the importance of keeping the pollution from the car industry to a minimum. Zero pollution locally was discussed as a future demand on the market due to stricter regulations from cities and local areas. The regulations from the cities was widely discussed and thought to become stricter from most interviewees, where a few mentioned that privately owned vehicles might be prohibited in cities by 2030. Some of the interviewees also mentioned a low global pollution as an important factor, however this was described as hard to measure and collaborate around since it needs global cooperation and restrictions while local pollution is easier since it can be restricted by local policymakers. Some though mentioned that the raised environmental awareness could increase the demand of green mobility from the end customer and that a certificate of green production could make a difference if the value proposition was similar otherwise. This was however mentioned only by a few and to have marginal impact which is why it is not taken into account as a success factor in the 2030 mobility market.

In this project, the success factor will thus be limited to only investigate the local pollution, which is defined as emissions of CO2, NOX and particles coming from the tailpipe. The pollution in this definition is therefore limited to not include pollution that comes from the production of the vehicle and its material, nor from the production of the fuel that powers the vehicle. Hence, how the electricity for electric vehicles is produced will not be considered in this success factor.

Within this area electrification was discussed as the main solution since it generates zero tailpipe-emissions. The development of renewable energy and battery production will thus be vital in order to gain maximal environmental impact of this technology. Some interviewees mentioned that it was not sure that electrification was the best way forward and that new technologies could come but that they would need to have a low or zero emission in order to be successful on the future mobility market.

4.1.2.3 Flexible Offering

The offering in the future of mobility will have to be flexible in many parameters according to most interviewees. The needs will differ widely from customer to customer and type of usage. As with when you buy a car today a big family needs a big car while others just need a small city car that is easy to park, which will not change in the future. Neither will the willingness to pay for premium and the presence of different customer segments. The change will rather be in what premium is according to many interviewees. Premium in the future could be speed, personal space or the ability to perform other tasks while in the vehicle. If mobility is provided more and more as a service as some indicate the ability to change your mobility service for different tasks will also be vital. You have different needs when you are going to work every morning than when you and your family is going for a skiing holiday in the mountains, to be able to have an offering that can cover all these needs will likely be an important success factor according to the interviewees. The price levels of the different offerings will also vary where some people still are willing to pay for exclusivity and luxury while others choose the cheapest option. This can already be seen today where services like Uber have different offerings, where you can pay a premium to get a luxury car or go with UberPool to get it cheaper if you are willing to ride with others.

The success factors Personal space and Services outside mobility is incorporated into this success factor. This since personal space could be premium in the future as mentioned above. An offering can also be changed and adapted to different needs by using services that is not strictly connected to mobility, making services outside of mobility one way of gaining a flexible offering.

4.1.2.4 Easy and Convenient Offering

Regarding the offering, some of the interviewees also discussed the convenience and ease of using the mobility service. Although it was not as widely discussed as the flexibility, many thought that for a mobility service to be successful in the future it will have to be as convenient as owning your own car today. The service needs to be easy both to understand and to use for customers to be willing to change from having a private car to using a mobility service. The definition of this success factor will therefore be that the mobility service is accessible when and where you need it as well as having nothing that hinders you of utilising it when needed.

The success factor Multimodality is incorporated into this success factor, since the use of several modes of transport could help make each journey as easy, efficient and convenient as possible. To be successful with multimodality, a good collaboration with other actors on the market will be needed according to some of the interviewees.

4.1.2.5 Efficient Urban Land Use

Around half of the interviewees mentioned urban land use as an important factor and stressed the fact that finding a way to use the land efficiently will be crucial in the future. This since the population as well as amount of vehicles is increasing continuously, which is making the streets and cities crowded. A current and growing problem is where to park all of these vehicles in the big cities without making the city environment less vibrant and green. Finding a way to store these vehicles at the same time as freeing up the attractive land in the cities is therefore a future success factor. Above the parking spaces, using the roads as efficiently as possible was also mentioned as an important factor on the future mobility market to free up as much space as possible for other things than infrastructure.

4.1.3 Discussion

The answers from the interviews that was conducted are quite focused on the use-phase of the car or mobility service in the future. This means that the identified success factors also is mostly in regards to the usage of the mobility service. The main question asked to all of the interviewees was not clearly directed to the usage but due to the fact that the conversations often revolved around the end-customer it is likely that many of the interviewees interpreted the question as focused on the use-phase. The results of the interviews might have been different if a greater focus had been placed on asking specifically about other areas than the usage of the mobility service.

4.2 Step B

In step B the competencies to reach the success factors was assessed in order to get an understanding about how well, both the case object Volvo Cars and the automotive industry in general, are prepared to meet the success factors of the future megacity mobility market. In this section the results from the data collection will be analysed in regards to each of the success factors from step A.

4.2.1 Analysis

In this section the different interviewees' answers about the present state at Volvo Cars and how they work with the five success factors from Step A will be discussed and analysed. This analysis is presented below in each respective success factor, where the goal is to get an understanding of Volvo Cars' ability and focus in each area today.

4.2.1.1 Low Total Cost per Kilometre

The interviewees agreed upon that Volvo Cars do not have a low total cost per kilometre as a focus, but rather sell premium cars that are priced above average in comparison to other automotive manufacturers. Volvo Cars has no performance indicators or goals that are measured in total cost per kilometre and rather focus on decreasing the production costs with maintained quality and performance. This is logical due to that most Volvo cars are sold to private persons who use the car below 10% of the time and therefore the car will become very old and out dated before the functions starts to break down due to driven too many kilometres. The design is therefore not focusing on driving as many kilometres as possible but rather to hold for as many kilometres as it has to in normal usage before it is worn out by time, which is usually around 250 000 kilometres. They however have a history and reputation of doing high quality cars, which makes them last longer than many of their competitors lowering the total cost per kilometre but the interviewees still ranked them lower than most of their competitors.

4.2.1.2 Low/no Local Pollution

The emissions and fuel consumption has for a long time been important to attract customers and is something that has been in focus for Volvo Cars according to the interviewees. Now they have also communicated that all vehicles sold after 2019 will be electrified in some way, which is a step in the direction of decreasing local pollution. The interviewees stated that Volvo Cars has a higher market share on electric hybrid cars, about 5%, than on normal combustion cars, around 1%. They though said that when it comes to fully electric vehicles some competitors are ahead of them. To summarize Volvo Cars has a clear focus and are rather good at working with low local pollution but has much work left to do before they reach no local pollution.

4.2.1.3 Flexible Offering

Flexible offering was seen in two different ways by most of the interviewees. One is the amount of different products that are offered and here Volvo Cars are rather limited as they mainly do one type of vehicles, medium sized to big premium cars. Competitors can offer a wider range of small city cars and big mini-vans and working vehicles. The other way is in which form Volvo Cars offer their products to the customers. Here new ways of buying and owning a car such as Care by Volvo, a car subscription for private persons, and the car sharing company Sunfleet where taken as examples. This gives customers with different preferences on how to own and utilise cars more options to suit their personal needs. Some interviewees also discussed the collaboration with Uber as a step towards more flexibility as they strive to give another option for customers than driving and owning your own car.

4.2.1.4 Easy and Convenient Offering

In regards to easy and convenient offering many interviewees talked about their focus on making the lives easier for their customer. This can be seen with services such as Volvo on Call, which is a communication service connecting your car to your cell phone. This makes it possible to give temporary keys via an app to others or order service straight from your phone. With this they work to add on more services to make the lives easier for their customers. One such example is the development of in-car delivery by many Swedish e-commerce companies. They get a temporary key to the car and can see where it is located and thereby deliver packages or food straight to your car. The interviewees however said that there was still much left to do but that they are ahead of their competitors as of now.

4.2.1.5 Efficient Urban Land Use

The interviewees discussed this area as a parameter that was not taken into account in today’s automotive industry. Volvo Cars are though bigger than their competitors according to one interviewee making them take more parking spaces in cities, this is however believed to have minimal impact. The Volvo Cars owned car-sharing company Sunfleet has worked together with property developers to decrease the need of parking spaces in connection to their properties. This can be done by providing shared cars in connection to the property, which can be used more efficiently than everyone owning their own car with a separate parking space. This solution makes it possible to use a bigger portion of land to build housing on or use for other purposes than parking spaces. It has been successfully implemented both at workplaces and with private apartment complexes.

4.2.2 Discussion

It is evident from the interviews that Volvo Cars are not working towards many of the future success factors in a concrete way today. This is however rather general if looking at the whole industry and in the parameters of no/low local pollution, flexible offering and easy and convenient, Volvo Cars has made progress and are experimenting with new solutions and offerings for their customers that could help them achieve these success factors. These new initiatives are all relatively new and an indicator that Volvo Cars are preparing for a changing industry.

4.3 Step C

In this section, the third step of backcasting will be presented. Firstly, existing circular economy solutions will be presented and discussed. Thereafter, the circular business models used in this thesis will be presented and explained. These circular business models were combined with the success factors from Step A into a framework for estimation of the circular potential, which also will be presented and explained in this section. Lastly, the results from the workshop will be presented, including the agreed upon estimation of the potential of each circular business model in regards to each success factors.

