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Electromobility's impact on supplier networks in the car industry

Assessing suppliers' awareness and readiness

Master's Thesis in the Master's Programme

Supply Chain Management

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Abstract

The automotive industry is currently facing four main trends described as SpACE; Service providers, Autonomous, Connectivity and Electromobility (Triathlon Group, 2017). The last trend refers to a transportation system based on vehicles driven by electricity. This concept is increasingly seen as favorable since it could avoid problems related to oil and biofuels. During the climate agreements in Paris 2015, Sweden stated it will be one of the first fossil-free developed countries (Smith et. al, 2018). The development and increasing sales of electric cars can be seen as one main goal to reach the agreements by 2030.

The development of electromobility and car manufacturers being more involved in sustainability put pressure on the upstream suppliers. Transforming the combustion powertrain, which has been developed in decades, to a fully electric powertrain results in changes of the existing powertrain. However, there is a lack of information on how this change will affect the supply chains within the car industry and what new requirements the suppliers will face. Thus, the purpose of this thesis is to examine how the development of electromobility will impact supply chains within the car industry. The thesis aims to study the main component changes between a combustion and a fully electric powertrain. Thereafter, the goal is to identify which suppliers are affected, explore the suppliers' preparation and define common key success factors for adapting towards electromobility.

The frame of reference consists of literature regarding electromobility, supply networks, sourcing strategies and change management. The drivers behind electromobility can be referred to concerns for energy security, air pollution and climate change legislation (Grauers et al., 2013). Abrahamsen and Håkansson (2012) mean that by combining different businesses within the network, the individual organization may derive greater value than if acting on its own. In addition, sourcing has become a strategic part of many businesses (van Weele, 2014) and Kotter (2011) has presented eight steps in a change model as a tool for successful change implementation.

The empirical data supporting the thesis was collected through interviews, where a qualitative strategy was used. This collection was divided into two main phases; the component study and the supplier study. The first phase consisted of interviews held with researchers and experts within automotive industry and electromobility. The second phase included interviews with suppliers currently delivering to car industry or potentially will deliver in the future. Data from the first phase was analyzed, together with online research and frame of reference, twelve components were identified on the powertrain. These components were divided in four different changes; radically, low/no, added or disappear. Out of these changed components, thirteen suppliers were identified and interviewed.

These thirteen suppliers were all somehow affected by the development of electromobility. Four different steps of adaptations were defined: affected by the changes, planned some adaptation, started some adaptation and deliver to electric powertrain. Most of the suppliers have already planned some adaptation but not yet started it. Car manufacturers do not demand large volumes for electric powertrains yet, which could be a reason why only 23% of the suppliers are currently delivering to fully electric powertrains. For the suppliers which have come far in the adaptation, three main key success factors could be identified; close relationships with few customers, being able to learn from the early adapters and avoid being replaced, defined as timing, as well as having the right competence.

Key words: electromobility, supply network, sourcing strategy, change management, car industry

Terminology/Abbreviations

Downstream chain	Customer side of the chain
Economies of scale	Reduced costs per unit that arise from increased total output of a product.
Electromobility	Development of electric-powered vehicles to shift away from fossil fuel driven vehicles
EV	Electric Vehicle
FKG	Fordonskomponentgruppen
ICE	Internal Combustion Engine
OBC	On-board Charger
OEM	Original Equipment Manufacturer
Upstream chain	Supply side of the chain
SpACE	Service provider, Autonomous, Connectivity, Electromobility

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1 Introduction

In this chapter the background is presented including the relevance of making this thesis. Furthermore, the purpose and research questions are given followed by the delimitations of the thesis as well as the disposition.

1.1 Background

The access to various technologies increases and makes the world move towards globalization and the changes happen fast. In late 2017, Triathlon Group, a global consultancy firm, defined four main disruptive changes within the automotive industry technology developments (Triathlon Group, 2017). The four changes were presented as SpACE; Service providers, Autonomous, Connectivity and Electromobility. The first disruptive change is referring to automakers becoming the service providers. According to Seba (2017), new technologies within the automotive industry change companies' business models due to market changes. Since technologies such as software as a service and platform as a service will get more members in the near future, companies should nowadays also consider transport as a service (Seba, 2017).

The second disruptive change refers to autonomous vehicles which are no longer a futuristic vision, the vehicles are already tested on public roads. Since most accidents occur by human mistakes, road transportation gets safer using autonomous vehicles (Volvo Cars, 2017). In addition, according to Volvo Cars, autonomous vehicles are more energy efficient because of smoother driving. The third change within the automotive industry is Internet of Things (IoT) and vehicles using connectivity. Using connectivity, vehicles are able to communicate to cities, people and other vehicles (Arnäs, 2017). Drivers can easily access real-time data of current traffic situations and route-changes as well as receive feedback concerning carbon footprint and emissions while driving.

The last change is the development of electromobility which can be described as the increasing commercially launch of electric vehicles. The spread of car ownership from the developed to the developing world, environmental legislation and concerns about the availability of fuels all together result in road transportation facing higher political and socio-economic pressure (Dell et al., 2014). Tougher regulations and higher taxes for emissions are introduced by governments to reduce the negative environmental impact. According to Sandén and Wallgren (2017), today's transportation relies heavily upon oil which is a scarce fossil fuel that contributes to climate change and air pollution. The concept electromobility refers to a transportation system based on vehicles driven by electricity. This concept is increasingly seen as favorable since it could avoid problems related to both oil and biofuels, as well as to meet customers' mobility needs and desires. Several actors both within and outside automotive industry predict the future of road transportation as one technological diversity.

During the climate agreements in Paris 2015, Sweden stated it will be one of the first fossil-free developed countries (Smith et. al, 2018). The Swedish government made the decision that 70% of the climate impacts from domestic transportation will be reduced at the latest 2030. The development and increasing sales of electric cars can be seen as one main goal to reach the agreements by 2030. Hence, Swedish companies within the automotive industry try to meet requirements from both government and users in order to ensure sustainability in future transportation.

In 2017, Volvo Cars, one large original equipment manufacturer (OEM), announced that from 2019 the production of making vehicles solely powered by internal combustion engines (ICE) will stop (Volvo, 2017). According to The Guardian, several car manufacturers, such as

Renault, Nissan, BMW and Volkswagen, have declared ambitious plans for electric cars with grants from governments (Vaughan, 2017). In 2016, the number of electric cars on the road globally hit 2 million, up from hundreds in 2005. However, some parts of the world are moving faster. In Norway, pure electric models accounted for almost 21% of new car sales in 2017 (Ayre, 2018). In China, 102 000 new passenger plug-in electric vehicles were registered in December 2017, which was an increase of 130% compared to the previous year (Pontes, 2018). In addition, one of the electric vehicle pioneers in China was ranked as the second bestselling electric model in December 2017.

However, the development of electromobility and OEMs being more involved in sustainability puts pressure on the upstream suppliers. Transforming the combustion powertrain, which has been developed in decades, to a fully electric powertrain results in changes of the existing powertrain. These changes will then probably impact what existing powertrain suppliers deliver today. According to Seba (2017), around hundred times less components will be used when changing from traditional combustion vehicles to electric. However, there is a lack of information on how this change will affect the supply chains within the automotive industry and what new requirements the suppliers will face. Actors related to automotive industry need to understand what type of changes the development of electromobility will result in, but also which suppliers that will be affected. Furthermore, there is a need for the car industry and the OEMs to know how aware and prepared upstream suppliers are of the increased electromobility.

1.2 Purpose

The overall purpose of this thesis is to *examine how the development of electromobility will impact upstream supply chains within the car industry. In order to reach the purpose, the work has been divided in two studies. The first study aims to investigate the main component changes between a combustion and a fully electric powertrain in order to determine which types of suppliers that will be affected. Thereafter, the second study aims to explore the suppliers' preparation connected to the foreseen component changes and identify common key success factors for adapting towards electromobility*.

1.3 Problem formulation and research questions

The car industry is in an era where technology develops fast and different trends will affect the future for actors within the industry. Many studies have been done concerning electromobility and the main drivers of its development (Grauers et al., 2017; Sandén, 2017; Figenbaum, 2015). However, there is a lack of literature concerning what impact this trend will have on the supply networks of the car manufacturers. It is of importance to investigate which car components will be changed, either completely exchanged or just modified, to foresee what adaptations will be necessary and for which suppliers these changes will apply. Therefore, the first research question is formulated as:

RQ 1: *What components are affected when changing from a combustion powertrain to an electric powertrain?*

The development of electromobility is happening with increasing speed, implying that there is a need for all actors within the car industry to keep up with the changes. By being aware of how an actor will be impacted, there is a higher possibility to be prepared when the changes actually happen (Fritzenschaft, 2014; Cameron & Green, 2012). Thus, the likelihood of being replaced or lose market share decreases drastically. There has previously been little research made on this area why it is of interest to examine how prepared the potentially affected suppliers are. Moreover, it is of interest to know what they are doing in order to adapt to the changes they are currently foreseen to face. Accordingly, the second research question is presented below:

RQ 2: *Which suppliers are affected and how aware and prepared are they for the change they are facing?*

1.4 Delimitations

The master's thesis takes into consideration the car industry alone with the focal point in OEMs and their upstream suppliers. No deliberation is taken to downstream actors in the supply chain of the OEMs. Neither are aftermarket services, such as maintenance and supply of spare parts, included.

Furthermore, the need of adapted infrastructure and charging stations is not taken into consideration since it in this thesis is defined as a downstream issue. Moreover, the likelihood of scarcity of material used for electric battery production is not considered. Finally, the impact of changes of the financial situation will not be accounted for, even though it is likely that a financial crisis would impact the demanded volumes of electric cars as well as strategic decisions made by the actors in the car industry.

1.5 Disposition

The report includes seven chapters which all concern different parts, all relevant to reach the aim of the thesis. The chosen structure is to make it easier to follow the thesis when reading but also to easier find more interesting or important parts for each reader. In *Chapter 1. Introduction* the background is given to present why the thesis is needed, as well as its purpose and delimitation. *Chapter 2. Methodology* walks through the specific studies and the methods used to collect and analyze the data, which then result in the findings. Thereafter, *Chapter 3. Frame of Reference* is presented to show previously done research within the thesis' main areas. This chapter presents relevant theories to be able to understand the thesis' content. In *Chapter 4. Findings & Analysis of the Component Study* the component study is presented as the first results of the thesis. These findings are then used for the second study in *Chapter 5. Findings & Analysis of the Supplier Study*. The supplier study presents the findings from the supplier interviews and analyzes the suppliers' awareness and preparation. *Chapter 6. Discussion* is where all collected data and analysis are discussed together with the frame of reference. Finally, *Chapter 7. Conclusion* gives the thesis' conclusions and answers the purpose and research questions.

2 Methodology

In this chapter the method used for the project is presented. The research strategy and process are described followed by a description of the data collection as well as the data analysis. The process, data collection and data collection are divided into the two different studies the thesis was divided in. Finally, the quality assurance is proven.

2.1 Research strategy

A qualitative research strategy was used in this thesis. Holme and Solvang (1986) stress that an advantage with the qualitative research is that it provides a holistic viewpoint. This was beneficial in the study since an increased understanding of the current situation regarding electromobility was essential in order to analyze the future prospects.

2.2 Research process

In order to answer the two research questions and to achieve the purpose of the thesis, the project was conducted in two main phases, named as component study and supplier study, see Figure 1. Before the component study could start, a literature review was conducted, in which scientific articles and books found on Chalmers' library database were used. Key words that were searched for were for instance; "electromobility", "supply chain networks", "sourcing" and "change management". Some articles used in the literature review were recommended by supervisors. The output of the literature study was the frame of reference, presented in *Chapter 3*.

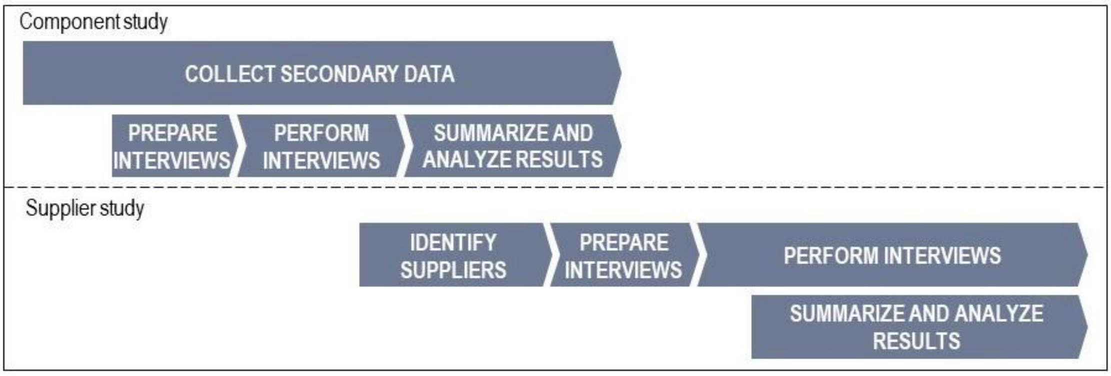

Figure 1. The process for executing this research.

2.2.1 Component Study

The first phase, component study, was executed during the beginning of the research process and its purpose was to answer the first research question. Along the study, secondary data was collected at the same time as interviews were prepared and performed. To establish the interview framework, a workshop together with Triathlon Group was held. The main goal of the workshop was to discuss potential interview questions and confirm the interview framework. This was done to ensure that the interview response later could answer the first research question. Interviews were held with researchers within electromobility at Chalmers University of Technology and car industry experts, see *Chapter 2.3*. In *Appendix 1*, the interview framework together with all questions is given.

Before the interviews were held, a rough mapping of the ICE and electric powertrain was done to be able to modify and confirm this during the interviews. The mapping displayed parts of the powertrain grouped into main components and this was mainly a result from online research and input from experienced consultants at Triathlon Group. The mapping was shown at the end of the interview to avoid inhibiting the interviewee's knowledge and thoughts. Accordingly, in the beginning of the component study, the mapping was modified and adjusted by the interviewees, but in the later part of the study, the mapping was confirmed. In some cases, an interviewee was again asked about some components to ensure that both parties agreed. Finally, all interviewees agreed on the powertrain components which was later used as input in the second phase of this thesis. The transition from the component study to the supplier study is described in Figure 2.

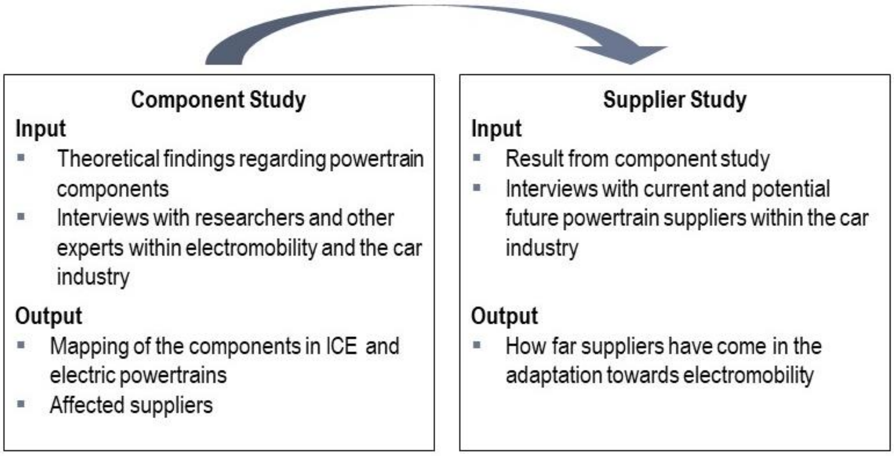

Figure 2. Input and output from each phase in this master's thesis.

2.2.2 Supplier Study

The second phase of the thesis, the supplier study, aimed to answer the second research question. The first activity, in Figure 1, was to identify which supplier that might be affected of the findings from the component study. Most of the suppliers were found from Fordonskomponentgruppen's (FKG) members list, where it was possible to find information about different companies in the automotive industry and their supplying components. Some additional suppliers were found during interviews with ISEA, from the component study, and online research.

Thereafter, the next activity was to prepare the interview, which was done by a workshop together with Triathlon Group to ensure that the interview response later could answer the research question. The main goal of the workshop was to discuss potential interview questions and confirm the interview framework. In *Appendix 2*, the interview framework including all questions is given. When the questions were decided, the next activity, perform interviews was done along with the activity summarize and analyze results.

