CHALMERS
UNIVERSITY OF TECHNOLOGY

Future dynamics of the Swedish heavy-duty truck industry

Scenarios for the adoption of autonomous, connected and electrified trucks by 2030

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

LUDVIG BÖRJESSON
ERIK SIDBRANT

Department of Technology Management and Economics
Division of Entrepreneurship and Strategy
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2018
Report No. E 2018:001

MASTER'S THESIS E 2018:001

Future dynamics of the Swedish heavy-duty truck industry

Scenarios for the adoption of autonomous, connected and electrified trucks by 2030

LUDVIG BÖRJESSON
ERIK SIDBRANT

Supervisor, Chalmers: Joakim Björkdahl

Department of Technology Management and Economics
Division of Entrepreneurship and Strategy
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2018

Future dynamics of the Swedish heavy-duty truck industry

Scenarios for the adoption of autonomous, connected and electrified trucks by 2030

LUDVIG BÖRJESSON

ERIK SIDBRANT

Master's Thesis E 2018:001

Department of Technology Management and Economics

Division of Entrepreneurship and Strategy

Chalmers University of Technology

SE-412 96 Göteborg, Sweden

Telephone: +46 (0)31-772 1000

Chalmers Reproservice

Gothenburg, Sweden 2018

Acknowledgements

Firstly, we would like to thank Joakim Björkdahl, our supervisor at Chalmers University of Technology, for providing us with guidance throughout the study.

Secondly, we would like to thank Triathlon Group and ISEA, the initiators of this master's thesis, for providing us with support throughout the study.

Finally, we would like to thank all the interviewees for taking the time to participate in interviews and discussions.

Ludvig Börjesson

Erik Sidbrant

Abstract

It is possible that the heavy-duty truck industry will be subject to considerable industrial transformation during the next decades. The significant increase of road transports has entailed new challenges, which need to be addressed in order to ensure a continuous economic growth that is consistent with a sustainable development. The most prominent challenges concern aspects such as increasing emissions of greenhouse gases, traffic safety and shortage of truck drivers. As a response to these challenges, and due to other potential benefits, the technological areas of autonomy, connectivity and electrification is about to be adopted by the heavy-duty truck industry. However, due to a number of reasons, the future diffusion of these technologies is uncertain. Hence, the focus of this study has been to increase the understanding of how these technological areas may develop until the year of 2030.

In addition, the study has aimed to increase the understanding of how this development is expected to influence the industry dynamics as well as the value chain structure of the Swedish heavy-duty truck industry. With the unique situation of hosting two global incumbent truck manufacturers, and at the same time being known for an ambitious political stance towards a sustainable development, the Swedish industry has the potential to impact this industrial transformation in a favorable way.

The study has been conducted as a scenario planning, where scenarios for the technical development of the heavy-duty truck industry were developed to help explore possible impacts on the industry dynamics and value chain. The developed scenarios were based on the information collected during 21 interviews with organizations surrounding the heavy-duty truck industry, focusing on the technological areas of autonomy, connectivity and electrification. Furthermore, nine additional interviews were performed with industry actors that are a part of the industry value chain. For these interviews, the developed scenarios were used as a base for discussion. By relating to the contexts of the specific scenarios, the interviewees were asked to elaborate on expected changes of the industry dynamics as well as the structure of the industry value chain.

The scenario planning resulted in four different scenarios, for which the development and adoption of the technological areas of autonomy, connectivity and electrification differed. The key uncertainties that are constituting the reason for why these scenarios differ are related to the political approach to data utilization, as well as the industry perspective on dominant future fuel for heavy-duty trucks. The future political approach to data utilization could range from more conservative to liberal, while the dominant future fuel could be either sustainable alternatives to the internal combustion engine or electricity.

The most significant change of the industry dynamics and the industry value chain is expected for a situation with a liberal political approach to data utilization and where electricity is becoming the dominant fuel. Such a situation would lead to both forward and backward integration, as well as disruption of incumbent actors and entrants of new players.