4.3.1 Existing Circular Economy Solutions

In this section, the three frameworks of solutions within circular economy which were chosen for comparison will be presented. The solutions are examples of different actions that can be made in order to move from a linear to a circular economy, or simply to create a circular economy from scratch. Firstly, the solutions from each framework will be presented and explained using some examples. Thereafter, a discussion will be carried out in order to find similarities and differences.

4.3.1.1 The ReSOLVE Framework by Ellen MacArthur Foundation

Ellen MacArthur Foundation (2015b) has together with McKinsey developed a framework called ReSOLVE, where a set of six actions for transitioning to circular economy have been identified:

- *Regenerate*
- *Share*
- *Optimise*
- *Loop*
- *Virtualise*
- *Exchange*

Bouton et al. (2016) mean that transitioning into a circular economy is a complex process that requires efforts at both local, national, regional and global levels. The six actions in the ReSOLVE framework therefore needs to be taken by both European governments and companies in order for a transition to happen. The framework offers businesses and governments a valuable tool to develop circular strategies and growth initiatives (Ellen MacArthur Foundation, 2015b).

The six actions are all, in different ways, increasing the utilization of physical assets, elongating their life spans and promoting the use of resources from renewable sources over finite sources (Ellen MacArthur Foundation, 2015b). An action can be used alone or in combination with the other actions, where each action is characterised by the fact that it accelerates the performance of the other actions. The actions can therefore have a profound impact when used together (Bouton et al., 2016). In the sections below each action will be presented with examples.

4.3.1.1.1 Regenerate

The action of regenerating entails a shift to renewable energy and materials, the return of recovered biological resources to the biosphere as well as to improve the health of ecosystems through reclaiming, retaining and regenerating. Examples are the European power sector that is investing in the use of renewables as well as Savory Institute which has influenced a regeneration of 2.5 million hectares of land (Ellen MacArthur Foundation, 2015a).

4.3.1.1.2 Share

This action mainly consists of maximising the utilisation of products and decreasing the speed of the product loop. This can be done through different kinds of sharing (peer-to-peer sharing of private products as well as public sharing of products in fleets), reusing during life-time (second-hand) or prolonging the life-time through maintenance, repairs, upgradability and design for durability. Examples are BlaBlaCar, a car sharing service with 20 million registered users and Airbnb, a home sharing service with over 1 million spaces for rent (Ellen MacArthur Foundation, 2015a).

4.3.1.1.3 Optimise

Optimising can be done either by increasing the performance or efficiency of a product, by removing waste in the supply chain or by leveraging big data, automation, remote sensing and steering. The action of optimising stands out since it does not have to change the product or technology behind it, which is exemplified by Toyota's lean production (Ellen MacArthur Foundation, 2015a).

4.3.1.1.4 Loop

The action of looping involves closing the loops of components and materials and to prioritize the inner loops. For finite resources, this include to remanufacture products or components and when not possible to recycle materials. When it comes to renewable resources, it rather includes anaerobic digestion and to extract biochemicals from organic waste. Examples for this action is sewage and waste plants that produces biogas/energy (Ellen MacArthur Foundation, 2015a).

4.3.1.1.5 Virtualise
Virtualizing is about delivering utility virtually, where examples are books, music, online shopping and virtual offices where value is provided virtually without the need of physical resources (Ellen MacArthur Foundation, 2015a).

4.3.1.1.6 Exchange
This action is both about exchanging materials, technologies and products/services and about choosing new and advanced ones instead. Examples are 3D printing, electric engines, multi-modal transport (Ellen MacArthur Foundation, 2015a).

4.3.1.2 Five Business Models for Circular Economy by Accenture
Accenture (Lacy et al., 2014) have identified five different underlying business models for circular economy. These business models are developed free of constraints from linear thinking and aims to help companies gain resource productivity. This at the same time as enhancing differentiation and customer value, reducing cost and generating new revenue streams while reducing risk. The five business models are as follows:

- *Circular supplies*
- *Resource Recovery*
- *Product Life Extension*
- *Sharing Platforms*
- *Product as a Service*

Similarly as the actions in the ReSOLVE Framework, each model can be used alone or in combination with the other business models. In the sections below, each business model will be explained further (Lacy et al., 2014).

4.3.1.2.1 Circular Supplies
This business model aims at using solely renewable, recyclable and biodegradable resources as input instead of scarce resources. This means that the traditional linear resource approaches is replaced while cutting waste and removing inefficiencies, turning the production and consumption systems circular. Example from the industry for this business model is the chemistry company Royal DSM, who have developed cellulosic bioethanol from a by-product of fermenting sugars derived from crops (Lacy et al., 2014).

4.3.1.2.2 Resource Recovery
This business model is about recovering the value at end-of-life for one product and using it in another life-cycle. This can be done through innovative recycling, reprocessing or upcycling which transforms waste into value and promotes return

chains. The advantage of this business model is that it eliminates material leakages and maximizes the value of each product. It is especially good to use for companies with large volumes of by-products and with waste that easily and cost-efficiently can be reclaimed and reprocessed. It can also be to take advantage of cross-company or cross-industry by utilising a symbiosis. Examples from industry are grocery store Kroger that converts food waste into renewable energy through anaerobic digestion as well as carpet manufacturer Desso that separates the yarn from the other material in old carpets, which enables the yarn to be used again (Lacy et al., 2014).

4.3.1.2.3 Product Life Extension

The aim of this business model is to extend the life-time of a product or asset as long as possible to maximize the value and hopefully increase the revenue. This can be done through maintenance, repairs, upgrades, remanufacturing or remarketing. It is important to manage the upgrades and target them in the right way in order to harvest the full potential of each product or asset. An example is the mobile phone arena, where Google's project Ara is trying to capture the full value of the smartphone by modular design. This gives the possibility to replace and swap the modules to customize the phone but also to repair it easily and cost-efficiently. The need for new material as well as waste is therefore reduced (Lacy et al., 2014).

4.3.1.2.4 Sharing Platforms

This business model advocates a platform that makes it possible for users to collaborate and share their products. It, similarly to other solutions, aims at maximizing the utilization by leveraging on the sharing of overcapacity and underutilization. The model can greatly benefit companies with a low utilization rates of their products but is more often seen at companies that does not produce the products but simply maximizing the utilization rate of other companies' products. Examples of this is Lyft, where the underutilization of cars (80 % of seats empty during normal use in city areas) is being taken advantage of by enabling ride sharing (Lacy et al., 2014).

4.3.1.2.5 Product as a Service

This model has been developed as a contrary to the traditional buy-and-own business model, where the products instead is leased or payed-per-use by one or several users. The model shifts the focus from volume to performance making features such as longevity, reusability and sharing drivers of revenue instead of risk of cannibalization. Companies with products that have a high cost of operation and are better at maintenance of their products than customer are most beneficial of using this model. One example for this model is Michelin, who sells tires as a service where customers lease tires and pay per miles driven. Michelin then takes care of the maintenance of the tires giving customers a hassle-free use. This model encourages Michelin to produce long-lasting tires which can be reprocessed into input for new tires other value-use (Lacy et al., 2014).

4.3.1.3 Circular Strategies by Circle Economy & ABN AMRO

The social enterprise Circle Economy, who works with helping companies and organisations to increase their circularity, has together with the Dutch bank ABN AMRO identified eight circular strategies that they believe will be important for the automotive industry (Kemps & Vos, 2016):

- *Recyclable, low impact materials*
- *Design for disassembly*
- *Smart systems*
- *Lifetime extension*
- *Revised & upgraded parts*
- *Take back*
- *Parts recovery*
- *Recycling & upcycling*

The different strategies entail different opportunities for the three phases of a car's life-cycle: design and produce, use and end-of-use. The first two strategies are mostly connected to the design and produce-phase whereas smart systems, lifetime extension and upgraded parts is connected to the use-phase and the last three most important for the end-of-use-phase. In the sections below, each strategy will be presented and exemplified using the automotive industry (Kemps & Vos, 2016).

4.3.1.3.1 Recyclable, low impact materials

This strategy involves the development of innovative materials that are safe and light-weight while being recyclable and having minimal impact on the environment. In today's automotive industry the pressure is high on reducing emissions, which has led to an increase in new, lightweight materials. However, the new materials (for example aluminium and carbon fibre) are often more complex, less recyclable and causing higher environmental costs than the traditional. To become circular, it will therefore be important to identify and start using materials that combines lightweight with reduced environmental impact (Kemps & Vos, 2016).

4.3.1.3.2 Design for disassembly

The aim for this strategy is to enable easier disassembly and recovery at the end-of-use by designing for modularity. In today's automotive industry it is quite common that car suppliers use a standardised platform in reaction to safety regulations and to reduce costs. For new business models it is however important for the cars to be easy to upgrade, repair, maintain and disassemble after use which puts a higher pressure on the design. By using new, innovative circular solutions that focuses on modularity and reconfigurability, it will be easier and less time-consuming to exchange and adjust parts (Kemps & Vos, 2016).