2.3 Data collection

Two different types of data were collected in this thesis. Primary data from interviews, both from the component study and supplier study, as well as secondary data from online research. Firstly, the data collection of the component study is presented, where the collection is divided into primary data through interviews and secondary data which was used as a complement to the primary data. Secondly, the data collection of the supplier study is presented where all data was collected from interviews.

2.3.1 Component study

The data collection in the component study is divided into primary data through interviews and secondary data used as a benchmark for the data analysis.

Primary data through interviews

For the component study phase of the thesis the primary data collection consisted of interviews with researchers and former and current employees at a car manufacturer. These former employees are called experts in the thesis since they have more than 30 years of experience and knowledge within automotive industry. Due to that both researchers and experts were used in the study, a more detailed view was given of what impact electromobility will have on supply chains. Furthermore, the interviews gave a deeper understanding of the affected components as well as information regarding drivers and challenges of electromobility.

The interviews were of semi-structure character which is a common approach when interviewing in qualitative researches Bryman & Bell, 2011). In a semi-structured interview an interview guide, a list of questions that cover a certain subject, is usually used by the interviewer. The interviewers were not constrained by the guide, follow-up questions were therefore asked in order to receive exhaustive answers from the interviewees. The semi-structured interview method gave the possibility to change and develop the interview through the study (Denscombe, 2014). This method was advantageous since it allowed the interviews to be open and the answers could be more elaborate, which was a good foundation for analysis of the primary data. In addition, all interviews were done face-to-face, which according to O'Gorman and MacIntosh (2015), is more suitable to perform when the interview is less structured. Hence, it is more effective since it absorbs more information. In total, six interviews were held with different experts and researcher within the car industry, detailed information about the interviewees is presented in Table 1. The interviews were 60 minutes to ensure that follow-up and control questions could be asked within the time slot.

Table 1. Detailed information about interviewees for component study

Company	Company description	Interviewee description	Number of interviews
ISEA	ISEA is a professional service organization that represents a large number of senior executives and experts	Senior experts with long experience in automotive industry	2
Chalmers University of Technology	Chalmers University of Technology is a Swedish university that focuses on research and education in e.g. Technology and management areas	Researchers within electromobility	2
Fordonskomponent-gruppen (FKG)	FKG is a Swedish organization for Scandinavian automotive industry suppliers helping member to become better suppliers	Chief executive officer	1

Original Equipment Manufacturer (OEM)	Global original equipment manufacturer in the car industry	Purchasing Manager, ICE and electromobility	1

Secondary data

As a complement to the primary data collected through interviews, secondary data was collected before the interviews in order to receive a better understanding of the selected subject and industry. The approach for collecting secondary data was to do research online, using Google and Chalmers' library's database. This method was used to give an understanding of the powertrain in a combustion car and an electric car. An issue with collection of secondary data for the component study was that different sources used different levels of detail when describing powertrains. Different descriptions of powertrains were used to define the components on a suitable detail level. However, the definition of the powertrain was presented to the interviewees during the component study which then gave a confirmation or input on what changes were needed. Accordingly, the definition of components in a combustion powertrain as well as an electric powertrain was set and used in this thesis. Further explanation of the powertrain, with different defined components on combustion and electric powertrain, is presented in *Chapter 4*.

2.3.2 Supplier study

In the second phase of the thesis, the supplier study, interviews had a more structured approach where the goal was to be able to compare the results from the interviews. An interview guide consisting of some closed, yes or no, questions and some open questions asking for thoughts and reasons. However, the interviewers occasionally asked follow-up question in order to receive exhaustive and more descriptive answers. The interviews were conducted over phone or by skype in order to cover as many suppliers as possible and the time slot was between 30-60 minutes.

In total 24 suppliers were identified as impacted by the changes. All these suppliers were contacted by phone or e-mail. However, some of the contacted suppliers deliver to the automotive industry, but not specifically to the car industry and will probably not deliver in the future, these were not in the scope and therefore not included in the study. Some of FKG's members were consultancy or service companies which also needed to be removed from the study, due to that they did not deliver any product. In addition, some suppliers did not follow up our request for an interview and some did not have the time to be a part of the thesis. A few identified suppliers were also about to shut down their company why an interview was not relevant. However, in total, thirteen suppliers were interviewed, and a detailed description of the interviewees can be found in Table 2.

Table 2. Detailed information about interviewees for supplier study

Supplier	Company description	Industry	Products	Interviewee description
1	A Swedish manufacturer of customer unique gearboxes, precision-grounded gearwheels, and other transmission-parts for automotive industry	Automotive	Gears, Axles, Gearbox	Technical Manager
2	A global market leading manufacturer of pneumatic components and systems	Automotive, Marine, Railway etc.	Valves, Cylinders, Gearbox	Sales Manager
3	A global pedal supplier delivering complete pedal systems to automotive industry	Automotive	Brake pedals, clutch	Product Development
4	A global manufacturer providing automotive industry with products connected to engines	Automotive, Energy & Transportation Systems etc.	Transmission in engines, Start engines, Sensors, Inverters	General Manager
5	A global supplier of electric motors, motor controllers, and auxiliary equipment for the industrial vehicle industry	Industrial vehicle	Electric generator, power electronics	Executive Direction Sales and Marketing
6	A Swedish company making cutting processes in cast iron, steel and aluminum for automotive industry	Automotive	Shafts, axles, battery boxes	Site and Production Manager
7	A global market and technology leader in joining-technology products in clamp, connect and fluid categories	Automotive	Battery and engine coolant system, Power electronics	Director Product Management
8	A global manufacturer providing automotive industry with customized components and part systems	Automotive	Bearings, Transmission	Vice President New Business and Innovation
9	A Swedish battery manufacturer providing several industries with battery cells and management systems	Automotive	Battery cells, Battery Management Systems	Director Business Development Engineering
10	A global car industry manufacturer and assembler for all wheel driving systems	Car	All wheel drive systems, Transmission	Product Development Manager
11	Global automotive supplier that develop and produce automotive fluid systems	Automotive	Fuel tank and delivery systems, Fluid carrying systems, Pipes	Commercial Manager
12	Global automotive manufacturer supplying components and systems for engine, transmission, chassis and accessory units	Automotive	Valve-lash, valvetrain, camshaft, belts, clutch, sensors	Director Key Account Manager
13	Global charger manufacturer supplying 12V and 24V battery charging systems	Automotive Equipment and Boats etc.	Chargers for starter battery	Senior Development Manager

2.4 Data Analysis

The analysis of the collected data was conducted in an iterative process throughout the study. The frame of reference was used in two different ways. Firstly, as the foundation for collection of primary data where an understanding of the subject was of importance in order to create an interview guide that would cover the selected topic. Secondly, it was used as a benchmark in the analysis of the collected data.

2.4.1 Component study

During the component study, the primary data from the interviews were compared and analyzed together with secondary data from online sources. This was an iterative process where the interviewees confirmed the previously identified components of a powertrain, see Figure 3. Furthermore, to facilitate the analysis and to give the reader an overview of the results of this phase, all key points were summarized in a table, *Chapter 5.1*, where the changes of the different components were presented together with some comments.

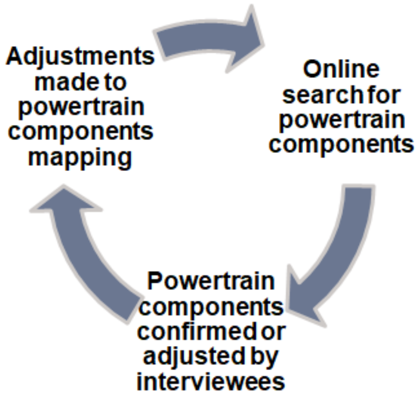

Figure 3. The data analysis of the component study was an iterative process which ended when the last interview in the component study was done.

2.4.2 Supplier study

The input to the supplier study was the result from the component study. This result was used to identify affected suppliers to later interview and collect data from. The result from the component study together with the results from the interviews were analyzed and compared. The analysis of the data was made from the perspective to receive a more holistic view of the suppliers' situation and potential future situation. The process for the supplier study data analysis is presented in Figure 4 below. To be able to analyze the data, the important key words or sentences were written down at post-its and put on a wall. These post-its were later moved and organized in different groups to analyze the findings in different ways. Hence, this post-it session avoided important data from the interviews to be forgotten. To structure the findings, graphs and tables were created for the type of questions that had generated short answers. By illustrating the data in this way, it was easy to understand the characteristics and preferences of the interviewed companies. For questions and answers that were more complex and could not be illustrated as graphs or tables, key points were written to summarize the most important aspects.

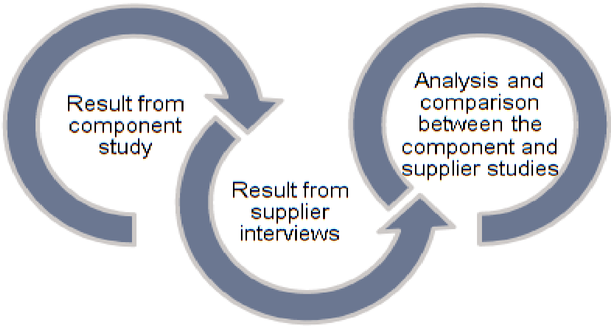

Figure 4. The data analysis process for the supplier study.

2.5 Quality Assurance

The concepts reliability and validity are used in order to assess the quality of a research (Bryman and Bell, 2011). However, the authors describe that it might be difficult to appraise the quality of a qualitative study. Nonetheless, it is believed that the concepts are applicable to use in this thesis. Therefore, they are described in this section to ensure quality of the master’s thesis.

Reliability means to what extent the study can be replicated into other areas (Bryman and Bell, 2011). This thesis is considered to be replicable since it covers a specific area within the car industry with main focus on actors in Sweden. The component changes, defined during the component study, are the same since a general powertrain was identified and used in this thesis. Hence, the same types of suppliers are affected by similar changes, but in other geographical areas. Therefore, the study is considered to be reliable.

Regarding the validity of the research this is considered to be achieved since an extensive analysis was performed, where primary data from the interviews and secondary data from literature was compared. In order to further validate the collected data, a mixed methods approach, also called triangulation, was used (Denscombe, 2014). Different methods of collecting data was used to improve the accuracy and quality of the data. This was beneficial since different methods was suitable in different situations in the project. Furthermore, Yin (2009) argued that it is advantageous to use data from different sources. Additionally, Denscombe (2014) emphasized that the use of triangulation would increase the understanding of the researched subject, which was necessary to conduct the interviews.

2.5.1 Criticism towards the strategy and process

The first phase of the thesis, the component study, has been of a qualitative character where interviews have been semi-structured and qualitative answers were asked during the face to face interviews. Moreover, the supplier study did not consist of enough interviews, nor did it have quantification of findings, to be able to refer to it as a fully quantitative study. Hence, asking follow-up questions during the interviews is one part in a qualitative study (O’Gorman & MacIntosh, 2015), to receive more detailed answers and reasons behind the interviewees answers. Therefore, the thesis is considered to be valid as a qualitative study.

In addition, the component study and supplier study could have been done at the same time to be able to reach several suppliers. The advantages of that would have been to collect more data and therefore be able to reach more valid conclusions. On the other hand, the delayed understanding of a powertrain's structure would probably have led to lack of knowledge to prepare and perform the supplier interviews.

2.5.2 Criticism towards the data collection and analysis

For the component study, both primary data from the interviews and secondary data from online sources were used. The secondary data can be questioned regarding its validity since there are several different online data sources used where few are scientifically anchored. However, these sources have been used to define and explain the powertrain, which looks different depending on car model and brand. Thus, there is no general picture of how the powertrain looks. Therefore, the different sources are believed to contribute to a more holistic and general view of the function of different components. Furthermore, the data received by the online search was confirmed with the interviewees in the component study as well as with employees at Triathlon Group. This confirmation was done to validate that the generic picture developed during this phase was as general and correct as possible.

3. Frame of Reference

In this chapter the collected literature is presented. The literature has been used as a foundation for the interview guides used during the interviews in both the component study and supplier study. Firstly, the definition of electromobility is found followed by a description of supply chain networks. Thereafter, an explanation of the concepts outsourcing and insourcing is presented. Finally, the concept change management is described.

3.1 Electromobility

The term 'electromobility' refers to a transportation system based on vehicles driven by electricity (Grauers et al., 2013). Electromobility includes both battery electric vehicles and vehicles that do not store their own electricity, such as trolley buses. Hybrid and electric vehicles are equipped with technology that make them capable to produce their own electricity. The electricity can also be sourced from outside the vehicle, usually called electric grid. When a transport system is using electricity, for instance from a grid, many different energy sources can be used without major modifications. Therefore, electromobility could improve the flexibility and robustness of the transport sector since electrified vehicles can use several types of energy sources. For instance, electricity can be produced from fossil fuels and nuclear power as well as from renewable resources such as wind and solar. Thus, electromobility can be more favorable than other technological alternatives such as biofuels, due to that the production of biofuels are limited to the availability of biomass (Grauers et al., 2013). The use of electromobility can also reduce CO_2 emissions, especially when the sourced electricity is produced using renewable sources. However, the climate impacts of electric propulsion can be negative if vehicles source electricity produced from coal, instead of gasoline or diesel fueled vehicles. Therefore, it is important to know where the electricity is sourced from to understand the benefits and drawbacks of different electric vehicle technologies. Furthermore, electromobility is a complex term since it involves technological development, policies and innovation as well as new driving behavior, business models and linkages between industries.

3.1.1 The understanding of electromobility

Fully electric vehicles have existed for over a century. The first commercially available electric vehicle was developed in the US 1897, but petrol-driven vehicles began to dominate in the US after 1920 due to the development of a more comprehensive road infrastructure (Grauers et al., 2013). Petrol-driven vehicles were faster and could travel further distances and were therefore seen as superior to the slow electric vehicle with limited range. During 20th century some mechanical counterparts in fuel injection systems, engine ignition and engine management have been replaced by electronic components and subsystems. Experts within automotive industry argue that powertrain is the last remaining non-electronic element (Grauers et al., 2013).

However, substituting ICE is not an easy task since technologies have been developed continuously for around a century due to the significantly use for road transport (Grauers et al., 2013). According to the authors, transforming the road transport system for new technologies, and compete with the maturity and efficiency of the ICE, is a huge challenge. The ICE has been developed together with the infrastructure, which have resulted in distributed oil extraction and refinement. Some experts mean that the ICE could be seen as a lock-in technology due to that all these systems are intertwined and are thus difficult to change.

The development of electromobility can be explained in terms of dominate drivers of change in the automotive industry (Grauers et al., 2013). These drivers of change can be referred to concerns for energy security, air pollution and climate change legislation. In addition, support for industrial competitiveness, recent technology improvements and growing interest for electromobility in key markets such as China (Conrady, 2012), may have increased the development. According to IEA (2012), petroleum accounted for more than 90% of the energy used for transport in 2010. Since oil is a finite and geopolitically sensitive source, oil dependence problems can result in fuel price shocks and supply interruptions (Grauers et al., 2013). Furthermore, transportation is strongly correlated to income growth and thus it is likely that the size of the global road vehicle fleet will grow dramatically in the coming decades, according to Grauers et al. (2013). Correspondingly, oil dependency is seen as unsustainable in both environmental and economic terms.

Additionally, electromobility is considered by many governments to be of strategic importance in the long run survival within automotive industries (Grauers et al., 2013). The economic crisis in 2008 had a big impact on the automotive industry where several industry players faced bankruptcy. To prevent job losses, national governments gave financial support where a large portion was spent on green technology. According to Grauers et al. (2013), money was made available for battery manufacturing and vehicle development. Due to the fact that automotive industry is of high strategic importance for many regional and national economics, it has faced major structural changes following the emergency of rapidly developing economies. Many experts also foresee that 30% of all cars produced globally will be sold in China in 2025 (KPMG, 2012). Thus, the Chinese government is a strong promoter of electromobility which is can be seen as one of the main drivers for the global automotive industry (Grauers et al., 2013).