Contents

1. Introduction 1
   1.1 Background 1
   1.2 Purpose of the study 2
   1.3 Research questions 2
   1.4 Definition of the industry value chain 3
   1.5 Delimitations 3
   1.6 Disposition of the report 4
2. Theoretical framework 5
   2.1 Scenario planning 5
3. Method 11
   3.1 Research design 11
   3.2 Data collection 12
      3.2.1 Primary data collection through interviews 12
      3.2.2 Complementary collection of secondary data 15
   3.3 Data analysis 16
      3.3.1 Comparisons of findings from interviews 16
      3.3.2 Applied steps for scenario planning 17
   3.4 Research quality 21
      3.4.1 Reliability 21
      3.4.2 Validity 22
   3.5 Ethical aspects 22
4. Expectations on development and diffusion of technologies 25
   4.1 Development and diffusion of autonomy 25
      4.1.1 Implications on Total Cost of Ownership 27
      4.1.2 Implications on transport efficiency and productivity 28
      4.1.3 Influencing aspects on autonomy diffusion 28
   4.2 Development and diffusion of connectivity 34
      4.2.1 Current state of connectivity 34
      4.2.2 Vehicle communication 35
      4.2.3 Connectivity as an order qualifier 36
      4.2.4 Connectivity for transport efficiency 37
      4.2.5 Connectivity as a revenue source 38
   4.3 Overview of electrification paths and alternative fuels 39
      4.3.1 Sustainable development as driver of change 39
      4.3.2 The internal combustion engine and alternative fuels 40

4.3.3 The electric powertrain and alternative electricity supplies 41
4.4 Future roles of electrification and alternative fuels 43
4.4.1 Implications of future attitude towards sustainable development 43
4.4.2 The future role of the internal combustion engine 44
4.4.3 The future role of the electric powertrain 47
5. Identification and ranking of factors 55
5.1 Description and motivation of ranked factors 55
5.1.1 Description and motivation of macro-factors 55
5.1.2 Description and motivation of micro-factors 59
5.2 Illustration of ranked factors 64
6. Development of scenarios 67
6.1 Clustering and presentation of basic trends 67
6.2 Clustering and presentation of key uncertainties 69
6.3 Scenario descriptions 71
6.3.1 Locked-in Potential 72
6.3.2 Offline Powerline 73
6.3.3 Autonomous Combustion 75
6.3.4 Force Unleashed 76
7. Implications for industry dynamics and value chain structure 79
7.1 Conservative political approach to data utilization 80
7.2 Liberal political approach to data utilization 81
7.3 Alternative fuels considered dominant in the industry 89
7.4 Electricity considered the dominant fuel in the industry 90
7.5 Interplay between high data utilization and electricity as dominant fuel 94
7.6 Visualization of impacts on the industry value chain 95
8. Discussion and proposal for future studies 99
8.1 Findings of interest not directly related to the research questions 99
8.2 Proposal for future studies 100
9. Conclusions 103
9.1 Scenarios for the Swedish heavy-duty truck industry by 2030 103
9.2 Changed industry dynamics 104
9.3 Implications on the industry value chain 105
Reference list 107
Appendices I
Appendix 1 – Interview template, orientational interviews I
Appendix 2 – Interview template, value chain interviews II

Figures

Figure 1. Definition of the industry value chain, as utilized throughout the study 3
Figure 2. Illustration of classification of factors 19
Figure 3. Illustration of scenario construction 20
Figure 4. Visualization of identified factors... 65
Figure 5. Visualization of the construction of scenarios 67
Figure 6. The four scenarios developed based on identified key uncertainties 71
Figure 7. Scenario: Locked-in Potential 72
Figure 8. Scenario: Offline Powerline 74
Figure 9. Scenario: Autonomous Combustion.. 75
Figure 10. Scenario: Force Unleashed 76
Figure 11. Illustration of concerned scenarios: Offline Powerline and Locked-in Potential 80
Figure 12. Illustration of concerned scenarios: Force Unleashed and Autonomous Combustion........ 81
Figure 13. Illustration of concerned scenarios: Locked-in Potential and Autonomous Combustion.... 89
Figure 14. Illustration of concerned scenarios: Offline Powerline and Force Unleashed 90
Figure 15. Illustration of concerned scenario: Force Unleashed.. 94
Figure 16. Visualization of value chain for Locked-in Potential 95
Figure 17. Visualization of value chain for Offline Powerline 96
Figure 18. Visualization of value chain for Autonomous Combustion 97
Figure 19. Visualization of value chain for Force Unleashed 98

Tables

Table 1. List of orientational interviews and related organizations 14
Table 2. List of interviews with industry value chain actors 15
Table 3. Summary of levels of driving automation according to SAE J3016 (SAE International, 2017) 25
Table 4. Compilation of uncertain areas affecting autonomy diffusion 29
Table 5. Efficiency gains for industry actors mentioned during interviews 37
Table 6. Identified macro-factors and corresponding classification 64
Table 7. Identified micro-factors and corresponding classification 65

1. Introduction

In this chapter, a background to the study is given, followed by the purpose of the study and research questions. In addition, a definition regarding actors in the value chain of the chosen industry is introduced, which will be an important distinction throughout the report. The chapter concludes with statements regarding delimitations and a disposition of the report.