4.3.1.3.3 Smart systems

For this strategy, the goal is to enable greater monitoring and tracking through intelligent and connected systems. Due to the fact that almost 75 % of the total emissions from a car is in the use-phase, the pressure from policies to decrease this impact is high. This, together with an increased customer demand for connected, comfortable and safe cars, has led to the development of sensors and innovative technology that optimises the vehicle operations. These new solutions are improving the resource use, maintenance and safety of the cars which are in line with circular economy (Kemps & Vos, 2016).

4.3.1.3.4 Lifetime extension

This strategy involves maintenance, repair and upgrade services with the aim of a continued functionality and a long life-time. The trend in the automotive industry right now is an increased utilization of cars due to new service models. This is making the maintenance and upgrades more important to manage in order to extend the life-time of vehicles. Examples of solutions that help manage and predict the appropriate timing is telematics solutions, sensor technologies and all-in-one service offerings, these solutions help to both maximize the utilization, minimise costs and prevent problems from occurring (Kemps & Vos, 2016).

4.3.1.3.5 Revised & upgraded parts

The aim of this strategy is, similarly as for *Lifetime extension*, a continued functionality but through enabling a supply of revised and upgraded replacement parts. The policy pressures that exist in the automotive industry for safety is making car manufacturers very careful about which parts they use in their cars, which is often resulting in them using virgin materials. However, the trend with higher utilisation of cars, due to new business models such as sharing, will increase the deterioration hence increasing the importance of revised car parts for reuse or even upgrading entire cars (Kemps & Vos, 2016).

4.3.1.3.6 Take back

This strategy simply aims at capturing the value of car parts at end-of-use. In today's automotive industry the recycling rate is as mentioned earlier not high even though vehicles have a lot of second-hand value at the end-of-use. This means that take-back programs are necessary and already have been established by car manufacturer both through public marketplaces and through their own buyback schemes (Kemps & Vos, 2016).

4.3.1.3.7 Parts recovery

In this strategy, reusable parts and components are harvest to be used again after end-of-use, which can be both as the same part or in another area of the industry. Today, parts recovery is mainly achieved by car manufacturers that harvest parts at end-of-use that have a sufficient second-hand value (Kemps & Vos, 2016).

4.3.1.3.8 Recycling & upcycling

This strategy is simply to maximise the material use in the industry by reusing and recycling for new innovative purposes. Today, processes exist in the automotive industry which ensure that metals and other materials are recovered when cars are scrapped. With the use of new innovative materials, it will be important to develop a way to recover these as well. Some companies have already started this development by conducting research to find recycling opportunities and innovative uses to maximize the value from materials used in cars (Kemps & Vos, 2016).

4.3.1.4 Discussion of the Three Frameworks

Through comparing the three different frameworks, the different circular economy solutions could be grouped into four main areas based on their similarity. These areas are presented in Table 4.2 below, where the solutions from the three different frameworks are categorized in one of the four areas. Each area is thereafter discussed further.

Table 4.2. Categorisation of circular economy solutions into four main areas

	ReSOLVE - Ellen MacArthur	Five circular business models - Accenture	Circular Strategies - Circle Economy & ABN AMRO
Design for circularity	Regenerate	Circular Supplies	Recyclable, low impact materials Design for disassembly
Extend life-time	Share	Product Life Extension	Lifetime extension Revised and upgraded parts
Optimize utilization	Share Optimise Virtualise Exchange	Sharing Platforms Product as a Service	Smart systems
Recover value	Loop	Resource Recovery	Take back Parts recovery Recycling & upcycling

The area *Design for circularity* includes using the right materials and design from start, which is discussed in all frameworks through the solutions *Regenerate, Circular Supplies, Recyclable, low impact materials* and *Design for disassembly*. The three first solutions are focused on using innovative, renewable and recyclable materials to decrease the use of virgin materials and therefore the impact on the environment. Furthermore, *Regenerate* and *Design for disassembly* highlights the importance of recovering the resources through either regeneration or by designing for modularity from start. This first area can therefore be strongly linked to the design and production-phase of the life-cycle, where the material and design choices are being made.

The next main area that have been identified, *Extend life-time*, is about maximizing the life-time extension through maintenance, repairs and upgrades. This is discussed in both *Lifetime extension* and *Revised and upgraded parts* in Circle Economy's framework and in *Product Life Extension* in Accenture's framework, where the goal is to manage the maintenance and upgrades to maximize life-time and value. Life-time extension is also included in *Share* from the framework by Ellen MacArthur. This solution will however be further discussed in the next main area, which similarly as this aims at maximizing the value but rather through finding new ways to optimise the usage. These two areas are therefore both connected to the use-phase of the life-cycle.

The third main area, *Optimize utilization,* is about optimizing the utility of a product during its life-time. Hence, this area is very broad and contains several of the solutions from the frameworks. *Share* and *Sharing Platforms* are naturally similar where the focus is on making it possible for users to collaborate and share underutilised products to maximize their usage. The solutions *Optimise, Smart systems* and *Product as a Service* are also included in this area since they all involve using new and innovative technologies, processes and value propositions to optimise the performance of the product. The two solutions *Virtualise* and *Exchange* from Ellen MacArthur's framework are not really similar to any of the other solutions in the frameworks and hence not discussed thoroughly in this thesis. However, if they should be included in one of the main areas it would be under this third one since they are both mostly including new ways to optimise the usage. This area therefore involves sharing, reusing and increasing the performance efficiency of a product with the goal to optimize the utilization and decrease the speed of each product loop.

The last main area, *Recover value*, evolves around remanufacturing, recycling and upcycling and hence include the solutions *Loop, Resource Recovery* as well as the last three from Circle Economy's framework *Take back, Parts recovery* and *Recycling & upcycling.* This area is therefore about recovering as much value as possible in the end-of-use-phase of one product to close the loops of materials and components. What would otherwise be considered waste can with these solutions be turned into value, where the recovered parts or materials can be used either to produce the same part, another part of the same product or in a completely different field within or outside the industry.

Several similarities can also be found between the four main areas where for example designing products to be modularized is mentioned under *Product Life Extension* in the first area and hence making this solution connected to *Design for disassembly* which is under the second area. The two first main areas are also connected by the fact that *Revised & upgraded parts* are about using recycled and revised parts in the car, which is what the first area is all about. However, the goal of this solution is rather to increase the life-time than to minimize the use of virgin materials. This solution is also more connected to the use-phase that the design and produce-phase of a car's life-cycle.

Moreover, the first area and the last area are linked since it is crucial that recycling and recovering of materials after end-of-use is at place in the industry to be able to decrease the amount of virgin material brought into the production.

4.3.2 Identified Circular Business Models

From the four areas presented above, seven business models about how a circular urban vehicle can be designed, manufactured, used and retained at end-of-use were developed. These were validated with an environmental strategist at Volvo Cars in order to ensure that they were relevant and applicable for the automotive industry. The choice to formulate it as an *urban vehicle in 2030* was done in order to make it easier to assess the potential in the urban future mobility market. The seven business models are presented below in Table 4.3 and thereafter described in greater detail.

Table 4.3. Circular Business Models

Area	Business Model
Design for circularity	The urban vehicle in 2030 is modularly designed to easily be upgraded and parts replaced
	The urban vehicle in 2030 is designed to reduce the amount of material and use as much renewables as possible
Extend life-time	The urban vehicle in 2030 is developed to last for as many kilometres as possible
	The urban vehicle in 2030 is continuously monitored to optimize its maintenance and service
Optimize utilization	The urban vehicle in 2030 is provided as a mobility service to the end customer
	The urban vehicle in 2030 and its value proposition is designed to enable shared mobility
Recover value	The urban vehicle in 2030 is retained at end-of-use to capture full value through reusing, remanufacturing and recycling

4.3.2.1 The urban vehicle in 2030 is modularly designed to easily be upgraded and parts replaced

The vehicle should be designed in standardised modules that can be exchanged easily. This goes for both non-visible parts vital for the function of the vehicle and for visible parts for the function as well as if they look or feel worn out. It is not limited to exchanging malfunctioning parts but could be used to upgrade hardware to update the vehicle and its performance and look. The modular design focus is on decreasing the need of exchanging the whole vehicle when a certain part is broken or feels out-dated. It also makes reparations and maintenance easier and less time consuming.

Modular design is commonly used to decrease the production cost and time with standardised modules utilising economies of scale. This is a positive and important aspect for manufacturing companies but not something that will be in focus in this research.

4.3.2.2 The urban vehicle in 2030 is designed to reduce the amount of material and use as much renewables as possible

This circular business model firstly focuses on decreasing the amount of material. This can be done both by taking away unnecessary material but also with new engineering and production solutions that demand less material. Thereafter the material that is needed should to the widest extent be renewable in some form. Recycled non-renewable is not covered in this business model as it is incorporated in business model seven.

4.3.2.3 The urban vehicle in 2030 is developed to last for as many kilometres as possible

Today's cars are not designed to last for as many kilometres as possible but rather for a specific amount of kilometres so that they last for many years. This is due to that cars are under-utilised today and therefore get old and out-dated before they reach this number of kilometres with normal usage. This circular business model aims to shift the focus to designing vehicles that lasts for as long as possible in order to decrease the need to produce new vehicles with all the material and energy that takes.