3.1.2 Main drivers for electromobility

Apart from the large growth of electromobility in the Chinese market, it is possible to find a range of recent technological developments supporting electromobility. For instance, the development of batteries, electronics and computers have increased the competitiveness of plug-in vehicles compared to ICE vehicles (Grauers et al., 2013). The large player of the electrification wave in California was General Motor's EV1, which used a nickel metal hydride battery. EV1's battery pack had an energy density of 20 Wh/kg, whereas most of the lithium-ion battery pack today have an energy density of around 80-120 Wh/kg. As a result, energy densities in batteries have increased fivefold over the last two decades. In addition, several studies predict that the cost of batteries for plug-in vehicles will decrease (Pavoni & Berger, 2012).

Furthermore, vehicles are the central element for road transport systems and the technologies utilized for vehicle propulsion are influenced by other factors as well (Grauers et al.,2013). The used technologies are competing with cost and technological alternatives, fuel cost, available infrastructure, public policies and demand for mobility. Grauers et al. (2013) mean that technological development is usually driven by the possibility for companies to gain benefits from their competitors or user preferences. However, user preference could not be seen as a main driver for electromobility. Most users are still satisfied with ICE and most vehicles using electromobility are inferior in terms of driving range and price compared to ICE. Still, there are few market forces for electromobility which are a significant obstacle for electromobility. Therefore, it is, according to Grauers et al., (2013), unlikely that electromobility can be driven only by market forces, which means that policies have to play a key role. Hence, several laws regarding fuel economy and CO_2 emissions have been implemented in several parts of the world. For instance, the renewed zero-emission vehicle mandate legislation in California; the EU goal and the Chinese target for plug in electric vehicles in 2020, 95g CO_2/km.

3.2 Supply chain networks

A supply chain network consists of several different actors connected with each other by relationships (Dass & Fox, 2011). The actors within a network can be defined as nodes and the relationships between the actors can be defined as links. Both nodes and links in the network have a lot of resources, competence and knowledge which is built up over time by investments, adaptations and interactions (Håkansson & Ford, 2002). Having a network structure gives the whole network, rather than individual companies, the opportunity to create competitiveness (Vervest & Zheng, 2008). Furthermore, the network structure creates interdependency between companies (Abrahamsen & Håkansson, 2012). By combining different businesses within the network, the individual organization may derive greater value than if acting on its own. Correspondingly, Dunn et al., (2009) also point out that businesses using the intelligence in a network will achieve better results than businesses not using it. A network will look different depending on from which perspective it is viewed, therefore it is essential to choose a focal point, normally a company, when observing it (Ford et al., 2002). When the focal point is changed, different actors will be involved in the network with different links connecting them. The position of an actor in the network is of importance since it has an impact on the performance of the actor (Dunn et al., 2009). The position could constrain or enable the actor to access relevant resources and having an awareness regarding the position is essential. Additionally, the network position will, according to Dooley et al., (2017), influence a company's strategic decisions. Moreover, Dunn et al. (2009) as well as Andersen and Christensen (2005) emphasize that networks are dynamic and the positions of actors along with the size of the network, change over time. Above all, it is important for smaller actors in the network to be flexible in order to be able to adapt to changes, they need to be able to meet their customers' changing demand (Andersen & Christensen, 2005).

A supply chain network normally consists of suppliers, customers, plants, distribution centers et cetera (Yildis et al., 2016). The authors point out that developing a network implies numerous questions to be answered, such as which suppliers to choose and how to distribute products to the customers. When answering these questions, it is essential to take into consideration risks associated with different network structures.

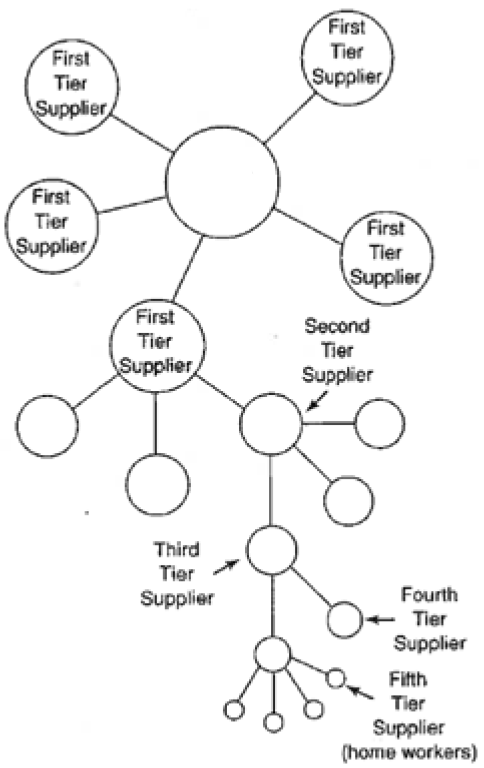

Figure 5. A network and its different tiers of suppliers (Ford et al., 2002).

To facilitate the study of a network it can typically be divided into a supplier network and a distribution network (Ford et al., 2002). A distribution network visualizes how the product reaches different end customers whereas the supply network displays the actors, which supply the focal company with for instance, raw material, components and modules. In addition, the supplier network consists of tiers of suppliers showing who has a relationship with who. An example of a supplier network can be seen in Figure 5. The first tier of suppliers entails the suppliers with which the focal company has direct relationships. Moreover, the other tiers consist of those suppliers which the focal company has indirect relationships with. Ford et al. (2002) point out that the network structure enables customers to access a large number of suppliers at a both geographical and technological spread by establishing and maintaining only a few relationships. Furthermore, the automotive industry is in general defined as a mature industry, with relatively low profit margins (Styhre & Kohn, 2006). As a consequence of low profit margins but also from the many globalization trends, the industry has been characterized by numerous mergers and acquisitions as well as joint ventures. Thus, the industry and the connecting networks are facing a lot of changes and modification in the supply chain networks.

3.3 Sourcing

Sourcing has become a strategic part of many businesses (van Weele, 2014), not the least within the car industry. Sourcing normally constitutes a large share of a company's total costs why it is essential to make the right sourcing decisions. Furthermore, Svahn and Westerlund (2009) claim that having a suitable sourcing strategy may increase competitiveness.

3.3.1 Make-buy strategies

Before deciding an outsourcing strategy, the decision on whether to make or buy a product or service needs to be made. Brandes (1994) has identified three perspectives to take into consideration when making this decision, namely; cost analysis, power/dependency and strategic resources. The most common perspective when making a make-or-buy decision is to investigate which alternative is the least expensive and choose this. However, the author emphasizes that this perspective alone does not give a sufficient foundation for decision. Therefore, the power/dependency perspective is of importance since it takes into account the risk and/or uncertainties of buying the product compared to making it. The products' characteristics are the foundation for this since complex products, in which the company has made large investments, should be kept inhouse. Lastly, it is of importance to take into consideration which resources are core for the company and which are not. Core business should be kept inhouse whereas other can be purchased.

Nevertheless, Brandes (1994) points out that some resources could be of high importance even though they are not considered as core, those should be handled through close collaboration with the supplier. Moreover, core skills can be lost if purchased instead of made inhouse. On the other hand, competence can also be transferred from the supplier to the buyer by close collaborations. Svahn and Westerlund (2009) point out this as an important factor to why also more strategic activities may be purchased. In Figure 6 below the process, as defined by Brandes (1994), is presented. It displays the three perspectives as questions to be answered yes or no, which leads to the decision of making or buying the product. This could be used a guideline on deciding what sourcing strategy is appropriate.

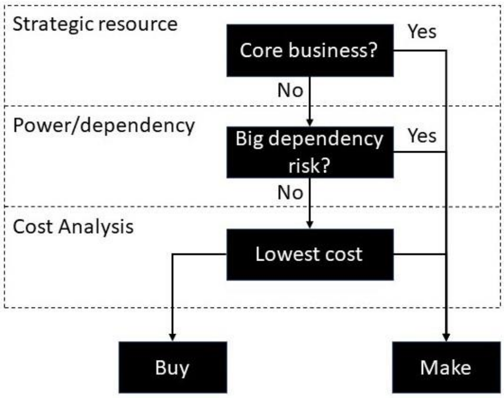

Figure 6. Make-or-buy decision process, modified from Brandes (1994).

3.3.2 Outsourcing

Outsourcing can be described as activities that previously were performed inhoused are relocated to an external actor (van Weele, 2014). The company outsourcing one or several functions of its business is here referred to as the buyer. Examples of activities that are normally outsourced are production, logistics and human resources services (Dinu, 2015). According to van Weele (2014), there are mainly two types of outsourcing; partial and turnkey outsourcing, describing to what extent the activity is outsourced. In a turnkey solution the external actor has full responsibility of the performance as well as coordination of the outsourced activities. In the other case, partial outsourcing, only a part of the activities or a function is outsourced and the coordination of activities remains in the buyer's responsibilities. Dinu (2015) points out some of the benefits of outsourcing as:

- Enables the buyer to focus on its core business
- Lowers the costs
- Gives access to expertise
- Improved services

On the other hand, Dinu (2015) mentions drawbacks as:

- Lost control of the activities
- Increased risk of confidentiality threats
- Increased transaction costs

3.3.3 Insourcing

Schniederjans et al. (2005) define the concept insourcing as allocation or reallocation of activities internally in the organization. According to Cabral et al. (2013) insourcing is *"the decision to reincorporate an outsourced activity within a company that had formerly been transferred to an external supplier".* Initially in a business' lifecycle it is common to insource activities, but as the business grows there might hard to find resources such as labor, material and finance, thus, there is a need to outsource some or several activities (Schniederjans et al., 2005). By insourcing previously outsourced activities, the buying company repossesses the control of the activities (Foerstl et al., 2016). In Figure 7 below, the benefits and costs of outsourcing versus insourcing is presented in more detail.

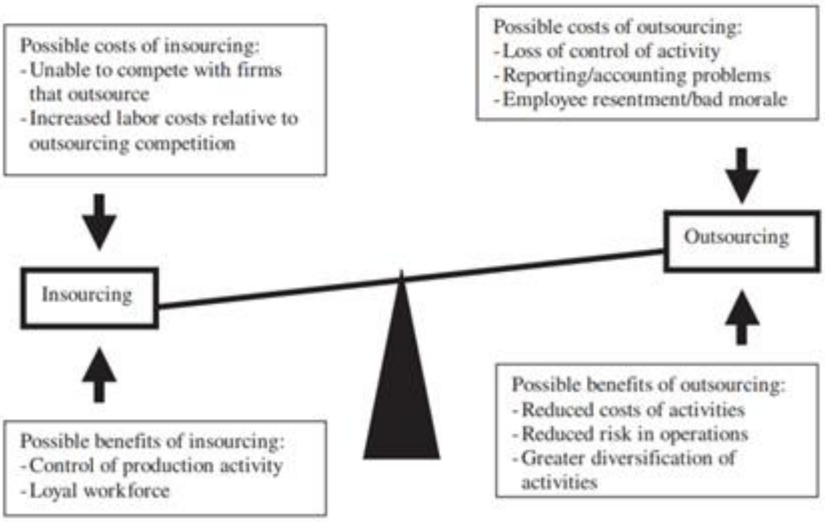

Figure 7. Benefits and costs of outsourcing versus insourcing (Schniederjans et al., 2005).

3.4 Change Management

According to Fritzenschaft (2014), change management is described as a complex phenomenon without any clear definition or boundaries. Some researchers point out that a universal definition of the term ‘change management’ does not exist (Burnes, 2009). However, Fritzenschaft (2014) means that it is about transforming an organization from a present state to a desired future state. This include all measures, tasks and activities in an organization that are necessary to initiate and execute the change. The main concern is to create readiness and willingness for change within the organization as well as an understanding and acceptance among employees.

3.4.1 Types of change

According to Fritzenschaft (2014), change management focuses inside the organization, on the people within the company. In addition, organizations have to change in order to be competitive and to survive. The characteristics of change initiatives, according Pescher (2008), depend upon several criteria, but in general change projects can be distinguished by three different perspectives, presented below:

1. Deliberateness of change: planned or unplanned
2. Reason for change: proactive or reactive
3. Intensity of change: evolution or revolution, adoption or reconstruction

The first perspective is related to deliberateness of change, whether the change is planned or unplanned (Pescher, 2008). Planned changes are planned ahead of time by the company and take place as intended. On the other hand, unplanned or emergent changes arise spontaneously, where no planning is done ahead. The second perspective is related to the reason of change, whether it is a proactive or reactive change. Proactive changes are often initiated and designed by the company, whereas reactive changes are a response to an external or internal event affecting the company. Reactive changes can be referred to changing factors in the business environment, such as decisions or actions taken by competitors. The third perspective is related to the intensity of change, companies either transform through drastic actions or through evolutionary adaptation. Perscher (2008) means that innovations in IT, technology or processes, shortage of resources or by rapid changes in business environment cause the changes.

Furthermore, the initiatives to change are often referred to the intensity of change and a common framework dealing with these different types of change is presented below in Figure 8 (Balogun & Hope Hailey, 2004).

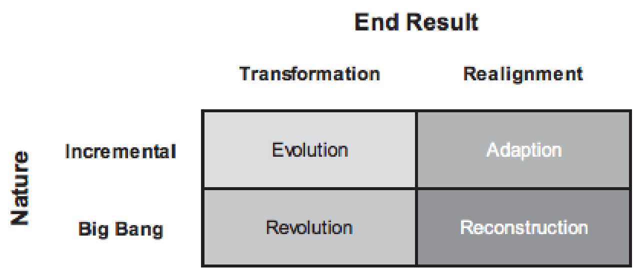

Figure 8. Types of change when an organization or company want to go from a current to a desired stage (Balogun & Hope Hailey, 2004).

The model described in Figure 8, can be referred to the third perspective presented above, where different intensities of change are given; evolution or revolution, adaption or reconstruction. Revolution and reconstruction change is referred to a big bang nature, where the change is happening fast and in one wave. Whether the end result is a transformation or a realignment, the big bang nature can turn into a 'revolution' or 'reconstruction' change. On the other hand, an incremental nature, where the changes are done in a step by step process, the type of change will result in 'evolution' or 'adaption'. The evolution change is a transformation where the change is transforming into something else, step by step, but still keeping the current layout. Whereas, an adaption is when the company is adapting the change step by step and start with larger changes such as reorganizations. In addition, pilot projects can be used to decide if a project is likely to become successful and should be implemented in full scale (Turner, 2005).

3.4.1 Key steps to successful change

When talking about change management, John P. Kotter is one of the most cited authors. Kotter identified the eight steps to increase the chance of successfully implementing a change initiative. According to Kotter (2011), it is necessary to go through all these steps in the right order to be successful when transforming a company. The eight steps are presented below:

1. Establish a Sense of Urgency
2. Forming a Powerful Guiding Coalition
3. Create a Vision
4. Communicating the Vision
5. Empowering Others to Act on the Vision
6. Planning for and Creating Short-Term Wins
7. Consolidating Improvements and Producing Still More Change
8. Institutionalizing New Approaches

The first step in Kotter's (2011) model is to establish a sense of urgency, where the organization has to be questioned and people, affected by the change, are driven out of their comfort zones. This first step is usually underestimated due to that people who should be aware and informed are not. The need for change must be spread and the information has to be communicated broadly and dramatically. The second step is to form a powerful guiding coalition, a group of people is brought together to share knowledge and experience. This team, which is the driving force behind the initiative, is usually working outside the normal hierarchy. The third step is to create a vision which is not too complicated or vague, but also clarifies clearly the desired future state of the organization. The fourth step is to communicate the vision, where new behaviors and ways of working need to be spread among the organization, by the guiding coalition. Every possible communication channel is recommended to use to avoid that the new vision and strategies are under-communicated.

The fifth step, according to Kotter's model (2011), is to empower others to act on the vision. In this step, all systems and structures undermining the vision have to be removed as well as the employees resisting the change need to be dealt with. In addition, new ways of working should be supported by encouraging employees in risk taking and by non-traditional activities and ideas. The sixth step is to plan for and create short-term wins in order to make the performance improvements defined and visible. This is crucial due to that most change initiatives takes long time and therefore it is important to set, meet and celebrate short-term goals. The seventh step is to consolidate the improvements and use them to create further changes. In this step it is important to not declare victory too soon, which is easy to do when this step is finally reached. The eighth, and last step, is to institutionalize new approaches and anchor changes in the culture of the organization. Hence, all new behaviors and ways of working should have been social norms and shared values at this stage.