1.1 Background

Transports of goods are an essential part of modern society, and has a strong association to economic growth (European Union, 2014). Road transportation of goods with trucks have experienced a strong growth, largely due to the flexibility of this mode of transport (Fenelon, 2017).

However, increased road transport of goods has brought some new challenges. From 1990 to 2007, Sweden experienced a strong growth in road transports of goods, but at the cost of increased emissions (Naturvårdsverket, 2017). Transports grew from 2007 to 2016 as well, but with emissions being reduced, which is attributed to the use of biological diesel (ibid). But biological fuels imply other negative side effects, such as competing for farmland with food sources (WWF, 2008). Currently, goods transported by trucks are responsible for approximately 9% of the total greenhouse gas emissions in Sweden (Naturvårdsverket, 2017). The trucking industry therefore remains an important area of improvement in terms of emissions.

Another area of concern with increasing road transport is traffic safety, with 31’000 fatalities on European roads in 2010 (European Union, 2014). Furthermore, due to low wages and harsh working conditions, the industry suffers globally from driver shortages (ATA, 2017). As an example, the American road transport industry is currently lacking 50’000 truck drivers (ibid).

To overcome these transport-related challenges, research and innovation could be the solution (European Commission, 2017a). Three promising technology areas currently under rapid development are autonomy, connectivity and electrification. An autonomous vehicle is one that can drive itself from a starting point to a predetermined destination in “autopilot” mode using various in-vehicle technologies and sensors (Gartner, 2017). Connected vehicles can exchange information wirelessly with the vehicle manufacturer, third-party service providers, users, infrastructure operators and other vehicles (ACEA, 2016). An electrified truck refers to operating the truck with an electric powertrain running on electricity, instead of the common internal combustion engine. These areas have all received recent attention due to technological progress within areas such as sensor technology, communication technology, battery technology and sustainable energy production.

When it comes to these three technology areas, trucks differ from cars, and thus the possibility to apply the technologies. Applying autonomy technology to heavy-duty trucks is challenging due to the long distance required to come to a stop, and that the danger involved with crashes is higher than for a car due to the increased weight. Connectivity services for trucks are challenged by strict legislation regarding data gathering and data sharing. Electrification of heavy trucks is commonly seen as a challenge, since a replacement of the conventional fuel tank with batteries would mean that long-haul trucks would need to carry several extra tons of batteries.

The future development of automation, connectivity and electrification of the heavy-duty truck industry is subject to certain circumstances in the Swedish market in particular. Sweden accommodates two large global truck manufacturers, namely Volvo Trucks and Scania, which have the ability to influence how these three technologies will be implemented in heavy-duty trucks in the future. Both companies are already developing technologies for autonomous and connected trucks, and experimenting with hybrid powertrains, which suggests that these two manufacturers want to be part of delivering solutions in these areas in the future. Sweden utilizes CO_2-neutral electricity sources to 96%, stemming mostly from large-scale utilization of water and nuclear power, based on data from 2011 (Nordic Energy Research, 2012), which makes the prospect of electrification attractive from an environmental perspective.

It is uncertain how the three technology areas will develop, and it is difficult to evaluate how they will impact the dynamics and value chain structure of the heavy-duty truck industry. For this study, impacts on the industry dynamics and value chain structure particularly refers to changes in roles and activities of current industry actors, emergence of new roles and repositioning of current actors in the value chain. Therefore, in this study, a comprehensive overview of the knowledge and thoughts regarding the future Swedish heavy-duty truck industry will be given. In this study, heavy-duty trucks are defined as having a total weight over 16 tons. Furthermore, this study focuses on Swedish long-haul truck transports, defined as transports carried out at least 200 kilometers away from the departing terminal, and regional transports with heavy-duty trucks, meaning transports that primarily are operated outside urban areas.

1.2 Purpose of the study

The purpose of this study is to increase the understanding of how the technological areas of autonomy, connectivity and electrification may develop until the year of 2030, and how this development is expected to influence the industry dynamics and the value chain structure of the Swedish heavy-duty truck industry.

1.3 Research questions

There are many uncertainties related to how the technological areas of autonomy, connectivity and electrification are going to develop. Therefore, it is also uncertain how the industry dynamics and the value chain structure will change in the future. To manage these uncertainties, a creation of plausible scenarios for the technological development of autonomy, connectivity and electrification has been considered a suitable approach, where the created scenarios are used as a base for the discussion regarding how the industry dynamics and the value chain structure might change. Therefore, two sequential research questions have been formulated as follows:

I. What are plausible scenarios for the technological development of autonomy, connectivity and electrification in the Swedish heavy-duty truck industry by 2030?
II. How are the industry dynamics and the structure of the value chain expected to change for each developed scenario?