4.3.2.4 The urban vehicle in 2030 is continuously monitored to optimize its maintenance and service

Modern technology with sensors can give knowledge about the products status in real time and increase the ability to predict and optimize maintenance and services. This could decrease the downtime and prolong lifetime of a vehicle. Predictive maintenance, where the product is monitored and the faults are predicted beforehand, is more efficient than reactive maintenance where the faults are only taken care of when they appear.

4.3.2.5 The urban vehicle in 2030 is provided as a mobility service to the end customer

To increase the utilisation of vehicles it would be better if they were provided as a service. This means that you pay per consumption of the vehicle which can be done in different ways. Today’s cars stand still for over 90% of the time and are one of the biggest investments a private person does. A mobility service is here defined as business models where the customer pays per consumption of the mobility service. Examples included in this definition are car sharing, where you pay for every time you use a car, taxi services, where you pay to be taken from point A to point B but also other modern solutions enabled by new technology that lets the customer pay for temporary access to a vehicle.

4.3.2.6 The urban vehicle in 2030 and its value proposition is designed to enable shared mobility

This circular business model aims as the previous one to increase the utilisation but instead of increasing the usage in time it is focused on increasing the number of passengers per car. A study in Switzerland showed that in peak hours it is only 1,34 persons per car today (Bösch, Becker, Becker, & Axhausen, 2018). If the vehicle and how it is sold would incentivise sharing both with known persons but mainly with stranger sharing it could decrease the need of vehicles both in total and on the roads. This differ from business model five in the way that this business model aims to increase the number of passengers per vehicle and the previous is rather about increasing the utilisation of the vehicle. One example to clarify the difference is that normal UberBlack, where you have exclusive access to the car with the driver, belongs to business model five whereas UberPool where you pick up more passengers along the road to share the ride belongs here in business model six. If the vehicle and how it is sold is designed to facilitate such value proposition it could increase the number of passengers per vehicle.

4.3.2.7 The urban vehicle in 2030 is retained at end-of-use to capture full value through reusing, remanufacturing and recycling

When worn out at the end of usage the vehicle should be taken back to the manufacturer in order to capture what is rest of the total value. The loops should be closed so that everything is taken care of through reusing, remanufacturing or recycling. First is should be assessed what parts that could be reused in new vehicles after that what could be remanufactured and lastly what need to be recycled in order to create new materials. This would decrease the need of virgin materials and also have the potential to lower the production cost of new vehicles. This is especially important with scarce materials. If the ownership remains at with the manufacturer the take back becomes easier to administrate.

4.3.3 Framework for Potential Estimation

After identifying both the circular business models, which is presented above and the success factors presented in Step A, a framework for potential estimation could be developed. This framework combines the seven circular business models with the five success factors in a matrix, which is presented below in Table 4.4.

Table 4.4. Framework with success factors and circular business models

Impact of circular business models		Success factors				
		Low total cost per km	Low/no local pollution	Flexible offering	Easy and convenient offering	Efficient urban land use
Circular business models	The urban vehicle in 2030 is modularly designed to easily be upgraded and parts replaced					
	The urban vehicle in 2030 is designed to reduce the amount of material and use as much renewables as possible					
	The urban vehicle in 2030 is developed to last for as many kilometres driven as possible					
	The urban vehicle in 2030 is continuously monitored to optimize its maintenance and service					
	The urban vehicle in 2030 is provided as a mobility service to end customers					
	The urban vehicle in 2030 and its value proposition is designed to enable shared rides					
	The urban vehicle in 2030 is retained at end-of-use to capture full value through reusing, remanufacturing and recycling					

Every box in the matrix represents a circular business model in comparison with a success factor, which adds up to 35 different combinations. These 35 combinations were all discussed and analysed during the workshop with Volvo Cars' employees. In the workshop, the participants were first asked to estimate the potential on their own and then these results were compared and discussed. After this discussion, an overall estimation was agreed upon by all participants of the workshop and the results of this estimation will be presented below.

4.3.3.1 Results and Motivation

The workshop showed that for more than half of the combinations, the circular business model would not have a significant impact on the success factor. The result of the workshop was namely that 17 of the 35 combinations were estimated as having zero impact, which is visualised with a blue colour in the Table 4.5 presented below. The rest of the combinations were assessed as having some sort of impact, where the green colour visualises a high positive impact, the yellow a low positive impact and the red a negative impact in Table 4.5 below.

Table 4.5. Framework with estimations of potential

Impact of circular business models		Success factors				
		Low total cost per km	Low/no local pollution	Flexible offering	Easy and convenient offering	Efficient urban land use
Circular business models	The urban vehicle in 2030 is modularly designed to easily be upgraded and parts replaced					
	The urban vehicle in 2030 is designed to reduce the amount of material and use as much renewables as possible					
	The urban vehicle in 2030 is developed to last for as many kilometres driven as possible					
	The urban vehicle in 2030 is continuously monitored to optimize its maintenance and service					
	The urban vehicle in 2030 is provided as a mobility service to end customers					
	The urban vehicle in 2030 and its value proposition is designed to enable shared rides					
	The urban vehicle in 2030 is retained at end-of-use to capture full value through reusing, remanufacturing and recycling					

In the coming sections, the motivations from the workshop for each of the coloured boxes will be presented by going through the success factors column by column. The blue boxes with no impact will not be motivated in detail in these sections.

4.3.3.1.1 Low Total Cost per Kilometre

The total cost per kilometre is positively impacted by all the circular business models but in different ways. That the vehicle is designed to last for as long as possible can dramatically increase the number of kilometres that the vehicle is driven, lowering the total cost per kilometre. For an electric vehicle that is developed to last, Ellen MacArthur Foundation (2015a) claims that it could last for as long as 1 000 000 kilometres. This is around four times longer than what a personal vehicle is developed to last for today. Above this, other similar industries such as trucks and busses has longer lifetimes for their vehicles and the workshop participants saw no reason why a personal vehicle that were developed to last could not last for as long.

Monitoring and optimized service also prolongs the lifetime of vehicles as well as decreases the cost of maintenance. Rolls Royce mean that they have managed to decrease the need for service with 25% utilising sensors and machine learning to predict faults (Rolls Royce, 2018a). Modular design also decreases the cost of service and can also prolong the lifetime of the car if parts are exchanged instead of changing the whole car. No adequate benchmarking results were found in regards to prolonging lifetime with modular design but it was still seen as an interesting opportunity among the workshop participants and hence ranked as high positive potential to decrease the total cost per kilometre.

To use new design and engineering solutions to decrease the amount of material used for a vehicle could reduce the cost of material and therefore decrease the production cost. This was discussed as extra vital in the future if raw material prices of scarce resources became more expensive. To use more renewables could also be a solution if this became the case. Engineering solutions such as 3D printing were mentioned as an example where new cars are said to weigh a lot less than similar vehicles and thereby consuming less material.

If the vehicle was provided as a mobility service instead of as today with private ownership, the investment cost could dramatically be decreased. Arbib and Seba (2017) predict that when autonomous vehicles become reality the costs could be ten times lower for the end customer per kilometre if they buy their mobility as a service through so called robo-taxis. This is extra important if technology advances and the personal vehicles becomes more expensive than they are today. How much cheaper it becomes if the mobility is provided as a service is thus depending on how far technology has come and how the value proposition of the service is constructed. As of today, taking a taxi is still more expensive per kilometre than owning your own car for most private persons. This is why it is ranked to have low positive impact. However, it was discussed that this potential is very hard to estimate as it depends greatly on what type of mobility service that it is going to be.

To design the vehicle and its value proposition to enable shared mobility was agreed to have a big positive impact due to that the costs of operating the vehicle each kilometre would be spread out on more people. Today during peak hours, each private car holds on average 1,34 persons. This number is doubled if the vehicle is provided as a shared solution to 2,6 (Bösch et al., 2018), which halves the cost per person per kilometre.

Lastly, to retain the vehicle at end-of-use to capture full value through reusing, remanufacturing and recycling was valued to have a low positive impact. This is due to the fact that remanufacturing and reusing is less expensive than producing new parts. Renault claims that they can remanufacture 46% of their parts to a 30-50% lower cost (Ellen MacArthur Foundation, 2013a). Rolls Royce state similar numbers in number of parts remanufactured or reused but does not include an economical saving in their report (Rolls Royce, 2018b). This would then reduce the manufacturing cost of new vehicles and thereby lower the total cost per kilometre.

4.3.3.1.2 Low/no Local Pollution

In regards to this success factor only two circular business models were believed to have an impact. This is due to that none of the others impacted the way that the vehicle was powered directly or how much energy is consumed during its usage. However, if the vehicle is continuously monitored and optimally maintained the workshop participants argued that the energy consumption could be monitored and optimized to be controlled in a better way than it is today. Also if the vehicle were shared the amount of pollution from each individual per kilometre would be decreased. This would though loose its effect if electricity or other forms of energy with zero local emissions powered the vehicle and therefore it was ranked to have low positive impact.