4 Findings & Analysis of the Component Study

In this chapter the findings and analysis from interviews with researchers and experts, along with complementary secondary data research, are presented. Firstly, the drivers and challenges for the development of electromobility are given according to the interviewees. Thereafter, the component study of ICE and electric powertrain is presented. These findings, *Chapter 4.2* and *4.3*, have been developed by searching for secondary data along with confirmation and modification from the interviewees.

4.1 Drivers and Challenges of Electromobility

To be able to understand how fast the development of electromobility is foreseen to happen and as a result affecting the supplier networks, experts and researchers were asked about drivers of electromobility. Most of the discussion was related to the environmental perspective, which has intensified during the last years. Regulations and policies in cities, mainly in Germany, regarding diesel driven cars, is a main driver for increased electromobility. In addition, there have been discussions in Sweden to introduce regulations in city centers and most interviewees also mean that China, with increased regulations for emissions, is in the front edge of this development. Moreover, some of the interviewees brought up the fact that the decreasing price of lithium-ion batteries is pushing the development of electromobility. Lastly, one of the interviewees also believed that Tesla, an OEM of electric cars, have a great impact of the development. Tesla have shown that it is possible to produce a fully electric car and this has driven other car manufacturers to develop their own electric cars. However, some interviewees also pointed out that it is important to remember that this technology is not new, electric cars have existed before. In addition, the technology is highly simplified compared to the combustion engine technology, which has been developed for decades.

To fully understand the future requirements when changing from ICE to electric, all interviewees were asked what challenges they believe the actors within the car industry are facing. This was also done to further understand how fast this development will happen. It was pointed out by several of the interviewees that this change from combustion to electric powertrain is the biggest technology change that has ever happened in the car industry's history. This implies several new challenges for the actors within the industry. One challenge, that some interviewees mentioned, was how OEMs will handle the safety regarding all additional power electronics that need to be installed in the cars. Components will be modified, and some will be exchanged, some experts pointed out that this needs to be considered and a lot of new safety tests needs to be performed. In addition, due to the high voltage in the lithium-ion battery it is a need for education on how to handle this, which must be taken into consideration.

Moreover, there will be a gap in competence at the OEMs regarding software development. The core business has previously been to develop and produce the powertrain. However, it is according to most interviewees likely that the core business will change since the electric powertrain will be simpler to develop and produce. The new core business will probably be to develop the battery packs in order to fit them into the cars geometrically and with adapted performance. Another challenge for the OEMs will be how to develop and sell electric cars to make profit. Electric cars are more expensive than ICE cars and one interviewee wondered how Tesla can handle their business in the long run by selling fully electric cars without any profit.

This discussion led to that all interviewees agreed on that the development of electromobility is happening now and most actors within the car industry have already started to think about it and have made some adaptation. All agreed on that the expectation is that the change from production of mainly ICE cars to fully electric cars will happen within 15 years, but not sooner than 10 years. This is due to foreseen drivers and challenges, as mentioned above. Accordingly, the interviewees expect that more than 50% of the new car sales will come from fully electric cars in 10-15 years. However, this is an estimation and it is, according to all interviewed experts, too hard to say in which rate the development will occur.

4.2 ICE Powertrain Components

Since powertrains differ depending on car brand and model, a part of this study has been to create a generic picture of an ICE powertrain. The generic picture is presented in Figure 9, where parts existing on the powertrain are grouped into seven main components. These components' outlines describe the foreseen changes each component will face when changing from an ICE to an electric powertrain. The components with red outlines display components that will not exist in an electric car. The yellow display components that face a radical change and the green outlines display components with low or no change in an electric car.

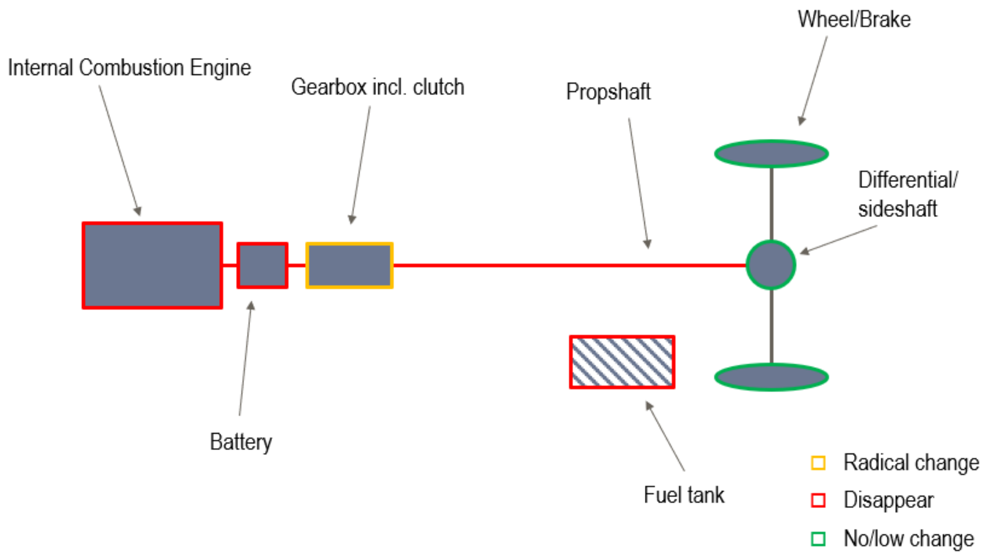

Figure 9. Picture of the identified components of an ICE powertrain.

The components presented in Figure 9 are described in more detail below. This includes parts the component consists of, function of the component and as well as what changes are foreseen when transforming from ICE cars to electric cars.

Internal Combustion Engine

In an ICE, the fuel burning (combustion) takes place in the cylinder of the engine (mech4study, 2014). The combustion generates heat and pressure, where the pressure drives the car forward. The ICE consists of several parts which can be seen in Figure 10 below. The cylinder block is the core in an engine, here the combustion takes place. Since combustion creates a lot of energy, high heat is generated why there is a need to cool this area which is done with a water jacket. On top of the cylinder is the cylinder head placed which function stop gases from entering or exiting the cylinder block. The piston is a small piece with cylindrical shape that moves inside the cylinder (Brain, 2000).

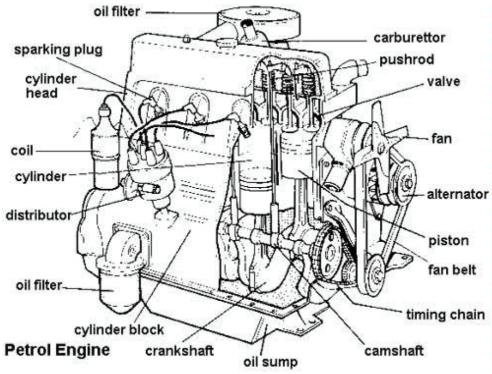

Figure 10. Internal combustion engine and its components (Pearltrees, 2014).

Based on the interviews held in this study, the ICE will be replaced to a much simpler electric machine. Meaning that the engine will consist of much less components. Today's engine is highly needed of maintenance due to the many mechanical parts. This business will partly disappear when changing to electric machines. Moreover, the ICE reaches high temperatures when it is running, implying the need for a cooling system. This need will, however, be almost completely reduced for an electric machine since it will not reach as high temperatures. This implies that the cooling system will no longer be needed. On the other hand, all interviewees point out that there will instead be an issue with heating and cooling the compartment of the car. This has before been easily handled since the ICE creates large amounts of energy waste which can be used for this purpose. For the electric car, heating or cooling the compartment will lead to decreased driving range. Some experts also stated that it might be necessary to have a smaller combustion engine in the car to be able to drive longer distances, far away from civilization. However, they added that it is a difference to build a small combustion engine and the one OEMs have developed for decades.

Starter Battery

The starter battery in an ICE car has the purpose to help when starting the engine (Battery University, 2016). Battery powers the lights and other electric attributes in the car (Autobattery, 2018). It normally consists of lead acid which has a high density (Battery University, 2016). As can be seen in Figure 11 below, the starter battery has many thin plates connected to each other in order to receive low resistance but high surface area.

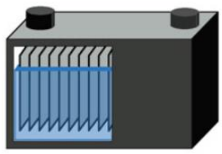

Figure 11. Starter Battery (Battery University, 2016).

According to all the interviewees the starter battery will not be needed in an electric car. This since the electric machine does not need an additional battery to start. One of the interviewees point out that there might be an issue when powering the lights and other accessories in the car since it will decrease the driving range. However, the interviewees pointed out that the starter battery is still used today on electric powertrains, even though the starter battery is not needed in theory. The main reason is that it is hard to build a safe system including handling for instance brakes, steering and battery management systems without having two independent batteries.

Fuel tank
The fuel tank is a container for the fuel used to drive the car, see Figure 12. This component will be completely replaced by the lithium-ion battery which will store power used for the electric machine, according to the interviewees.

Figure 12. Fuel tank (GB Radiator, 2018).

Gearbox
Car transmission or gearbox is the part of the vehicle that transfers or transmits the rotational power generated by the engine to the wheels (Carbibles, 2018). The gearbox is dependent on the power supplied by ICE and no power means that it would not be able to transmit anything to the wheels. However, the traditional gearboxes need to be in the best shape to make the vehicle reach its full potential regarding power and fuel-efficiency. The gearbox is presented in Figure 13.

Figure 13. Gearbox (Hardy Engineering, 2018).

According to the interviewees, the heavy mechanical transmission will not be needed in an electric car since it is closely connected to the ICE, which will disappear. Most mechanical parts will be removed, and the gearbox used in an electric powertrain will be integrated in the electric machine. Due to the radical change the traditional gearbox will more or less disappear, and the gearbox linked to the electric machine will include only four bearings and four gears, according to one interviewees.

Propshaft
The propshaft's function is to transfer torque from the gearbox or differentials to the wheels (My-cardictionary, 2018). A propshaft is shown in Figure 14 below. It is used only in four wheel and back wheel driven cars. The propshaft is located in the middle of the car reaching from the front to the rear, as can be seen in Figure 9.

Figure 14. Propshaft (Indiamart.com, 2018).

According to most of the interviewees, the propshaft will not be needed in an electric car since it is most likely that the car will have smaller engines connected to each wheel and therefore there is no need to transfer torque from the engine to the wheels.

Differential/sideshaft

Differentials' function is to transform power from the engine to the wheels, allowing the wheels to rotate at different speed (Nice, 2000), presented in Figure 15. The wheels need to rotate at different speed when turning and if there are no differentials the wheels would be locked at the same speed, leading to difficulties to turn the wheels. The sideshaft provides the dynamic connection between engine and driving wheels (GKN, 2018), and is closely related to the differential.

According to the interviewees, differentials and sideshaft are needed in the electric car and only small changes may be needed. In special applications where sideshaft and differential take too much space it is possible to develop and install electric machines inside of all the wheels. However, an electric machine inside each wheel has negative effects on the driving experience when driving in high speed and/or at rough ground, according to one interviewee. Furthermore, it is also more expensive than using a sideshaft and differentials.

Figure 15. Differentials (Overdrive, 2018).

Wheels and brakes

Most conventional modern cars have brakes on all four wheels operated by a hydraulic system (Howcarworks, 2018). The basic idea is that the brake pads clamp onto a metal disc creating friction which decreases the speed (Stewart, 2017). The kinetic energy is turned into wasted heat. To stop the car, the front brakes play a greater part because braking throws the weight forward on the front wheels (Howcarworks, 2018).

According to Stewart (2017), the electric machine runs as a generator when slowing down. The previously wasted energy from a traditional brake system is used to recharge the battery, and depending on how much regeneration the software engineers allow when designing the car, the force can be powerful enough to stop the car. Hence, the drivers, according to the theory, only need one pedal. According to the car manufacturer Nissan, next generation Leaf driver will never need the brake pedal, even though it will still be there in case of panic stops (Stewart, 2017). According to the interviewees, the brake system will remain almost the same since there is still a need for a system for emergency stops. Furthermore, it is important to consider that the use will heavily be reduced, which can result in some necessary changes in the production and choice of raw material. Reduced use will probably result in lower maintenance cost, but also some kind of evaluation and adoption for existing suppliers.

Comparing the wheels used for an ICE car with the electric car, all interviewees claim that no large change is foreseen in the following years. However, the possibility to fit motors inside the wheels for an electric might lead to some necessary changes for the existing wheel suppliers. The main advantages are more room for passengers and elimination of all transmission losses (Masson, 2013). Already in 2013, Masson saw in-wheel motors at the car manufacturer Toyota, even though this technology has a lot of challenges. For instance, all modern cars have an electronic differential for stability and traction control, but those established systems would not work with in-wheel motors. Furthermore, the device which makes the inside wheel turn at lower speed than the outside one, when in a curve, requires additional software. Some of the interviewees did not think this technology will break through for cars used in people's everyday life due to the additional cost and reduced driving experience.

4.3 Electric Powertrain

In Figure 16, the additional components that do not exist in the ICE powertrain are presented and marked with green outlines. If comparing the ICE powertrain in Figure 9, with the electric powertrain below in Figure 16, several components are integrated. Hence, the electric powertrain is divided into five main components, where the electric machine includes both power electronics and inverter. The gearbox that was defined as a radical change, in Figure 9, is according to all interviewees a part of the electric machine on the electric powertrain. Therefore, the gearbox is not described as an own component. Moreover, the electric powertrain components are described more in detail below.

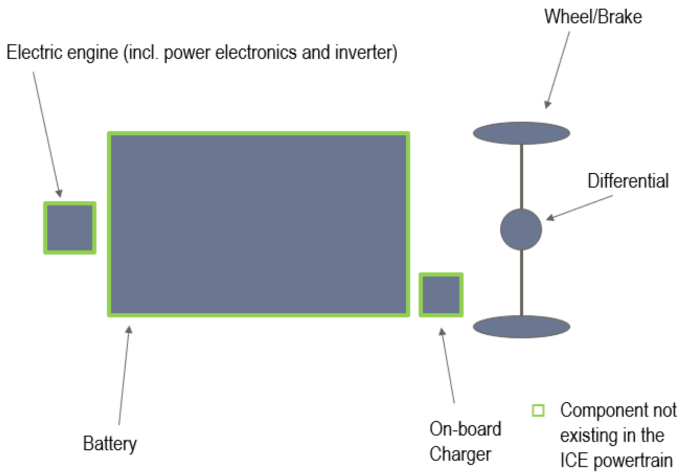

Figure 16. Identified components in a fully electric powertrain.

Electric machine

The electric machine is not a radical change comparing with ICE, it is a completely different and added system to the electric powertrain. The basic idea of an electric motor is very simple, electricity is added into the engine at one end and an axle rotates at the other end, which gives power to drive some kind of machine (Woodford, 2017). Comparing the 2 000 moving parts in an ICE, an electric machine has only around 20 (Driveelectric, 2018). This will result in less maintenance, for instance, it is no need for oil change. The electric machine can be seen in Figure 17 below.

Figure 17. Picture of electric machine (Siemens, 2015).

All interviewees agreed that an electric machine is completely different from an ICE and will be added to the electric powertrain. The structure and technology are highly simplified and with only a few moving parts, no maintenance is needed. In general, an electric machine includes ion, copper, bearings and sensors. The bearings need oil but with today's technology it is possible to make bearings with lubrication that lasts for a lifetime. Some experts that were interviewed did not believe that OEMs will produce their own electric machines in the following years, but they knew that OEMs are currently considering the possibility to change their production of ICE to electric machines. The main problem is that the manufacturers need to have high knowledge about software. Hence, the long experience of detailed development of combustion engine parts could lead to slow progress to make the electric machine inhouse. Another expert means that OEMs will only produce electric machine inhouse if it is possible to be competitive.

Power Electronics
According to the interviewed experts, power electronics become more important when changing from ICE to electric, since most power electronics are included in the electric machine system. The main function is to regulate how much power goes into the engine, which then regulates the speed. Power electronics are highly dependent on semiconductors which have some established suppliers but not in directly supply to the car industry. According to the interviewees, there are several challenges to fit the future demand from car industry. For instance, there are few established suppliers that are able to supply power electronics to OEMs, which increases the price and limit the supply.