4.3.3.1.3 Flexible Offering

The success factor flexible offering is estimated to be impacted by all circular business models expect those concerning what material is used and how it is taken care of at end-of-use. The maintenance and monitoring of the vehicle was expected to have too little impact in regards to flexible offering, meaning that it could be neglected.

A modular design was estimated to have a low positive impact due to that parts could easily be replaced which changes the vehicle and how it can function. A comparison was made to system cameras where you easily can exchange the lens to change the functionality and use it for more purposes.

If the customer buys their mobility as a service, the flexibility was expected to be positively impacted since the customer can buy a different service for each purpose. Today usually one car is used for all purposes in a household but if this was bought as a service the vehicle or mobility solution would probably differ between different times. As an example a typical customer would want another type of vehicle when going to work each morning than they would want when going to the beach with the whole family on a weekend.

If the vehicle is designed to last for as long as possible this was considered to have a negative impact for the flexibility. This due to the fact that if the vehicle lasts longer it would take a longer time before it is exchanged and thereby the offering could not be adapted in the same pace as if changing the vehicle more often. Lastly if the vehicle and its value proposition were designed to enable shared mobility it was also valued to have a negative impact due to that you have to consider others' wishes and travel patterns and hence cannot choose exactly when and where the vehicle should go by yourself.

4.3.3.1.4 Easy and Convenient Offering

For easy and convenient offering it is estimated that three out of seven circular business models has an impact. The ones concerning the material choice and how it is retained at end-of-use is, as with the previous success factor, estimated to have minimal impact. A modular design was thought to potentially make it easier for the customer to change parts but this was accounted for in the potential for a flexible offering instead. Also how long the vehicle is developed to last for was estimated to have minimal effect on the easiness and convenience of the offering.

To continuously monitor to optimize the service was estimated to have a small positive impact due to the fact that it would decrease the downtime for the vehicle and also decrease the amount of surprising breakdowns of the vehicle. This would hence make the offering easier and more trustworthy. To provide the vehicle as a service was during the workshop discussed to have a high positive impact on this success factor, with the reservation that it had to be done in a good way in order to make it more easy and convenient than owning your own vehicle. If this was accomplished the workshop participants saw big benefits to consume mobility as a service since the customer would not have to consider reparations, services, cleaning and everything else that comes with owning your own vehicle.

To design and provide the vehicle as shared was estimated to have a negative impact on the easiness and convenience for the end customer. This has a similar motivation as for flexible offering since it becomes less easy and convenient when the customer has to consider other customers' needs and wills.

4.3.3.1.5 Efficient Urban Land Use

The impact on the urban land use is only estimated to be impacted by two of the seven circular business models. The business models concerning production, material choices, service and maintenance, how the car is taken care of at end-of-use and if it is modularly designed are estimated to have no or marginal impact on the urban land use. Some of them were discussed to have an impact on the global land use but none for the urban land use as the success factor was defined.

To provide the urban vehicle as a service was estimated to have a low positive impact as the amount of vehicles needed in total would decrease. This would not mean a decrease in number of vehicles on the roads but would open up space designated for parking today, as the vehicles would be rolling for a bigger portion of the time. These parking spaces could then be used for other purposes. The same argument goes for the shared vehicles but the impact here is estimated to be high. This since it also would free up space from roads as the total amount of vehicles on the roads would decrease if they were shared.

4.3.3.2 Discussion

The success factors brought up here was in the urban megacity setting and hence circular business models that more aims to solve global environmental issues has little impact on many of the success factors, examples are that the vehicle should be designed with less material and use renewables as well as how it is taken care of at end-of-use. The questions regarding the success factors was asked mainly regarding what will be important for customers when they use mobility in the future. This explains why the circular business models that focused on the use phase were estimated to have much more impact on the success factors than other circular business models.

During the workshop the participants agreed on most impacts, especially after discussing them together and giving examples on how the circular business model could impact the success factors.

4.4 Step D

In this section each of the circular business models will be analysed first regarding its potential and then regarding the effort needed to implement it. Thereafter a discussion will be presented around what solutions that should be prioritised based on this analysis.

4.4.1 Potential and Effort of Circular Business Models

In the following sections, each of the circular business models will be gone through. Firstly, the potential of the business model and then the effort needed to implement it will be presented and analysed.

4.4.1.1 The urban vehicle in 2030 is modularly designed to easily be upgraded and parts replaced

Potential - As shown in Table 4.5 from Step C, this circular business model has a high positive impact on low total cost per km and a low positive impact on flexible offering. For the other three success factors, it was evaluated as having no impact. This means that this circular business model is not affecting a majority of the five success factors, no success factor was however judged to be negatively impacted if this business model would be implemented. The overall potential is therefore positive but an implementation of this business model solely will probably not be of great importance in the future.

This business model is frequently spoken about as a way to prolong the life-time of a product, which in this case would give a high impact on decreasing the total cost per kilometre. This also means that it has the possibility to enable the third circular business model, to develop the vehicle to last for as many kilometres driven as possible. The workshop participants also discussed the potential of selling modules rather than whole cars as a new business solution. This would give a greater connection to the customer as well as decrease the waste from scrapping parts of products that are not worn out at the same pace as others. It could also be a solution to prolong the feeling of a fresh and modern vehicle if some vital parts where exchanged after a number of years, updating it to feel as new again. This could be connected to the circular business model about retaining the full value at end-of-use as a modular design would make it easier to separate and reuse parts in new vehicles that still are functioning as intended. The same motivation was partly used for the positive impact on flexible offering, since if parts could easily be replaced it will be easier to make changes to the vehicle and how it can function. This is therefore not limited to only update the parts if they are worn out but also if a customer’s needs changes, making it possible to adapt the vehicle to each customer higher.

Effort - The automotive industry has worked with modules for a long time but primarily in order to lower production costs and increase the variability for customers when ordering their own car. It has not been implemented to make maintenance and exchanging parts easier. This has rather become more complicated with time as the car has become more complex with more electricity and digital solutions according to the workshop participants. One example was given with exchanging a lamp in a car, before it could be done at home but now it has become so complicated that it has to be done by professionals.

Volvo Cars has been working with implementing new standardised platforms (called SPA) lately. These could be a foundation to continue a modular design on. The employees participating in the workshop however said that the focus needs to shift from only lowering production costs to also make it easier and more convenient to exchange parts.

4.4.1.2 The urban vehicle in 2030 is designed to reduce the amount of material and use as much renewables as possible

Potential - As shown in Table 4.5 from Step C, this circular business model only has a low positive impact on low total cost per km and no impact on the rest of the success factors. This means that by itself it will not be greatly beneficial in the future. However, if crucial non-renewable materials will substantially decrease and hence increase in price in the future, this business model could be very important for success. This since the cost of the vehicle can be kept low due to a low material usage and low dependence on scarce non-renewable materials. New engineering technology, such as 3D printing, was discussed to potentially lower the usage of material drastically if successfully implemented and hence increase the potential to decrease the usage of materials.

Furthermore, this business model has a great positive impact on the global environment in general since it minimizes the depletion of scarce material through both using as little material as possible and using renewables. However, this is not reflected in the five success factors and hence the potential of this business model might be bigger than shown by the evaluation in Step C.

Effort - To reduce the amount of materials in a vehicle has been in focus in the automotive manufacturing industry for a long time but mostly in order to reduce the weight of the vehicles. Volvo Cars' vehicles are however 300 kg heavier than the average European car and 100 kg heavier than their direct competitors' vehicles.

New engineering solutions that make the vehicles lighter are a big focus. With the rapid development of 3D printing much is happening. 3D-printing has reached production in a small scale and is on the brink to go in to full production. This is already done in other industries such as specific components for airplanes and spacecraft.

In the last couple of years many manufacturers have started to experiment with renewable materials. This is though mainly done in places where the functionality is not crucial and as of now not in a big scale.

4.4.1.3 The urban vehicle in 2030 is developed to last for as many kilometres as possible

Potential - As shown in Table 4.5 from Step C, this circular business model has a high positive impact on low total cost per km and a negative impact on flexible offering. Regarding the other three success factors, it was evaluated as having no impact. This means that the business model might not be that beneficial in the future. However, to make the vehicle last longer has the highest impact out of all the circular business models on lowering the total cost per km for the vehicle. This since the cost per kilometre drastically can decrease if the vehicle can be used for many more kilometres, since all the fixed costs of the vehicle will be spread out on more kilometres. Since the success factor of lowering the total cost per km is the one that most interviewees mentioned and highlighted, the ability to impact this can also be seen as more important than to impact the other success factors.

Furthermore, if this business model is combined with providing the vehicle as a mobility service, the fifth circular business model, it can impact the total cost per km even more. This would namely increase the focus on prolonging the life of the vehicle as every extra kilometre it is rolling adds revenue for the service provider. In comparison to selling it as a one-time investment, where the manufacturer wants the customer to buy a new one eventually, this business model could substantially decrease the cost per kilometre even if the production cost of the vehicle would go up with more robust components.