Inverter
According to Gable and Gable (2018), an inverter is an electric device that transfers the direct current (DC) into alternating current (AC) of the type that can be used to drive another device. The rotating speed of the electric machine is proportional to the electrical AC frequency applied by the inverter. The output torque from the electric machine is roughly proportional to the AC current supplied by the inverter. Furthermore, the software in the inverter controls the vehicles' characteristics and more work effort is put on the software instead of the engine itself. The inverter can have the same function as the brakes to save energy and take care of AC and transfer to DC, which recharges the battery. In addition, the inverter can help some anti-locking braking system (ABS) functionalities to reduce the wheel slip when braking in an emergency. According to the interviewees, the inverter will be added to the electric powertrain closely related to the electric machine system.

Lithium-ion Battery

Lithium-ion batteries can be found in commonly used products such as laptops, cell phones and tablets (Brain, 2006). In general, they are much lighter than other types of rechargeable batteries due to being made of lightweight lithium and carbon. According to Brain (2006), energy can be easily stored in its atomic bonds since lithium is a highly reactive element. Lithium-ion batteries have very high energy density compared to other competing technologies, such as nickel-metal hydride or lead-acid battery. Another reason why lithium-ion batteries are widely used today is due to their ability to keep their charge. In addition, there is no need to completely discharge them before recharging, as is necessary for other battery chemistries. A battery cell is a single unit that perform the functions of the "battery" (Insideevs, 2014). Most battery cells are shaped like sheets packed in a laminate pack which are slightly smaller than the size of an A4 paper. When connecting several of these cells together in a metal case, a battery module is performed. These modules are later connected with sensors and a controller to perform the battery pack. The battery pack is unique for each car module and one example is presented in Figure 18.

Figure 18. Lithium-ion battery pack (Morris, 2018).

According to the interviewees, lithium-ion battery could be seen as the new fuel tank. It is defined as the car´s power source and no charge mean that the car is not able to move. Most interviewees do not think OEMs will produce their own battery cells due to the lack of knowledge and high market barriers. Currently, there are a few big players within battery industry which provide the OEMs with components to the battery pack. The battery modules and battery packs are foreseen to be developed by the OEMs to fit in each car model. The experts within the industry do not agree that this will be core business for OEMs, where they can make business and be competitive. Some interviewees mean that this process is more about fitting the battery pack in each car model.

On-board Charger

Hybrid electric and electric cars need an on-board charger (OBC), presented in Figure 19, to charge the high-voltage battery on the car from commercial power supply (Texas Instrument, 2017). Due to the essence of charging time, the on-board charging needs to be highly efficient with high power density (Infineon, 2018). In addition, the on-board charging needs to fit the limited space and weight requirements.

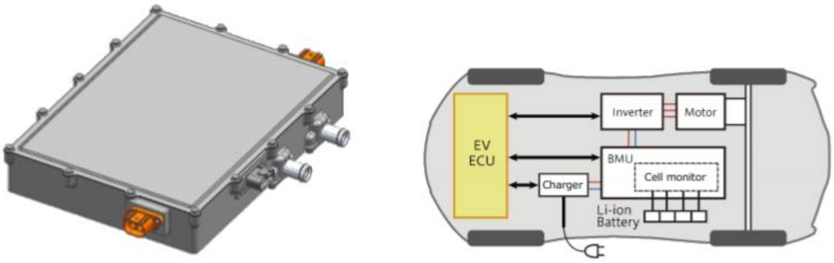

Figure 19. On-Board Charger (Mitsubishielectric, 2018).

All interviewees pointed that this is a component that will be added and nothing similar can be found in the combustion powertrain. Some business is already established due to that the hybrid electric cars have been at the market longer than the fully electric cars. However, if the OEMs want to make the electric car as a standard there are possibilities for new actors to enter this market.

5 Findings & Analysis of the Supplier Study

In this chapter the findings from the interviews with suppliers in the car industry are presented. Firstly, a summary of the affected suppliers is given, which is based on the defined powertrain components. Thereafter, the result of the suppliers' awareness and preparation is presented together with an analysis of stated supplier impact. Moreover, the challenges connected to the development of electromobility from a supplier perspective are portrayed. Lastly, findings regarding potential supply network changes from a supplier perspective are given together with a make-buy analysis.

5.1 Affected Suppliers

In Table 3, a summary of all defined components is presented together with the defined change; disappear, radical, low/no or added. Furthermore, some general comments are added to each component to easier understand in what way suppliers, supplying sub-components and subsystems to these components, will be affected. This input is taken from the component study in *Chapter 4*. In the fourth column, the affected suppliers are defined for each component depending on what the suppliers currently deliver to the car industry, or what they foresee to deliver to the car industry in the future. How these suppliers were identified and selected can be found in *Chapter 2.3*.

Table 3. Summary of component study in Chapter 4.2 together with identified affected suppliers.

Component	Defined change	Comment	Suppliers affected
Internal combustion engine	Disappear	▪ Less components ▪ Reduced maintenance business ▪ Reduced need of cooling system ▪ May be a need for a smaller combustion engine	Supplier 1 Supplier 2 Supplier 8 Supplier 12
Gearbox	Radical	▪ Most mechanical parts removed ▪ Even more linked to the engine ▪ Highly simplified (only one-gear-system)	Supplier 1 Supplier 2 Supplier 6 Supplier 8 Supplier 10 Supplier 12
Starter battery	Disappear	▪ Engine does not need an additional battery to start	Supplier 13
Fuel tank	Disappear	▪ Replaced by the lithium-ion battery	Supplier 11
Propshaft	Disappear	▪ Replaced by smaller engines connected to each wheel	Supplier 6
Differentials/ sideshaft	Low/no change	▪ Allowing wheels to rotate at different speeds ▪ Change foreseen only for sport cars	Supplier 1 Supplier 6 Supplier 10

Wheels/ brakes	Low/no change	▪ Most speed reducing from engine ▪ Need brake system for emergency situations	Supplier 3
Electric machine	Added	▪ Few moving parts ▪ Low/no maintentance ▪ OEM low experience ▪ Simplified gearbox included	Supplier 4 Supplier 5 Supplier 7
Inverter	Added	▪ Closely related to the electric machine ▪ Importance of software	Supplier 4
Power electronics	Added	▪ Closely related to the electric machine ▪ Few established actors on the market ▪ Low capacity and high prices	Supplier 5 Supplier 7
Lithium-ion battery	Added	▪ Replacing fuel tank ▪ OEM is likely to produce their own battery pack/module ▪ High investments and low knowledge ▪ Few actors	Supplier 7 Supplier 9
On-board charger (OBC)	Added	▪ Nothing similar can be found in the combustion car ▪ Few actors on the market ▪ Possibilities for new actors to enter the market	Supplier 4

5.2 Supplier adaptation

To be able to define the suppliers' awareness and the degree of adaptation of electromobility, the suppliers were first asked whether this development will affect their business or not. Suppliers that have been in the industry for more than 50 years stated that they will be affected by a volume decrease for the products they currently deliver to car industry. In addition, new competence and modifications of the product were something they saw as the main changes, affecting them. In some cases, where the suppliers have started to deliver some components to electric powertrains, or at least to hybrid powertrains, the suppliers see increased revenues compared to the components they deliver to the ICE powertrain. However, the cost is higher in most cases, due to exchanged material and low volumes, which results in low ability to make profit. Other reasons for low profit are the large investments, currently low volumes and that suppliers have not reached economies of scale. A correlation between increased and decreased revenue can be seen based on what the supplier provides to the car industry. For instance, the new components are quite unique at the market, implying that the revenue is likely to increase. On the other hand, if component ICE powertrain is delivered by several suppliers, then the revenue is likely to be reduced due to lower demand from OEMs.

For the suppliers that are relatively new or do not deliver to the car industry today, the business is affected in the opposite way. The suppliers foresee volume increases of the components they currently, or in the future probably will, deliver to car industry. Some of these suppliers are today operating in other industries and if electromobility grows and the technology is proven and accepted, they believe they will face demand from the car industry as well. Furthermore, one supplier stated that they are afraid of doing wrong and they would rather wait until the technology is more mature, before entering the car industry. The same supplier also stated that there can be a lack of components for other industries and markets, since the automotive industry will probably take all existing capacity. To avoid the lack of capacity, the supplier has already started to place its orders in advance to the sub-suppliers, to be prepared for volume increases. In addition, one supplier stated that it takes around three to four years to go from prototypes developed together with OEMs to reach full production and large volumes.

However, all suppliers included in the study stated that they are somehow affected by the development of electromobility. In Figure 20, the degree of adaptation is presented in order to understand how many of the affected suppliers that have taken some actions. The degree of adaptation is divided into four main parts; if the supplier is affected of the change, if the supplier has planned some adaptation, if the supplier has started some adaptation and if the supplier already delivers components to electric powertrains.

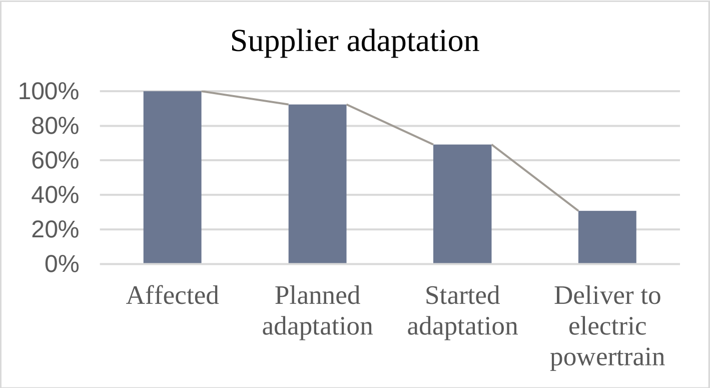

Figure 20. Degree of supplier adaptation in order to adapt to the development of electromobility. If a supplier has reach the last step "Deliver to electric powertrain", a full adaptation has been performed.

According to the Figure 20, 100% of the interviewed suppliers stated that they are in some way affected by the transformation to electric powertrains. In addition, 92% have already planned some adaptation towards production of components to a fully electric powertrain. This planning towards electric powertrain components could for instance include R&D projects, long-term action plans to supply more electrified components, training within electromobility et cetera. Moreover, 69% of the suppliers have started some adaptation towards production of components to fully electric powertrains. For instance, this adaptation could for instance include investments in new production lines or ongoing pilot projects with OEMs, where prototypes are being produced. Moreover, 31% of the suppliers are currently delivering components to fully electric powertrains.

5.2.1 Affected

The supplier that has not yet planned any adaptation for electromobility, was placed in the first stage of adaptation. This supplier is currently delivering to automotive industry but has many other business areas as well. New products with more electronics and less mechanicals parts are needed to be able to make some adaptation. Involvements have been done in different megatrends, but not specifically in the development of electromobility. In addition, the supplier foresees closer and fewer relationships with customers and will probably be more involved in the customer's development in the future.

5.2.2 Planned adaptation

In this second stage, the suppliers have planned some adaptation towards electromobility. Some suppliers in this stage need to implement more automation if they shall start deliver to automotive industry. Others foresee lack of capacity when OEMs ask for more electrical components, but also lost product areas due to the changed demand. In most cases, when the suppliers have planned adaptation, but not yet started, the OEMs have taken the initiative for new components. Hence, new collaborations and relationships might be needed for the suppliers to be able to produce the required components. In addition, different OEMs ask for different solutions, which according to one supplier, makes it hard to know what to focus on. Regarding the competence, most of the suppliers stated that they do not have the competence to fully adapt today, but there will not be any problem to acquire the right knowledge.

5.2.3 Started adaptation

In the third stage, the suppliers have started the adaptation of electromobility, but are not currently delivering components to the electric powertrain. One supplier in this stage has recently acquired a new company within electromobility to prepare for the transformation. The acquisition was done to receive the competence and products aimed for the new technology, which the supplier did not have inhouse before the acquisition. Another supplier identified in this stage, stated that they need additional investments in capacity and competence, which they are currently planning for. Furthermore, some of the suppliers are involved in pilot projects in small scale production, mostly on behalf of the OEMs. One supplier mentioned that they have acquired competence in the last two years thanks to projects with different customers. Another supplier stated that their management realized that they needed to change, so they started by planning for capacity increases. In addition, one existing supplier meant that the revenue per component is foreseen to be increased by six to eight times compared to the old component. However, they need to make large investments in equipment and capacity, since new production methods are needed for the new components.

5.2.4 Deliver to electric powertrain

In the fourth and last stage, the full adaptation has been done and the suppliers are already delivering components to electric powertrains. Most suppliers in this stage are not sure when they will need additional investments to be able to handle the increased demand from OEMs. Hence, they believe that policies and regulations will control which impact the development of electromobility will result in. One supplier pointed out that they need to change what they currently produce and have to learn how to automate the production. However, they are currently educating the employees to be prepared for demand changes. Another supplier foresees volume increases of its existing components since seven times more of the supplier's components are used in an electric powertrain compared to an ICE powertrain. In addition, the suppliers mentioned replaced material as one key change that they are currently facing.

Furthermore, most suppliers are involved in an early stage, which is, according to several suppliers, to keep up with the changes and being prepared. One supplier pointed out *"picking the late train"* as one disadvantage of being late. Additionally, another supplier mentioned the problem of choosing only one customer to develop new products with. For instance, several customers want support to develop more electrified components added on the electric powertrain. However, the supplier has not the time or financials to be involved in all customers, but still, it is hard to choose the one which results in business at the end.

5.3 Correlation between supplier adaptation and defined impact

The defined component change in Table 3; disappear, radical, low/no and added, can be translated into a defined impact for each affected supplier. Due to each component having a defined change, each supplier delivering the component, sub-component or subsystem has been given a defined impact based on the findings in *Chapter 4*. This impact is evaluated to be high if the related component will disappear or radically change. On the other hand, the impact on suppliers is considered to be low if the related component will have a low or no change. The medium impacted suppliers are the once delivering components expected to be added to the electric powertrain since most of those suppliers exists today, but are not delivering to the car industry. Therefore, those suppliers are considered to have an easier change journey than the ones delivering radically changed components. Due to most components being added or disappearing when changing from ICE to electric powertrain, the impact on most suppliers has been defined as medium or high. Furthermore, some suppliers deliver sub-components and subsystems to several defined components. In these cases, the highest foreseen impact has been defined for the supplier. However, if the supplier mainly delivers sub-components to a component defined with low change, but a few to a component with radical change, the impact will be reduced. Hence, the degree of impact is rather low since most of the supplier's business comes from the component with low change.

If the supplier adaptation from Figure 20 is combined with the foreseen supplier impact, it is possible to find the correlation between impact and awareness. In Figure 21 below, the correlation is presented where the vertical axis shows the degree of adaptation for each supplier and the horizontal axis shows the degree of supplier impact. One dot in the Figure represents one of the 13 interviewed suppliers. The size of each dot is defined depending on the supplier's turnover, where a turnover of less than 500 MSEK is identified with the smallest dot. Suppliers with more than 5 Billion SEK are identified with the largest dot and the rest of the suppliers are identified with the medium dot size. In addition, the dots are marked with three different colors depending on if the suppliers mainly delivery components which are: added, disappeared/radically changed or low/no changed. The trend line shows where there is a 1:1 correlation between the supplier impact and supplier adaptation, meaning that the supplier is as prepared for the coming changes as the theory and interviewed experts foresee. If the supplier is above the trendline, the supplier's adaptation is higher than the supplier the expected impact, meaning that the supplier is more prepared and have done more actions than what is probably needed. In those cases, most suppliers deliver components which were defined with low/no change in *Chapter 4*. Hence, it is easier to make the necessary changes and adapt to electromobility.

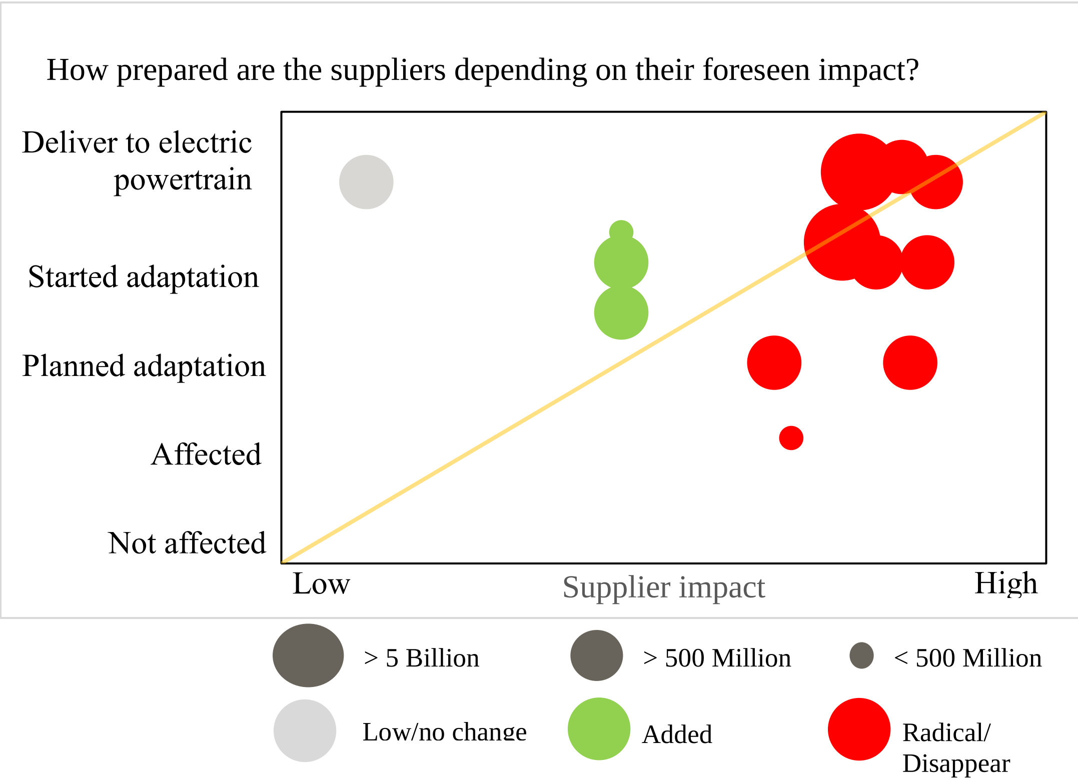

Figure 21. Supplier adaptation and foreseen impact of development of electromobility. The grey dot is defined with low/no change, green dots are defined as added and red dots are defined as radically change or disappear. The stage not affected is added in order to cover all stages of adaptation towards electromobility even though no suppliers is in this stage.

According to the Figure 21, approximately 50% of the suppliers are well prepared for the foreseen changes and have made adaptations that might be more than potentially needed. These suppliers either deliver components that will be added to the electric powertrain or components with no or low change compared to the ICE powertrain. On the contrary, about 50% of the suppliers are in theory more affected by the development of electromobility than they are aware of and have made actions for. In this case, suppliers which currently provide the car industry with most components to ICE and transmission are defined due to that those components will disappear or go through a radical change. However, it is easier to be prepared if the impact of the supplier is lower due to that the component, the supplier already deliver, are added from other industries or have low or no change compared to the ICE powertrain.

For the suppliers that currently deliver components which are foreseen to be added to the electric powertrain, some similarities are found. One power electronic supplier is currently not delivering to the car industry, but to the heavy-duty industry and will thus not directly be affected. However, the components can be used for car's electric powertrain and the demand is foreseen to increase due to few actors currently supplying these types of components. In addition, this supplier pointed out that the heavy-duty industry will follow shortly after the car industry’s change towards electric powertrains. Hence, the supplier will probably be affected in the short-term even though they are not directly affected of the transformation towards electromobility in the car industry.

5.4 Supplier challenges when adapting towards electromobility

To fully understand the complexity of changing from ICE to electric powertrains the suppliers were asked about foreseen challenges with the adaptation. The main challenges are presented below in Figure 22.

Figure 22. Challenges connected to electromobility from the supplier perspective.

Most suppliers are facing challenges with finance as well as competence and equipment. Finance can refer to additional large investments needed for the adaptation and is closely related to equipment. However, a supplier can have good financials but still problems to find the right equipment to produce the component since the technology and material are new. One supplier already saw additional lead times for the raw material due to increased demand and few actors at the current market. Another supplier pointed out that Swedish suppliers to car industries have difficulties getting loans from the banks since the banks have low understanding of the potential the suppliers have. This leads to difficulties to adapt production to components for the electric powertrain.

Moreover, all suppliers agreed that competence is a challenge in general. However, all the suppliers claimed that if they do not have the competence right now they will be able to acquire the competence when needed. Hence, this was not seen as a relevant challenge by all why only 54% actually mentioned this as a challenge during the interviews. Some of the suppliers have already started to develop competence within electromobility by, for instance, acquisition of companies with the right technology competence as well as by recruiting personnel. On the other hand, it might not be as easy as the suppliers think to acquire the right competence. The main issue is to know what type of competence is needed in advance to be able to have the right timing. Hence, timing was mentioned by several suppliers, the importance of not being too early or too late. If OEMs are behind the development of electromobility, the supply will exceed the current demand and if the suppliers are too late, they will probably be replaced by another actor.

Furthermore, management support was mentioned by most of the interviewees as something critical. However, according most suppliers, it is generally hard to get management onboard for changes. Only some of the suppliers pointed out that management will be a challenge when making the adaptation. Additionally, incentives were pointed out from some of the suppliers, meaning that the suppliers must have reasons why making the adaptations. For instance, some suppliers have already poor capacity to deliver the currently demanded components in a short-term perspective. The first action would probably be to make investments to ensure delivery for current components, but then the long-term perspective to adapt to the foreseen changes is not taken into consideration. Moreover, incentives can be related to that the supplier does not think that the development of electromobility will affected them in the near future. This results in no incentives to make the adaptation, even though all suppliers believe they will be affected by the technology change in some way in the future.

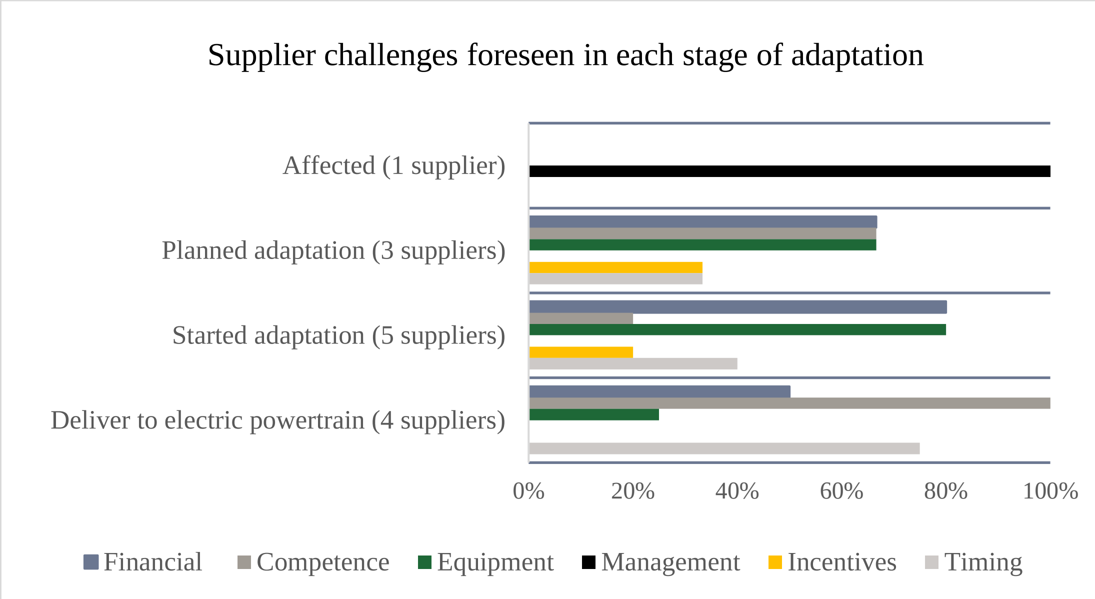

Figure 23. Supplier challenges in each stage of adaptation.

As presented in *Chapter 5.2* the suppliers have been divided into four different stages depending on how far they have come in the preparation for adapting to electromobility. The challenges the suppliers in different stages are facing can be seen in Figure 23. For suppliers in the first stage, affected but no planning initiated, the biggest challenge is to get the management onboard for the transformation they are facing. This is not considered to be a challenge for anyone of the suppliers further down the stages. It may be the case that the suppliers in the other stages have already dealt with the management and got them onboard for the upcoming changes. Further down the stages, the suppliers are facing other challenges, for instance, finance, competence and equipment are the biggest challenges when suppliers have planned for the adaptation but not initiated it. One supplier mentioned that they have started to look into what new competence is needed and what they have inhouse already. For the next stage, when adaptation is started, the suppliers need to deal with more different challenges overall. On average the suppliers in this stage have three main challenges they are facing; finance, equipment and timing. The biggest challenges are considered to be finance and equipment, which 75% of the suppliers in this stage recognize as challenges. However, finance and equipment is strongly correlated even though equipment in this case refers to the challenge of finding the needed raw material and the right machines, rather than having the financial means.

For the last stage, where the suppliers are delivering to the electric powertrain, the main challenge is considered by all suppliers to be competence. It is interesting to notice that when the suppliers have started the adaption but not yet started to deliver, finance is considered as one of the biggest challenge. This seems reasonable since it probably demands more investments in order to actually start delivering components that can be used in the electric powertrain. However, when the suppliers have started to deliver, finance is only considered to be a challenge by 50% of the suppliers. Instead competence is the biggest challenge. It is likely that the suppliers in this last stage have overcome the financial issues and have made the necessary investments for adaptation. However, they have now realized that they do not have the competence needed to scale up production and thus need to acquire more competence.

5.5 Supply network changes

Based on the answers from the interviewees is it not likely that there will be any major changes in the supply chains. All suppliers believe that OEMs will continue to buy products from them even if, in some cases, the suppliers will deliver different variants of the products in the future. Most of the suppliers have noticed a trend in that the OEMs are, to a greater extent than before, asking for complete systems rather than individual components. Implying that the suppliers deliver increasingly complex solutions.

Furthermore, OEMs lack competence, according to the suppliers, in several areas which leads to difficulties if they were to insource some areas. Some of the suppliers mentioned that they will have to completely change the type of products they supply to the car industry since present products will not exist in the electric powertrain. For instance, the clutch pedal and other mechanical parts becoming electric. Therefore, the suppliers will have to acquire new competences. However, as mentioned in *Chapter 5.2*, all suppliers believe that the competence challenge will not be a big issue since they either already possess the needed competence or will be able to acquire it if needed. One supplier mentioned that as long as the suppliers fulfill the OEMs' demand, the OEMs will not replace them or insource their production. On the other hand, some suppliers see a risk that OEMs might insource production of their products in the future since they have seen this happen in other industries. Moreover, they have started to see that the trend of outsourcing production is about to turn around towards insourcing. For instance, in Germany, the OEMs have kept large part of their production inhouse and this might inspire other OEMs to do the same.

Furthermore, developing and producing the combustion engine has previously been considered as core by the OEMs. However, when changing towards electromobility this will no longer be the case and there will be a lot of freed up resources since producing an electric machine is not difficult according to several of the suppliers. One supplier even expressed it as *"anyone can make an electric machine, it does not require extraordinary competence"*. When this happens, the OEMs will have to find something else to produce and might insource production in some area. On the other hand, the suppliers mentioned that they will most likely continue to develop the components together with the OEMs even if production of the specific component is insourced by the OEM.

Moreover, all suppliers stated that they have, or aim for having, a close relationship with all their customers. The objective is to have a few, around 5-10, long-term relationships rather than many in an arm's length relationship. The majority of the suppliers foresee this to remain the same in 10-15 years. However, some suppliers believe that they will have more customers in the future, mainly because the changed components might attract other customers than the traditional within the car industry. One supplier expects it will have fewer customers, but closer relationships, to be able to be more involved in development of the OEMs' products. Additionally, it was pointed out during several of the interviews that it is crucial to listen to the end customers' as well as the direct customers' demands, in order to be prepared for which components to develop and produce. Of the suppliers which claimed having close relationships with their suppliers, several referred to themselves as development suppliers. Some of the suppliers also stated that they are at the customers' site up to three times a week. On the contrary, there are a few suppliers which have up to 50 customers, but these suppliers do not have close relationships with all customers only with a few, mostly larger customers. Several of the suppliers mentioned that they are involved in pilot projects within electromobility together with the customers. They have also worked with the customers within the industry for several years, some suppliers have up to 100 years in the industry.

6 Discussion

In this chapter the main discussion is presented where the findings of the two different studies are discussed along with the frame of reference. The chapter is divided into four main areas where the divers and timing of electromobility is first presented. Moreover, the changes in supplier networks are given as well as the foreseen sourcing strategies. Finally, the impact of change management is presented.

6.1 Drivers and timing of electromobility

When talking about electromobility it is important to keep in mind that the technology is not entirely new. Fully electric vehicles have existed for over a century (Grauers et al., 2013). This was also something that most experts and researchers pointed out during the component study. Even though the technology is not entirely new, most suppliers stated that this is the largest change in the automotive industry in a century. Hence, a lot of investments needs to be done as well as collection of new competence. Grauers et al. (2013) mean that the powertrain is the last remaining non-electronic element in automotive industry. However, substituting ICE, which has been developed continuously for around a century, is not an easy task. Probably one of the main reasons could be referred to the infrastructure and all services related to ICE. According to Grauers et al. (2013), ICE could be seen as a lock-in technology due to all systems being intertwined which are thus difficult to change. This could also be related to that most suppliers and experts, according to the interviews, see the development of electromobility as one of the largest disruptive changes in automotive industry.

The development towards fully electric vehicles leads to another question pointed out by the interviewees. Due to the increased use of power, the government in Sweden and the rest of the world, need to ensure that the power sources are enough. However, most power produced in the world does not come from reengineered sources, which can result in larger negative impact than using traditional combustion cars. This can also be confirmed by Grauers et al. (2013), which stated that electric propulsion can be negative if vehicles source electricity produced from coal. Even though in Sweden most electricity comes from water and fusion power, it is not the same in the rest of the world. Some suppliers also pointed out that the ongoing discussion about fusion power, where no further investments are done to maintain the nuclear power station, leads to uncertainty about Sweden's access to renewable power sources in the future.

Furthermore, Grauers et al. (2013) mean that a technological development is usually driven by the possibility for companies to gain benefits. Most of the suppliers indicated that the components to electric powertrain are more expensive compared to the once they already deliver. Due to the large investments and complex manufacturing methods, the suppliers need larger volumes to reach economies of scale. Hence, the volumes will not increase until the price of an electric car is in the same range as for a combustion. According to Grauers et al. (2013), most users are satisfied with ICE since electric vehicles are inferior in terms of driving range and price compared to ICE. However, when the consumers find it less expensive to own a fully electric car and when they can drive longer distances, car volumes will, according to the interviewees, increase. Several studies also predict that the cost of batteries for plug-in vehicles will decrease, as well as the energy density have increased fivefold over the last two decades (Pavoni & Berger, 2012).

Even though people are not yet fully convinced about the benefits from fully electric cars, drivers such as support for industrial competitiveness, recent technology improvements and growing interest for electromobility may increase the development. Key markets such as China, where the first driver can be referred to concerns for energy security, air pollution and climate change (Conrady, 2012), can also be seen as one large step towards electromobility. Most interviewees mean that China is a large market with big impact on Europe. This can also be confirmed by experts who expect that 30% of all cars produced globally will be sold in China in 2025 (KPMG, 2012). Since transportation is strongly correlated to income, the size of global road vehicle fleet is likely to grow dramatically in the coming decades (Grauers et al., 2013). Hence, the development of electromobility must happen to ensure sustainability is both environmental and economic terms. Additionally, the Swedish government made the decision in 2015 that 70% of the climate impacts from domestic transportation will be removed at the latest 2030 (Smith et. al, 2018). However, most experts and suppliers pointed out that they do not know how fast it will happen and how largely they will be affected.

Moreover, some automakers are proactive and have heavily invested in electromobility (Grauers et al., 2013), even though there is a lack of customer demand. The OEMs believe in increased customer demand and since there are long lead times from pilot projects to actually sell fully electric cars in larger volumes, the OEMs need to act fast. When the remaining question marks regarding safety, price and driving range are reduced, the demand is foreseen to increase a lot. For instance, in 2016, the number of electric cars on the road globally hit 2 million, up from hundreds in 2005 (Vaughan, 2017). However, most interviewed experts and researcher mean that this development will take time, even though it is possible to see a steep adaptation curve on the customer side in the recent years.