If combined with providing the vehicle as a service, the negative impact on flexible offering could also be reduced. The motivation for the negative impact when discussed during the workshop was that if the vehicle last for a longer time, it will not be changed in the same pace and hence not as adapted to the customers' latest needs. However, when providing a long-lasting vehicle as a service it will not be the same customer that uses and owns the same vehicle for a longer time but rather that the vehicle is in service for a longer time and provides mobility to many different customers with different needs.

Effort - The workshop participants mentioned that Volvo Cars had, compared to their competitors, been historically famous to build long lasting cars. This difference was however discussed to decrease, even though the quality focus is high at Volvo Cars. For the automotive industry as a whole it is important to build high quality vehicles but the focus on making them last for as many kilometres as possible is not there. This is due to the way they are used at the moment with a low utilization rate. Studies, and also after talking to employees at Volvo Cars, shows that it would be relatively easy to build a vehicle that last longer, in terms of kilometres, if the focus shifted to that. As an example it was mentioned that trucks, that are similar in their functionality, last much longer than a car today.

For electric vehicles, this also becomes easier since an electric powered vehicle does not get worn out as fast as a combustion car that has many more mechanical parts. The battery however loose some of its effect and might therefore need to be exchanged sometime during the lifetime. To summarise it the effort would be relatively low, in comparison to other circular business models, to build a vehicle that lasts for many more kilometres, especially if done with electric vehicles. However, for Volvo Cars to earn money from building vehicles that way the value proposition to the customer would also need to change. If they sold vehicles that lasts much longer with today's business model they would only sell less vehicles since the customers would buy new less often.

4.4.1.4 The urban vehicle in 2030 is continuously monitored to optimize its maintenance and service

Potential - As shown in Table 4.5 from Step C, this circular business model has a high positive impact on low total cost per km and a low positive effect on low/no local pollution as well as easy and convenient offering. Regarding the other two success factors, it was evaluated as having no impact. This shows that having a continuously monitored vehicle with optimized service and maintenance can be rather important in order to be successful on the future mobility market. The high impact on low total cost per kilometre was motivated with that already today some taxi cars has a double lifetime guarantee on some vital parts of the powertrain with more frequent services. The optimized services make them last the double amount of kilometres and hence there is a big potential to extend the lifetime of the vehicle, reducing the cost per kilometre. During the workshop it was also discussed that modern monitoring technologies and sensors could decrease the cost of service and maintenance as the vehicles condition could be monitored. Decreasing the cost for maintenance and service was also seen as a potential to decrease the total cost per kilometre but not to have as big impact as extending the lifetime.

For low/no local pollution the workshop participants discussed the potential to have better control over the engine and its condition as an engine that is not functioning correctly will emit more. This potential would however be irrelevant if electric vehicles took over the market and therefore not seen as to have a big impact. For easy and convenient offering it was discussed that if faults and breakdowns could be anticipated and prevented with monitoring and predictive maintenance it would make the offering more convenient and reliable for the customer. The impact was however not estimated to be big due to the fact that it is relatively rare that a vehicle breaks down and hence not something most private customers consider on their everyday journey.

Effort - Sensor and monitoring technology has evolved lately both in performance and what it can do but also in price as it has become cheaper. Manufacturing companies, like SKF, has started to make this part of their business. In vehicles, manufacturers have for a long time worked with sensors to monitor some vital parts, such as oil temperature and air pressure in the tires. This has however only been developed to help the user and has not yet been connected to the manufacturer after they have produced the vehicle. Hence, there is a knowledge about sensor technology and how to monitor the vehicle but it is not connected and monitored as of today. The workshop employees said that if vehicles became more connected overall it would be relatively easy to work more with monitors.

To accomplish a better service scheme with predictive services an extensive service network is important. Here Volvo Cars collaborates with brand service centres and the connection has become better in recent years. As cars become more and more complicated the need of specific brand service centres increases. This collaboration could be used to further collaborate around improving the service and maintenance for the customers.

4.4.1.5 The urban vehicle in 2030 is provided as a mobility service to the end customer

Potential - This circular business model has a positive impact on four out of the five success factors, where it has a high impact on flexible offering as well as easy and convenient offering and a low impact on low total cost per km as well as efficient urban land use. For low/no local pollution is was judged as having no impact. By simply looking at the evaluations of its potential in Table 4.5 from Step C, this circular business model is the one with the highest combined potential. The participants in the workshop all agreed that this business model is getting more and more popular as well as important for mobility providers to understand and implement.

For low total cost per kilometre it was estimated to have a low impact since it can optimize the usage of the vehicles in a better way and therefore decrease the importance of the investment cost. The potential to combine this with the third circular business model, to develop a vehicle that last for as many kilometres as possible, was discussed as very interesting and in that case the potential to lower the cost per kilometre could be higher. For efficient urban land use it was estimated to have a positive impact since many parking spaces could be used for other things if less private vehicles needed parking in urban areas. It would though not decrease the number of vehicles on the roads and therefore the impact was estimated to be low.

For easy and convenient offering as well as flexible offering the potential was estimated to be high. This since providing mobility as a service rather than a big investment gives the customer much more flexibility in using different forms of mobility for different needs. It also makes it easier and more convenient as the customer does not need to care about maintaining the vehicle and does not carry the financial risk it is to own a vehicle today. However, during the workshop one participant had put easy and convenient offering as negative impact if the service was not provided in a very good way. This since owning a private car is easy and convenient in terms of that you always know where it is and can use it as you want. Therefore, the service has to be provided so that you always can get a vehicle when you want and that you can use it as you would have done with a private vehicle, then it has the potential to become more easy and convenient.

This circular business model can be combined efficiently with several of the other business models. For example, providing the vehicle as a service enables mobility providers to own the vehicles throughout its life-cycle and hence gives them better control over the vehicle and its material. This helps both the seventh business model, to capture full value at end-of-use, and the fourth business model, to continuously monitor the vehicle to optimise the maintenance and service. When combining this business model with a few others, the economic and environmental benefits can therefore be major in the future.

Effort -The participants in the workshop mentioned that Volvo Cars are taking steps towards this circular business model already today, with project such as Care by Volvo. Care by Volvo is a subscription service where the customers no longer buys the car with a one-time investment but instead leases the car for a monthly fee. This enables Volvo Cars to retain the ownership of the car as well as include more services in its offering to the customers. However, today the cars from Care by Volvo are sold on the aftermarket when taken back after two years and hence not provided as a service through the lifetime. The same goes for Sunfleet, which is owned by Volvo Cars. They provide mobility as a service where customer can access cars temporarily in a carpool. Their vehicles are also sold to the aftermarket after two years in service.

Volvo Cars has also entered a cooperation with Uber which is another step towards providing mobility as a service. However, this cooperation is today mainly based on Volvo Cars providing Uber with cars to be used in their existing fleet. Hence, Volvo Cars is not part of developing or providing the actual service. The collaboration is a good start for moving into the service business but Volvo Cars are today far from providing the service themselves.

4.4.1.6 The urban vehicle in 2030 and its value proposition is designed to enable shared mobility

Potential - This circular business model has an impact on all of the five success factors, it is however positive for three of them and negative for two of them. The negative impact applies to the success factors referring to the offering, namely that it is flexible as well as easy and convenient. The business model is above this judged as having high positive impact on low total cost per km as well as efficient urban land use and low positive impact on low/no local pollution, as shown in Table 4.5 from Step C.

In total, the circular business model has the chance of being greatly beneficial in the future as long as the negative impact on the offering is erased or minimized. This is thought to be possible, similarly as for business model three, by combining this business model with business model five - to provide it as a mobility service. If the mobility service is designed in a good way, the negative impact on flexibility and convenience might not have to be high. If many customers use the mobility service and the service is provided in a good way, the workshop participants believed that riding shared vehicles would not decrease neither the easiness and convenience nor the flexibility. This as many people would use it and hence many rides that fit each customer's needs would leave at a frequent pace. This would therefore not force any customer to adjust its travel behaviour to a wide extent.

The potential to increase the efficient urban land use was judged as high as the number of vehicles on the roads would decrease if they were shared. During the workshop, and also while talking to experts in the subject of the future of mobility, the possibility for policymakers to incentivise people to go in shared vehicles is already present. An example is specific lanes for shared vehicles in American cities or cities in Asia where you can only enter certain areas if you are more than one in the vehicle. It was also discussed that it could become more common to prohibit people to go alone in vehicles hence making shared mobility an order qualifier in some big cities.

The total cost per kilometre for the customer was estimated to go down if people ride in shared vehicles simply by the fact that there are more persons splitting the cost. The cost for the vehicle itself per kilometre however was estimated to not be affected. By the same logic the local pollution was estimated to go down as fewer vehicles emit less emissions. However, the effect of this is taken away if the vehicles are powered by electricity or other power sources with zero tailpipe emissions.

Effort - Volvo Cars has of today neither made any advances to specifically design its cars to enable shared mobility, nor to provide a service for sharing. However, the cars are design for several people where all of the models have at least five seats. The workshop participants saw it as unlikely that Volvo Cars would start adjusting the design of the cars to be more suited for shared mobility as all their focus today is on providing personal vehicles. The physical design is thus rather easy to change and if the demand for vehicles that are suited for shared mobility would rise it would probably be rather easy for the designers at Volvo Cars to come up with such solutions.