Finally, when taking the drivers and the current challenges into account, all interviewed experts and researchers expect that more than 50% of the new car sales will come from fully electric cars in 10-15 years. On the contrary, most of the supplier were not convinced that the transformation will happen this fast. A lot of current suppliers stated that the timing is crucial for the future investment. Even though everyone knows that the electric car volumes will increase (Grauers et al., 2013), it is hard to state in what rate. Hence, it is difficult for the suppliers to know in what rate their currently delivered components will be exchanged to components for electric powertrains. In addition, new actors need to make investments without having any turnover from old business. Most current suppliers mean that they need to keep their old business to be able to pay for the increased new business, they also believe that OEMs want ICE components for many years in the future. This can be confirmed by an interviewed researcher that pointed out that it will probably be some kind of smaller ICE in the vehicles in the future. However, ICE is a lock-in technology (Grauers et al., 2013) and it is still a need for spare parts and aftermarket services, even though that business will be reduced.

6.2 Changes in supplier network

As pointed out by Ford et al. (2002) a network looks different depending on which focal point is chosen. Therefore, it is of interest to discuss the supply chain network from both the OEMs perspective and the suppliers. It is clear that OEMs in the car industry have large supplier bases for powertrain, consisting of several hundred suppliers. This goes in line with what Ford et al.

(2002) said regarding network structures giving customers access to a large number of suppliers, spread both geographically and technologically. Having access to many suppliers is likely to lead to a power advantage for the OEMs. This imply that they can pressure prices and purchasing terms by having several suppliers playing against each other. However, having this power over the suppliers also puts pressure on the OEMs since they will have a greater responsibility when transforming from combustion powertrain to electric. If current suppliers are not able to produce what is demanded by the OEMs, they will most likely be replaced. Nevertheless, since there are a lot of risks associated with different network structures (Yildis et al., 2016), it would be beneficial for the OEMs to keep the current network structure as constant as possible. Having to change the supply network implies costs and risks when evaluating new suppliers and new sourcing strategies. It was confirmed by the interviewed OEM that they want to keep their current suppliers by having them produce new components and systems suitable for the electric powertrain as well. This is a strategic decision what will impact the whole network (Dooley et al (2017), but at the same time probably reduce the risk for the majority of actors in the network.

Nonetheless, the suppliers will not only have to adapt production towards electromobility but also keep the production for products used in combustion powertrains, since end customers will probably demand ICE cars for several years in the future. The transformation will not happen overnight and it is therefore important to survive the transition time. As was emphasized by Andersen and Christensen (2005), networks are dynamic and actors change position and new actors enter the network while other leave. Producing components for both ICE and electric cars is a combination that might be hard for some suppliers to achieve but will be essential in order to remain the business and keep its network position. OEMs will keep a supplier, which only produces components for one type of powertrain, only if the supplier is a one of a kind. Furthermore, the supplier might be kept if there are other transaction costs that will lead to a negative business case if changing supplier.

As presented in the findings it was clear that most of the suppliers focus on having only a few customers and develop close relationships, in many cases referred to as partnerships. They have built up competence as well as made adaptations over several years and therefore an interdependent relationship has been developed, which is common in a network (Abrahamsen & Håkansson, 2012). It seems like it is hard to become a new supplier with close relationship with OEMs in the car industry since most of the suppliers have been in business for at least 20 years and some up to 100 years. Håkansson and Ford (2002) stated that relationships are built up over time which is aligned with the suppliers' statements. Several are involved in electromobility projects in collaboration with the customers. On the other hand, some suppliers have up to 50 customers and still claim that they have close relationships with their customers which seems hard to achieve. Nonetheless, it is likely that these relationships might change in the future due to the upcoming technology shift. Some suppliers pointed out that their customer base might change since they may not deliver directly to the OEMs in the future. New actors might enter the market and take over as first tier suppliers, implying that current first tier suppliers will become second tier suppliers. This will imply big changes for several actors in the network since new relationships will have to be initiated and old will be diminished. These changes will probably lead to some suppliers leaving the network and other suppliers will be added.

Furthermore, especially the smaller suppliers need to be flexible and responsive to the changes in the network. Small suppliers need to maintain a close relationship with their customers to survive when there are changes in the network (Andersen & Christensen, 2005). This is also the strategy used for most of the suppliers and is likely to be essential to survive. Some of the suppliers maintain close relationships with key customers by visiting their sites several times per week. Furthermore, one supplier stated that they previously had their customers come to their sites but in the future, they will have to go to the customers in order to maintain relationships and thus sales. This shows the importance of maintaining good relationships. For those suppliers that may disappear from the network it is of importance to keep up with the technology change happening now. By being responsive to changes and listening not only to the direct customers but also to end costumers will give a greater possibility to survive the transformation.

6.3 Foreseen sourcing strategies

When discussing potential changes in the network it is interesting to also discuss the causes of these changes. The changes will not only come from new actors entering the market and other actors leaving. It might also happen due to changed sourcing strategies from OEM's. Since sourcing is a strategic decision in many companies (van Weele, 2014), it is of importance that this is overlooked carefully. Several of the interviewees said they have seen a trend during the last couple of years where the OEMs outsource more and more production and also development of products. The suppliers express that OEMs want to buy full systems, which can easily be integrated in the car at manufacturing, rather than single components. This can be compared to what van Weele (2014) refers to as partial or turnkey outsourcing, where the trend has been to use more turnkey outsourcing. It is likely that this trend has arisen due to the excellence of many of the suppliers to the car industry. The OEMs trust their suppliers and are therefore willing to let on more responsibility to them. This has given the OEMs possibility to focus on their core business, for instance, produce and develop the combustion engine. Which goes in line with Brandes (1994) idea where strategically important activities should be kept inhouse whereas other activities can be bought if it is beneficial from other perspectives such as cost. The suppliers confirm that one of the reasons why OEMs want to buy full systems is that it is not viable for one OEM to produce the components. However, the suppliers have the possibility to scale up production and thus achieve economies of scale.

Nevertheless, due to the upcoming changes the OEMs will have to change their core business, it will most likely no longer be the engine that is considered as core business. For instance, one supplier claimed that it is not difficult to produce and develop an electric machine. This was also confirmed by the interviewed researchers. Due to these changes, the OEMs will have to reconsider their sourcing strategies and might have to insource some production. It is of importance for OEMs to have a well-thought strategy since that may increase their competitiveness (Svahn & Westerlund, 2009). In this case the related suppliers will be challenged since they will be either completely replaced by the OEMs inhouse production or they have to start producing other components for the car industry. Some of the suppliers claimed that this will not be an issue since the OEMs will not have the competence nor the capacity to start producing their products. Others express this a potential threat in the future, especially since a few of the suppliers have actually seen this happen within some areas.

The change towards electric cars will imply reduced need of production and development of the ICE. This means that OEMs today producing the ICE inhouse will need to find something else to produce in order to retain control of resources and activities. By insourcing previously sourced products the OEMs will repossess control of these activities (Foerstl et al., 2016). Schniederjans et al. (2005) point out that disadvantages with insourcing might be increased costs of labor and material compared to companies that outsource. Since these resources were previously used for production of the ICE, the switch of focus should not lead to large increases of cost. However, there might be an issue for the OEMs regarding the need of competence.

Thus, it is essential for the suppliers to be aware of the possibility of OEMs insourcing production of some components due to freed up resources from the production of ICE. Especially the suppliers with close collaboration with only one or a few OEMs should be prepared of this since a large share of the business then will get lost if one customer decides to insource. In order to maintain the production at the suppliers' sites, the suppliers need to make it clear what they have that is unique and why their production is better and cheaper than what OEMs can achieve. Therefore, it is important to have the right competence and also to acquire the right competence of new technologies. Many suppliers have pointed this out as a challenge, although they believe that they will be able to acquire the competence by either develop it or buying it. One supplier has even obtained competence by acquisition of another company.

6.4 The impact of change management

To be able to adapt to the foreseen changes for each supplier and be able to survive, the awareness and readiness is crucial in order to see in what stage each supplier is. Fritzenschaft (2014) means that change management is about transforming an organization from a present stage to a desired future stage. Since all interviewed suppliers were somehow affected by the development of electromobility, they must go through this transformation and use necessary tools of change management. Most suppliers pointed out that they had made some planning to be prepared for the foreseen changes. According to Fritzenschaft (2014), the main concern, in this early step of awareness and adaptation, is to create readiness and willingness for change within the organization, but also understanding and acceptance among employees. Even though planning towards components for an electric car is initiated, there were around one third that have not started any adaptation yet. Hence, it could be explained by Pescher's (2008) characteristics of change initiatives, where a change can be distinguished by three different perspectives. In a case where a supplier has planned for the change in advance and also working proactively to be able to handle the change when it happens, the degree of awareness must be higher. On the other hand, an unplanned change and a reactive reason for change must result in lower degree of awareness.

Since the highest stage of awareness was defined as a supplier already started to deliver to electric powertrains, the intensity of change, stated by Pescher (2018), is seen as an adaption. All interviewed suppliers pointed out that this change is done step by step since the volumes are still low. From start, the OEMs, in most cases, asked the supplier to develop and explore the possibility to deliver components to electric powertrains. Due to that, a tight collaboration was set, the change nature could therefore be seen as incremental, according to Figure 8. For most suppliers, these changes will result in new production lines, new sub-suppliers and new required competence. Hence, the end result must therefore be a realignment due to the change being more than a transformation. To sum up, the type of change, according to Balogun and Hope Hailey's framework (2004), must be seen as an adaption. However, this might be the hardest stage to reach, but also results in a fully adaptation of the required change.

Furthermore, suppliers in the early stage of adaptation pointed out that the biggest challenge is to get the management's support for the transformation they are currently facing. There are several new available technologies in the automotive industry (Triathlon Group, 2017), and the interviewed suppliers mean that it is hard to know which to focus on. Kotter (2011) points out the sense of urgency and a powerful guiding coalition as the first two steps in his model to successfully implement a change. Thus, the impact of electromobility must be argued and communicated along with all, as well as positively spread from management to be able to reach full adaptation. According to Kotter (2011), the vision must be clear which clarifies clearly the desired future state of the organization. Therefore, it is important for the suppliers to work close to the customers in order to know what future stage is required due to the changed demand. This can be confirmed by most suppliers which work with a few and tight relationships to increase the possibility to acquire new technologies and competence.

Moreover, several suppliers mentioned concerns about having seen revenue increases but no observed profit. In addition, one interviewed expert pointed out the concern regarding Tesla, which produces fully electric cars without making profit. However, the suppliers believe in better profit in the future when they have more knowledge within the area and are able to scale up production to achieve economies of scale. Kotter (2011) means that it is crucial to plan for and create short-term wins in order to stay successful. Hence, the suppliers need to find short-term benefits in order to manage the preparation and adaptation. For instance, the government can make higher incentives to continue the adaptation by regulations, policies and grants. This can be confirmed by several car manufacturers, such as Renault, Nissan, BMW and Volkswagen, having declared ambitious plans for electric cars with grants from governments (Vaughan, 2017).

Finally, the suppliers that have already started some adaptation were also in most cases involved in different pilot projects. The investments were done a couple of years ago, but due to the concern about the right timing and the currently low demand from OEMs, some suppliers have not yet made the final transformation. According to Turner (2005), pilot projects can be used to be able to later decide if the project was successful and should be implemented in full scale. Since Kotter (2011) points out the risk of declaring victory too soon, one way to avoid this might be pilot projects, where smaller improvements are reached as well as lower sunk cost used. However, this is confirmed by the suppliers that already have started to deliver to electric powertrains.

7 Conclusions

In this final chapter, the conclusions of the master's thesis will be presented with focus on fulfilling the purpose and answering the research questions. Initially, the research questions will be answered followed by a presentation of the success factors that were to be identified in this study.

7.1 Answers to the research questions

During the component study, in total 12 affected components were identified. Seven components in the combustion powertrain were identified to be impacted with three different types of change; radical, disappear and no/low change. The gearbox will be radically changed, whereas the internal combustion engine, starter battery, fuel tank and propshaft will disappear. The differentials as well as the wheels and brakes will have no or low change. Regarding the electric powertrain there are five components which do not exist on the combustion powertrain and will thus be added; electric machine, inverter, power electronics, lithium-ion battery and on-board charger. It is important for suppliers of impacted components to be aware and prepared of the upcoming changes. Finally, it was concluded that the experts and researchers in this study expect the biggest transformation to happen in 10-15 years. Meaning that after this more than 50% of new cars' sales will consist of electric powertrains. Meanwhile, the suppliers will have to ramp up their production of electric powertrain components in order to be competitive and avoid being replaced.

In total, 13 different suppliers were identified and interviewed. All suppliers are affected by the development of electromobility even though not all are facing a large change. Suppliers delivering components with low or no change to fit the electric powertrain, were in general more prepared than what they were foreseen to be. Suppliers delivering components with radical change or components added or removed from the powertrain face a larger change. Hence, they are in some cases not as prepared as desired. Most of these suppliers have already planned some adaptation but not yet started it, in some cases due to the lack of financials or competence. In addition, they felt uncertain of when and how fast the demand for electric powertrain components will increase. OEMs do not demand large volumes for electric powertrains, which could be a reason why only 23% of the suppliers are currently delivering to fully electric powertrains. However, all suppliers need to be aware and prepared when the volumes increase. Seventy percent of the interviewed suppliers have started some adaptation, but they need to ensure that the started projects are fulfilled in order to be able to deliver to electric powertrains in the future. Furthermore, all suppliers are looking positively on the future and most of them believe in volume increases without making a lot of adaptations. Only a few believe that their volumes will decrease drastically and therefore need to find new customers. The OEMs care about their current relationships and want as far as possible to keep their suppliers. Nonetheless, the suppliers cannot rely on the current relationships, but need to make the full adaptation in order to survive.

7.2 Key success factors

A part of the purpose of this study was to identify key success factors which will be essential in order for the current suppliers to survive the transformation towards electromobility as well as for the potential new suppliers to be able to enter the car industry. The three identified key success factors are: tight relationships with only a few customers; be able to acquire necessary competence and make the adaptation in the right time. However, all trends, SpACE, within the automotive industry will impact the success of the suppliers. The success factors identified in this thesis have its foundation in electromobility but could also be seen as general success factors when making a large change, involving many actors. Therefore, it is of importance for the suppliers to apply these factors in order to remain competitive with regard to all trends.

7.2.1 Relationship

All of the suppliers that were interviewed said that they have or aim to have close relationships with their customers. In general, the suppliers have 5-10 large customers which they in many cases identify as partners. What differ between the suppliers is that the suppliers that have come the furthest in the adaptation are at the customer sites several times per week. Furthermore, most of these suppliers are collaborating with one or more OEMs in different development projects. Therefore, it has been concluded one factor that is key in the car industry to succeed in the long term is to have close relationships with the customers. Additionally, it is of importance to listen to not only the direct customers but also the end customers in order to be prepared for the changes that will happen.

7.2.2 Competence

One of the challenges that was somehow mentioned by all the suppliers was competence. Most of the suppliers mentioned that they do not have the competence needed for the upcoming technology change but that they will be able to acquire it in one way or another. The transformation towards electromobility is happening within 10-15 years and the demand for electric powertrain components is currently increasing. Thus, it is essential for the suppliers that have not yet acquired the necessary competence to do that in the near future. This will reduce the risk of being replaced by other actors that might see this technology change as an opportunity to enter a new market. The possession of the right competence has thus been identified as the second key success factor.

7.2.3 Timing

To be able to implement the right changes in the right time, timing is needed. Since most suppliers already deliver to the car industry today, and deliver components to combustion powertrains, they need to continue with that in order to gain profit. At the same time, they need to make investments in the new technology in order to avoid being replaced. Thus, this is something they always face when new technology is being available. However, this is the largest transformation in the automotive industry in decades and not only OEMs will be affected. Since some components are completely replaced, it is essential for the affected suppliers to be aware and prepared for the foreseen changes. According to the change management theory, step by step implementation by a strong and clear purpose is critical to succeed. Furthermore, being prepared and alert to a change and therefore being able to invest in the right time, can give large benefits and competitiveness. Pilot projects are a competitive solution to ramp up and secure that investments are profitable at the end. Several examples of suppliers investing in wrong technology or in projects that never became profitable can be identified. In addition, being late can result in suppliers being replaced by another. To sum up, there is always a tradeoff between being too early and being too late, but at least being prepared and implement pilot projects would minimize that risk.