Volvo Cars has a collaboration with Uber, who provides the shared mobility service UberPool. This might evolve in the future and make Volvo Cars ahead of their competitors in the field of shared mobility if they collaborate to provide more customers with shared mobility.

4.4.1.7 The urban vehicle in 2030 is retained at end-of-use to capture full value through reusing, remanufacturing and recycling

Potential - As shown in the Table 4.5 from Step C, this circular business model only has a low positive impact on low total cost per km and no impact on the rest of the success factors. This means that by itself it will not be able to be greatly beneficial in the future. However, as mentioned earlier, if this business model is combined with providing the vehicle as a service and hence retain the ownership of the vehicle, it can be of great value. This since the material much easier can be captured at the end of each vehicle's and its respective parts' life-cycles.

Furthermore, this business model has a great positive impact on the global environment in general since it minimizes the depletion of scarce material through reusing as much material as possible, meaning that less material will have to be extracted from the earth. However, this is not reflected in the five success factors and hence the potential of this business model might be bigger in a global environmental perspective than shown by the evaluation in Step C.

Effort - Several actors in the automotive industry has engaged in remanufacturing and recycling for a long time but not in a very broad scale. It is hard to fully implement the reversed supply chain that is needed in order to take back a big portion of the cars. The workshop participants discussed that this would need a new organisation as well as incentives for the car owners to return their cars. It would also need new types of factories as remanufacturing and recycling demands other processes than only producing new parts. If the manufacturer kept the control of the vehicle during the whole lifetime, and sold it as a service as in business model five, it would be easier to take back the vehicles and extract the value that is left at end-of-life in a better way. Overall the effort needed to do this in large scale would be rather high but the technology is there and the work is in progress to extend the amount of recycled and remanufactured parts.

4.4.2 Discussion of Potential and Effort

As can be seen when estimating the potential of the circular business models many of them are better if combined thus choosing one over the other is hard. However, providing the mobility as a service can be seen as an important, both in terms of the potential it had on the success factors in the framework but also that is can be seen as a key to unlock the potential from many of the other circular business models. It is however rather tough to transform the business to provide mobility purely as a service as this demands new capabilities and resources in the company. Other business models that has less impact but also demands less effort are developing a vehicle to last for as many kilometres as possible and that it is continuously monitored to optimize its maintenance and service. These two are evaluated to be easier to implement but in order to make it in a profitable way for the manufacturer it would demand new types of business models. This due to that today's vehicles are not serviced by the manufacturer directly and there are no incentives to make a vehicle today last much longer as it only would result is less vehicles sold. However, if these two were combined with mobility as a service it could have a great potential.

Overall the total potential of the circular business models is not fully considered as most success factors are mainly connected to the use-phase of the future of mobility. This decreases the impact that circular business models focusing on the production or end-of-life treatment has. However, these can have a big impact on the production cost of vehicles and especially on the global environmental impact of producing vehicles. This is not considered in the success factors as only local pollution was seen as a success factor by the interviewees.

5 Conclusions and Discussions

In this chapter, the findings from the thesis will be summarized and presented in a conclusion. Thereafter, a discussion of the findings will follow and lastly a recommendation for further research will be presented.

5.1 Conclusions of the Findings

Circular economy is a hot topic that can help not only the environment but also companies to find new business models. This is also true for the automotive industry and especially in the future mobility business. However, the future is very uncertain and especially in the mobility business as the industry is going through rapid technology changes. The topic is also broad, which makes it hard to give concrete estimations about the future. In this conclusion, the two sub research questions will be addressed before the main research question, regarding the potential of circular business models within the future of mobility, will be answered.

Firstly, to answer the question "*What will be important success factors on the future mobility market?"* all the interviewees and also literature in the area agrees that it is very uncertain. So much is happening with the technology and legislations that it is hard to predict what is going to happen and how fast. The thing that most agree upon is that the industry will go through changes in faster pace than has happened recent decades. This is mainly driven by the three trends that is shared economy, automated vehicles and electrification. From the interviews with experts on the future of mobility both internally at Volvo Cars and with external researchers and stakeholders five success factors were compiled as the most important, shown in Figure 5.1 below. These were seen as important to be good at for any actor trying to be successful on the future mobility market. Volvo Cars, and other automotive manufacturers, lacks the potential to meet many of these factors as of today with the current business model and product range.

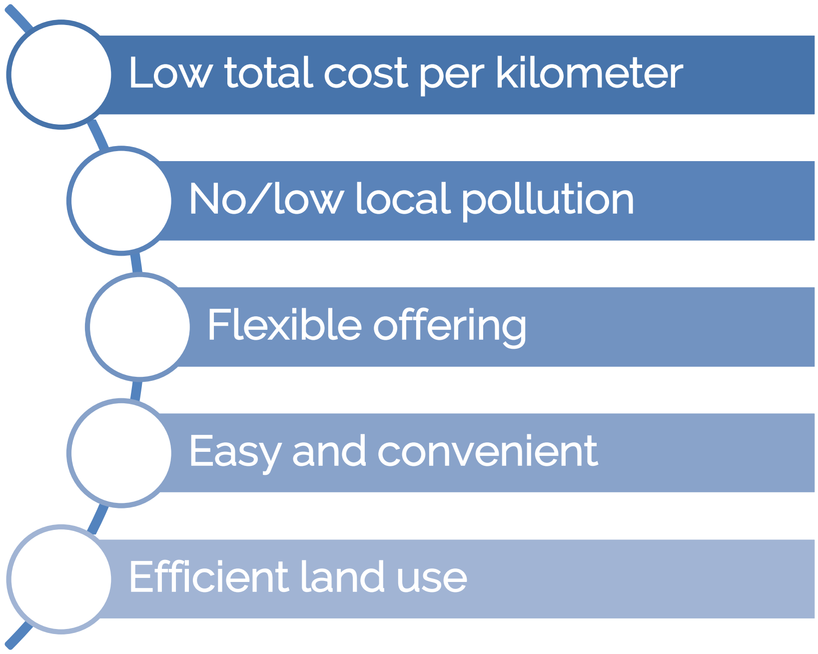

Figure 5.1. The success factors on the future mobility market

The other sub research question "*Which circular business models have the potential to impact these success factors on the future mobility market and then in what way?"* deals with how well different business models are suited for this future mobility market. To answer this, seven circular business models for the automotive industry were generated, shown in Figure 5.2 below, and their potential in regards to the previously explained success factors estimated. The results from this estimation showed that some circular business models have more impact than others on the success factors. Primarily to build an urban vehicle and its value proposition that is provided as a mobility service to the end customer was estimated to have the highest positive potential in regards to the success factors. To implement all seven of the circular business models had the greatest impact on offering a low total cost per kilometre which was also one of the most important success factors as it was mentioned in almost all interviews. Overall from the discussions held, it is clear that circular business models can have a great impact on the future of mobility if it is done right. Since the success factors focuses on the use phase of the mobility it is hard to capture the full value of many of the circular business models. Some of them focus on using less virgin materials in the production of the vehicle, which could have a great impact on the global environment. This is however not accounted for in this research as none of the success factors for the urban mobility market address this issue.