References

Andersen, P. H. and Christensen, P. R. (2005) *Brides over troubled water: suppliers as connective nodes in global supply networks.* Journal of Business Research, vol 58, pp. 1261-1273.

Abrahamsen, M. H. and Håkansson, H. (2012) Networks in transition. The IMP Journal, vol 6, pp. 194-209.

Arnäs, P-O. (2017) *Future challenges in transportation 2017* https://chalmersuniversity.app.box.com/s/zdyt36u9j2glqo3xqdbs1xf92c9qwgyh [Accessed 4 February 2018]

Autobattery (2018) https://www.autobatteries.com/en-us/how-car-batteries-work/how-a-battery-starts-your-car [Accessed 26 March 2018]

Ayre, J. (2018) *Over 50% Of New Car Registrations In Norway In 2017 = Plug-In Vehicles Or Hybrids.* Clean Technica. https://cleantechnica.com/2018/01/04/50-new-car-registrations-norway-2017-plug-vehicles-hybrids/ [Accessed 13 April 2018]

Balogun, J. and Hope Hailey, V. (2004) Exploring Strategic Change, 2nd ed., Harlow.

Battery University (2016) http://batteryuniversity.com/learn/article/lead_based_batteries [Accessed 26 March 2018]

Brandes, H. (1994) *Strategic changes in purchasing: two main tracks.* European Journal of Purchasing and Supply Management. vol 1, no. 2, pp. 77-87.

Brain (2000) *How car engines work* https://auto.howstuffworks.com/engine1.htm [Accessed 26 March 2018]

Brain (2006) *How Lithium-ion Batteries work https://electronics.howstuffworks.com/everyday-tech/lithium-ion-battery.htm* [Accessed 12 March 2018]

Bryman, A. and Bell, E. (2011) *Business research methods.* Third edition. Oxford, New York: Oxford University Press.

Burnes, B. (2009) Managing Change: A Strategic Approach to Organisational Dynamics, 5th ed., Harlow.

Cabral, S., Quelin, B. & Maia, W. (2014) *Outsourcing Failure and Reintegration: The Influence of Contractual and External Factors*. Long Range Planning, vol. 47, no. 6, pp. 365-378.

Cameron, E., Green, M. & Books24x7 (e-book collection) 2012, *Making sense of change management: a complete guide to the models, tools, and techniques of organizational change,* 3rd edn, Kogan Page, London;Philadelphia. Conference on Energy and Automotive Technologies.

Carbibles (2018) *Transmission Guide: Everything you need to know https://www.carbibles.com/transmission-guide/* [Accessed 12 March 2018]

Conrady R. 2012. *Status quo and future prospects of sustainable mobility*. In Trends and Issues in Global Tourism 7, 237-260.

Dass, M. and Fox, G.L. (2011) *A holistic network model for supply chain analysis*. International Journal of Production Economics, vol 131, no. 2, pp. 587-594.

Dell, R., Moseley, P.T., Rand, D.A.J. & ScienceDirect (e-book collection) (2014) *Towards sustainable road transport,* First edn, Elsevier Academic Press, Waltham, MA.

Denscombe, M. (2014) *The good research guide: for small scale research projects*. Fifth edition. Maidenhead: Open University Press.

Dinu, A-M. (2015) *The risks and benefits of outsourcing.* Knowledge Horizons, vol 7, no. 2, pp. 103-104.

Dooley, K., Yan, T. and Yang, S. (2017) *A theory of supplier network-based innovation value*. Journal of Purchasing and Supply Chain Management, vol 23, pp. 153-162.

Driveelectric (2018) https://driveelectric.org.nz/fleet/what-is-an-ev/ [Accessed 3 March 2018]

Dunn, A., van Liere, D.W. and Vervest P.H.M. (2009) *The Network Factor – How to Remain Competitive.* The Network experience – book.

Figenbaum, E., Assum, T. & Kolbenstvedt, M. 2015, "Electromobility in Norway: Experiences and Opportunities", *RESEARCH IN TRANSPORTATION ECONOMICS,* vol. 50, pp. 29-38.

Foerstl, K., Kirchoff, J.F. & Bals, L. (2016) *Reshoring and insourcing: drivers and future research directions*. International Journal of Physical Distribution & Logistics Management, vol. 46, no. 5, pp. 492-515.

Ford, D., Berthon P., Brown, S., Gadde, L-E., Håkansson, H., Naudé, P., Ritter, T. and Snehota, I. (2002) This business marketing course, John Wiley & Sons, p.30-37, p.40-44, p. 48.

Fritzenschaft, T. 2014; *Critical success factors of change management: an empirical research in German small and medium-sized enterprises,* 1;2014; edn, Springer Gabler, Wiesbaden.

Gable & Gable (2018) *Inverters and Converters in Hybrids and EV.* ThoughtCo. https://www.thoughtco.com/how-inverters-and-converters-work-85612 [Accessed 4 April 2018]

GB Radiator (2018) http://gbradiator.com/services/fuel-tanks-gas-tanks-greensboro-nc-27405/ [Accessed 26 March 2018]

GKN (2018) *Vehicle Architecture and Integration https://www.gkn.com/en/our-divisions/gkn-driveline/our-solutions/cvjs/vehicle-architecture-and-integration/* [Accessed 26 March 2018]

Grauers, A., Sarasini, S. & Karlström, M. 2013, *Why electromobility and what is it?*

Hardy Engineering (2018) https://www.hardyengineering.co.uk/gearbox-repairs/ [Accessed 26 March 2018]

Håkansson, H. and Ford, D. (2002) *How should companies interact in business networks?* Journal of Business Research, vol 55, pp. 133-139.

Holme, I.M. and Solvang, B.K. (1986) *Forskningsmetodik: Om kvalitativa och kvantitativa metoder*. First edition. Studentlitteratur Lund.

IEA (2012) *Energy Technology Perspectives 2012 - Pathways to a Clean Energy System*.

Indiamart.com (2018) https://www.indiamart.com/proddetail/drive-shaft-assembly-14953794233.html [Accessed 28 March 2018]

Infineon (2018) *(H)EV-on-board battery charger* https://www.infineon.com/cms/en/applications/automotive/product-solutions-hev-ev/onboard-battery-charger/ [Accessed 28 March 2018]

Insideevs.com (2014) *Nissan LEAF Battery NerdGasm* https://insideevs.com/nissan-leaf-battery-nerdgasm/ [Accessed 2 May 2018]

Kotter, J. P. (2011) Leading Change: *Why Transformation Efforts Fail*, in: Harvard Business Review (ed.): 10 must reads on change, Boston 2011, pp. 2-12.

KPMG International. (2012), *KPMG's Global Automotive Executive Survey 2012*.

Masson, J. L. (2013) *The Pros and Cons of Using In-Wheel Motors in Electric Cars*. Plugincars. http://www.plugincars.com/pros-and-cons-wheel-motors-127174.html [Accessed 2 April 2018]

Mech4study (2014) http://www.mech4study.com/2014/03/main-parts-of-internal-combustion-engine-or-automobile-engine.html [Accessed 28 March 2018]

Mitsubishielectric (2018) https://www.mitsubishielectric.co.jp/automotive/tms2017/english/system/pdf/on-board_charger.pdf [Accessed 28 March 2018]

Morris, C. (2018) Charged Electric Vehicles Magazine: *Nissan starts LEAF battery exchange program in Japan* https://chargedevs.com/newswire/nissan-starts-leaf-battery-exchange-program-in-japan/ [Accessed 2 May 2018]

My-cardictionary, 2018. https://www.my-cardictionary.com/drive-train/drive-shaft.html [Accessed 28 March 2018]

Nice, K. (2000) *How differentials work.* howstuffworks.com https://auto.howstuffworks.com/differential.htm [Accessed 26 March 2018]

O'Gorman, K. & MacIntosh, R., (2015), Research methods for business & management: a guide to writing your dissertation, 2nd; edn, Goodfellow Publishers Ltd, Oxford, England.

Overdrive (2018) https://overdriveheavyduty.com/service/heavy-duty/differentials/ [Accessed 26 March 2018]

Pavoni, F. and Berger, R. (2012) *The Lithium-Ion Battery Value Chain.* International Conference on Energy and Automotive Technologies.

Pearltrees.com (2014) *http://www.pearltrees.com/bretth98/engines/id12931186/item124457289* [Accessed 15 March 2018]

Pescher, J. (2010) Change Management: Taxonomie und Erfolgsauswirkungen, Wiesbaden.

Pontes (2018) *2017 China Electric Car Sales Blow World Out Of The Water*. Clean Technica. *https://cleantechnica.com/2018/01/29/2017-china-electric-car-sales-blow-world-water-baic-ec-series-superstar/* [Accessed 12 April 2018]

Sandén, B. and Wallgren, P. (2017) *Systems Perspectives on Electromobility.* Chalmers University of Technology, Gothenburg.

Schniederjans, M.J., Schniederjans, D.G. & Schniederjans, A.M. (2005) *Outsourcing and insourcing in an international context,* M.E. Sharpe, Armonk, N.Y.

Seba, T. (2017) *Clean Disruption, Why Conventional Energy & Transport will be Obsolete by 2030 Boulder* https://www.youtube.com/watch?v=fVYwBsSYjSg [Accessed 4 February 2018]

Sheth, K. (2017) *All about the automotive industry*. World Atlas. https://www.worldatlas.com/articles/all-about-the-automotive-industry.html [Accessed 4 February 2018]

Siemens (2015) *Innovative motor technology for hybrid and electric vehicles* https://w3.siemens.com/topics/global/de/elektromobilitaet/PublishingImages/antriebe-pkw/pdf/sivetec-mrs-mri-siemens_en.pdf [Accessed 20 February 2018]

Smith, K., Omanaovic, J., Åberg, B., Klarberg, P., Åkesson, A., Wallrup, E., Lundström, L. & Halef. R. (2018) *Fossilfria drivmedel för att minska transportsektorns klimatpåverkan* *https://data.riksdagen.se/fil/EE20BCB5-1593-4298-A58A-5F6FA643E4BF* [Accessed 12 April 2018]

Snehota, I. (2002) *Business Network and Marketing*, pp. 30-45.

Stewart, J. (2017) *Look ma, no brake! You'll drive electric cars with one pedal* *https://www.wired.com/story/look-ma-no-brake-youll-drive-electric-cars-with-one-pedal/* [Accessed 4 April]

Styhre, A. & Kohn, K. 2006, "The struggle over meaning: Rethinking the car in automotive industry", *Journal of Change Management,* vol. 6, no. 1, pp. 21-34.

Svahn, S. and Westerlund, M. (2009) *Purchasing strategies in supply relationships.* Journal of Business & Industrial Marketing. Vol 24, no. 3, pp173-181.

Texas Instrument (2017) *On-Board (OBC) & Wireless Charger* http://www.ti.com/solution/hevev_onboard_obc_wireless_charger?utm_source=GOOGLE&utm_medium=cpc&utm_term=%2Bonboard%20%2Bcharger&utm_campaign=ATO_HEP_WW_N_M_General&utm_content=09db4f8b-b8a3-44f2-beda-07bdc4481fd4&gclid=Cj0KCQjwxN_XBRCFARIsAIufy1Z1lI6iEOz4hu4ggsK3eyG68URBt0cSaCQ44KuSwQEIN1jTXPYnEKUaAg0fEALw_wcB [Accessed 4 Feb. 2018]

Turner, J.R. (2005). The Role of Pilot Studies in Reducing Risk on Projects and

Programmes. International Journal of Project Management 23: 1–6.

Triathlon Group (2017) *AUTOMOTIVE GOES SpACE.* http://triathlon.se/content/files/pdf/2017-4_automotive_goes_space.pdf [Accessed 4 Feb. 2018]

van Weele, A.J. (2014) *Purchasing and Supply Chain Management.* 6th edn. The Netherlands: Cengage Learning.

Vaughan (2017) *All Volvo cars to be electric or hybrid from 2019.* The Guardian.

Vervest, P.H.M. and Zheng, L. (2008) *The Network Experience – New Value from Smart Business Networks*. The Network experience – book.

Volvo Cars (2017) *Autonomous Driving* https://www.volvocars.com/intl/buy/explore/intellisafe/autonomous-driving [Accessed 4 February 2018]

Woodford, C. *Electric motors* http://www.explainthatstuff.com/electricmotors.html [Accessed 4 February 2018]

Yildis, H., Yoon, J. and Talluri, S. (2016) *Reliable Supply Chain Network Design*. Decision Science. Volume 47 No 4, August 2016.

Yin, R.K. (2009) *Case Study Research: design and methods*. Fourth edition. Thousand Oaks: SAGE Publications, Inc.

Appendix I – Interview guide OEM/researchers/experts

Aim with interview

To investigate on a high level what components in the car's powertrain that are affected by the development of electromobility. Thereby, examine types of suppliers that are facing a potential change for their supply to car industry.

Background

1. What is your professional background?
2. In what activity domain are you currently working and what are your responsibilities?

Body

Electromobility

1. Define and explain your view of electromobility?
   a. What is the history behind?
2. What are the drivers of electromobility?
3. What collaborations/projects do you have with the car industry?
4. How large share of the car fleet is electrified today?
   a. Types of electrified vehicles (BEV, PHEV, HEV etc.)?
5. When do you foresee a fully electrified car fleet?

Components and suppliers

1. On a high level, which components are related to the powertrain?
   a. How many are produced inhouse/purchased?
2. What components will be affected by electrification (disappear, low change, radical change etc.)?
   a. What parts in each component will be affected?
   b. How will the parts in each component be affected (volume increase/decrease)?
3. What types of suppliers will be affected?
   a. In what way will they be affected?
   b. Kind of relationships with those suppliers today/after the development of electromobility?
   c. Will the number of relationships increase/decrease?
4. What is a key supplier in car industry?
   a. How large share of the total supplier base are considered as key suppliers?

Challenges

5. What challenges do you see with the development of electromobility?
6. Do you think car industry will be able to adopt to the necessary changes?
7. Do you think OEMs are able to adopt to the changes?
   a. Do they have the competence needed?
   b. Do they have the willingness?
8. Do you think the upstream suppliers are be able to adopt to the changes?
   a. Do they have the competence needed?
   b. Do you think they are able to deliver the volumes needed (e.g. battery cells)?
   c. Do they have the willingness?
9. Something else you think is important to add?

Appendix II – Interview guide suppliers

Aim with interview

To investigate how prepared suppliers are for the changes they will face as electromobility increases.

Background

1. What is your professional background?

Body

Current situation

1. What type of products do you produce/develop?
   a. What products do you deliver to the car industry?
   b. How large share of your products are delivered to the car industry?
   c. How long have you been active in the car industry?
2. What kind of relationship do you have with your customers within the car industry?

Future situation

3. Based on research we have made in our study, the change of production from ICE cars to fully electric cars will happen in 10-15 years, do you think this is likely?
4. Do you think this will affect your business?
   a. If yes, how (volume increases/decreases, new competence/customers/products)?
   b. Will the revenue per sold product/system to electric cars increase or decrease compared to ICE cars?
   c. If no, why not?
5. Have you already *planned* some adoption of your production to products used in electric cars?
6. Have you already *started* to adopt your production to products used in electric cars?
   a. What are you doing to adopt to the changes?
7. Do you think you will have the *capacity* to deliver the demanded products to car industry in the future?
8. Do you think you will have the *competence* to deliver the demanded products to car industry in the future?
9. Do you think the OEMs will produce your product inhouse in the future?
   a. If yes, do you think OEMs have the capacity and competence?
   b. If no, why not?
10. Do you think your customer base will change?
    a. If yes, in how many years (10-15, when fully electric)?
    b. Do you think the number of close relationships will increase or decrease?

Challenges

11. What challenges do you see with the development of electrification?
    a. Equity, competence, equipment, leadership, incitement, etc.
12. What challenges do you have?