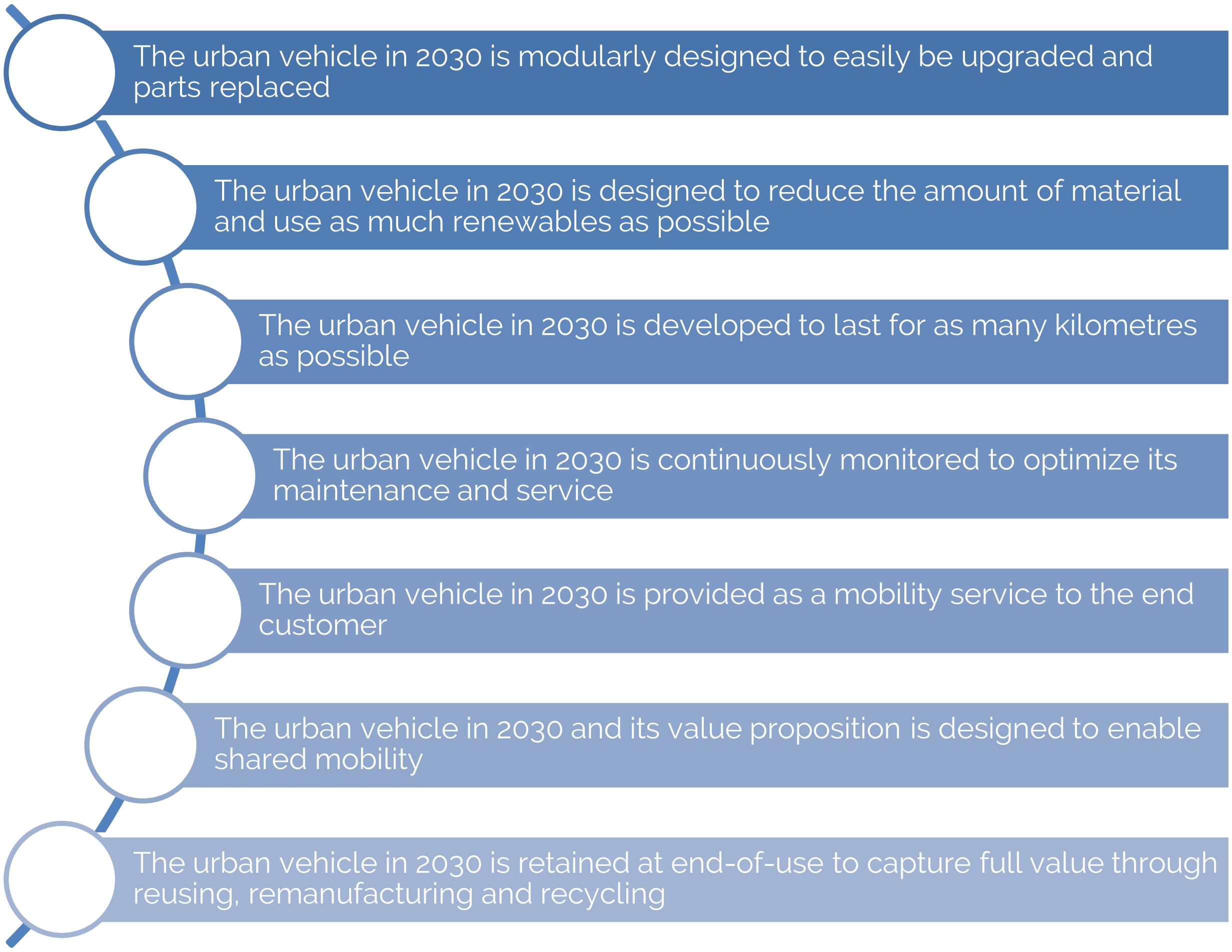

Figure 5.2. Circular business models for the future mobility market

Some of the circular business models are already today being used in a limited scale or are in a development phase at Volvo Cars. However, to be fully implemented, Volvo Cars and other automotive manufacturers have a long way to go. The potential of these circular business models is in many cases greater if combined making it harder for the automotive manufacturer to see the benefit of implementing them one by one. The business model that has come the furthest is working with remanufacturing, recycling and reusing since programs for this exists at both Volvo Cars and other automotive manufacturers. Examples can also be drawn from other industries where this progress has come further. However, this has little impact on the success factors investigated in this research since it has little or no impact on the use phase of the mobility solution.

To address the main research question *"What is the potential with adopting circular business models for automotive manufacturers in the future mobility market?"* it can be concluded that a lot about the future of mobility is yet to be discovered. New technology is expected to change the circumstances for all parties in the industry and how we as private persons consume mobility, especially in urban megacities. From this research it seems like circular business models can have an important role to play in this new reality but exactly how and what the impact will be is impossible to say. The concept of circular economy is getting attention from companies in many sectors as well as governments and organisations and it could be time to investigate further how automotive manufacturers can work with circular economy to not fall behind. With the rapid technology advancements in electrification, automation and the trend of shared economy it could be the time to try new circular business models as automotive manufacturers has to go through big changes anyway.

5.2 Discussion

The purpose of the thesis, to create a broader understanding about the potential of circular economy within the automotive industry, is regarded as fulfilled where the results of the study can be used as a foundation for future discussion and research within the area. The main research question of the thesis has been answered, though the exploratory nature of the question will not result in a concrete suggestion as an answer.

The conclusion described above is dependent on the circumstances of the industry today as well as the case object which means that in other circumstances it might differ. If the automotive industry moves in another direction than where it is heading today, with automation, electrification and shared economy, the answer of sub research question a) will likely not be the same. This as the success factors in the industry changes with the circumstances and hence result in other success factors than the ones identified in this study. The same goes for the answer on the sub research question b), as the potential of the circular business models are dependent both on the success factors and on the environment they operate in. As an example, if the development will slow down and not much will differ from today’s industry, many of the circular solutions will lose their positive impact. These two answers are the foundation for the main research question and hence the answer to this is also related to the development on the mobility market. One concrete example is the development of self-driving vehicles. If no breakthrough will come and self-driving vehicles won’t come to the mass market, the circumstances to apply circular solutions on will change dramatically. For an example it will be much harder to provide mobility as a service if the vehicle cannot drive itself. This is just one out of many uncertain circumstances that can change the rules on the mobility market and therefore make some of the estimations in this thesis irrelevant.

The findings in the thesis has been generated specifically for the case object Volvo Cars, which means that the results and conclusions cannot be directly applicable onto other organisations or industries. It could however be used by other automotive manufacturers whom are similar to Volvo Cars. As mentioned in Quality of Research (see chapter 3.3), the rapidly changing nature of the industry studied, means that the findings might be different even for the same case object in a not so far future. The findings can therefore not be said to be generalised. However, the method used in this thesis can be applied by companies in the same industry as well as in other industries in the future.

In addition, some of the findings of the thesis might be usable for other companies. For example, the success factors that was identified in Step A, could be applied to other actors in the mobility market since these are regarding success on the future mobility market as a whole. As mentioned in chapter 3.2, Step B and Step D, concerning the current situation and effort needed implement the circular solutions, is focused solely on the case object Volvo Cars making the findings less generalised. The same accounts for Step C, where the findings to an extent are dependent on the case company since the workshop was conducted solely with employees from Volvo Cars because of the participatory backcasting approach chosen. However, the findings from this step could to some extent be generalised to other automotive manufacturers that are similar to Volvo Cars and are going through the same changes.

5.3 Recommendations

The area studied in this thesis is highly interesting and relevant in today's society. How the mobility of the future will evolve and how the actors on this market best can adapt to this development is of great importance both for the actors as well as the environment. To continue the research on what possibilities environmental-friendly solutions, such as circular business models, can provide is therefore important both to increase awareness and to incentivise the implementation of sustainable solutions. More research within this area should therefore be conducted to find other relevant solutions as well as new potential benefits with these.

The problem might have to be divided into smaller parts in order to bring about more reliable and detailed predictions. For example, each of the circular business models that have been analysed in this thesis have several aspects to them and can therefore impact the future in different ways. If each of these business models were analysed, new potential benefits and drawbacks could be found and analysed. This would generate a more reliable overall prediction.

In future research it is recommended that different future scenarios are analysed to better understand how the mobility market will develop and hence how different sustainable solutions can meet this future. This will give a further understanding of the market and the opportunities that both exist today with circular business models as well as what possible opportunities they can bring in the future depending on scenario. If several scenarios are studied and analysed, a more reliable overall picture and a broader understanding can be reached.

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Appendix

The appendix shows an interview guideline used during the interviews as well as the results from these interviews. The interviews were semi-structured which means that they did not follow the exact order of the guideline presented here.

A. Interview guideline

Before the interviews, the form below was sent to all interviewees including the main question for the interview that was broken down into four subcategories.

What do you envision will be the success factors of the leading mobility providers in the megacities-market in 2030?			
Economic	Environmental	Value proposition	Other

During the interview, the master thesis project was described before the following general questions were asked:

- *Can you tell us about yourself and how you work with the future of mobility today?*
- *What do you think will be the general trends on the future mobility market?*

This in order to get a better understanding about the knowledge of the interviewee and their work and to get the conversation going.

Thereafter, the main question below was asked to the interviewees:

- *What do you envision will be the success factors of the leading mobility providers in the megacities-market in 2030?*

The four categories in the form above were gone through one by one with follow up questions to keep the interview rather structured and not go too far off track. Lastly the interviewees were asked if they felt that something was missing or if they wanted to complement on any answers given.

B. Success factor interview results

Economic				
Success factor	Volvo interviewees		Other interviewees	
	Normal	Highlighted	Normal	Highlighted
Low total cost per km	1	4	3	2
	Mentioned			10
	Points			**16**
High value --> high utilisation	1	2	1	0
	Mentioned			4
	Points			**6**
New form of tax	2	0	2	1
	Mentioned			5
	Points			**6**

Environmental				
Success factor	Volvo interviewees		Other interviewees	
	Normal	Highlighted	Normal	Highlighted
Low/no local pollution	1	4	5	1
	Mentioned			11
	Points			**16**
Environmentally friendly as order winner	2	1	2	0
	Mentioned			5
	Points			**6**

Value proposition				
Success factor	Volvo interviewees		Other interviewees	
	Normal	Highlighted	Normal	Highlighted
Flexible offering	3	2	3	3
	Mentioned			11
	Points			**16**
Easy and convenient offering	4	1	1	2
	Mentioned			8
	Points			**11**
Services outside mobility	3	1	2	0
	Mentioned			6
	Points			**7**
Multimodality	2	0	2	1
	Mentioned			5
	Points			**6**
Personal space	1	2	0	0
	Mentioned			3
	Points			**5**
Safety & trust	2	0	4	0
	Mentioned			6
	Points			**6**

Other				
Success factor	Volvo		Other	
	Normal	Highlighted	Normal	Highlighted
Efficient land use	2	1	2	1
	Mentioned		6	
	Points		**8**	
Data management	1	0	0	2
	Mentioned		3	
	Points		**5**	