1.4 Definition of the industry value chain

The study investigates the impact of technological development on the industry dynamics and value chain. The industry value chain is in this study simplified and explained as the activities performed by Component Suppliers, OEMs (Original Equipment Manufacturers), Haulers and Freight Forwarders. Component suppliers deliver parts, modules or subsystems that will be used to assemble a truck, such as powertrain components or components for the body of the truck. OEMs produce some components and typically performs the assembly of the truck, which is then sold to haulers by a brand division or by a separate company. Haulers refer to the companies which are operating the trucks, and transporting goods from one destination to another. Freight Forwarders fulfill the role of consolidating goods and organizing shipments of goods to the transport customer. An illustration of the value chain can be found in figure 1.

Figure 1. Definition of the industry value chain, as utilized throughout the study

1.5 Delimitations

A delimitation to the study was made in terms of sampling. Transport buyers were not interviewed due to available time being focused on the industry actors, which could have reduced the insights into customer demand in terms of automation, connectivity and electrification. However, to mitigate the impact of this delimitation, interviewed industry actors were asked to comment on customer demand.

A geographical sampling delimitation was made, since only Swedish companies or the Swedish divisions of international companies were interviewed for the study. This might have limited the insights into technological, social and political developments in other parts of the world that will impact the Swedish transport industry. Instead, interviewees were asked to give comments regarding technological developments from a global perspective, and to reflect on other international changes that would affect the Swedish transport industry.

Another delimitation of this study was the decision to undertake a wide scope, involving predictions within three large technology areas, in combination with short time available. Involving all three areas was seen as important, as initial research on the topic showed a lack of an overarching understanding of how the three technologies could possibly correlate during future development, and thus impact the industry. However, the decision to include all three technology areas has reduced the possibility to perform in-depth analyses of each one.

In addition, a delimitation to the analysis of the study is the omission of quantitative details. The developed scenarios are based on general technological development paths, but are not quantified in terms of the extent that the technologies have spread in the industry. This was a decision made due to the high uncertainty related to the technological development and diffusion, and because the inclusion of quantitative estimates was not deemed to support the realization of the purpose of the study.

To create the possibility for interviewees to share their opinions freely, the questions asked concerned the technologies themselves and the industry as a whole, and were not focused on particular industry actors. This interview strategy was adopted, since the business strategies for the technology areas might be company secrets.

A methodological delimitation is that the scenario planning was carried out by two researchers, whereas scenario planning typically is performed in a workshop setting with several participants with industry expertise. To mitigate the lack of industry expertise during analysis, the findings were controlled by two truck industry experts, and the process was controlled by a Scenario Planning expert.

1.6 Disposition of the report

In the next chapter, chapter two, the theoretical framework utilized during the study is introduced. Then, chapter three presents how the study was designed, how data was gathered and how the data was analyzed. Chapter four compiles the insights regarding possible technological development paths for autonomy, connectivity and automation. In chapter five, the identified factors influencing technology and industry development were extracted and analyzed according to the scenario planning methodology. Chapter six consists of an assembly of four distinct scenarios based on the identified factors. Chapter seven represents gathered insights from companies in the Swedish heavy-duty truck industry regarding how developed scenarios would impact the industry value chain, if they were to come true. A discussion regarding interesting findings not directly related to the research questions and proposals of future studies are presented in chapter eight. Finally, the study ends with chapter nine, where the conclusions from the Scenario Planning and expected implications on the industry dynamics and the value chain structure are drawn.

2. Theoretical framework

The following subchapter aims to describe the managerial tool and method referred to as scenario planning. The subchapter has been structured in order to give an understanding for what a scenario planning is, what characterizes a scenario, why a scenario planning should be conducted, when a scenario planning is applicable and how a scenario planning is conducted.

2.1 Scenario planning

Introduction to scenario planning

According to Peterson et al. (2003), scenario planning can be described as a method that facilitates the ambition to think creatively about possible futures, which are both complex and uncertain. This view is shared by Schoemaker (1995), who further declares that scenario planning has been used by numerous companies to imagine possible futures, and how these futures might impact certain issues. However, scenario planning and the resulting scenarios are not supposed to be a prediction of the future. Instead, scenarios are supposed to enable for the practitioners to perceive possible futures in the present (Schwartz, 1996). Since there are many important uncertainties influencing the development of the future, a certain and accurate prediction of the future is difficult to achieve (ibid). Hence, scenario planning instead aims to result in a variety of possible futures for which these uncertainties have been taken into account (Peterson et al., 2003). Ringland and Schwartz (1998) have managed to capture this focus on uncertainties in his definition of scenario planning, which reads:

> *"That part of strategic planning which relates to the tools and technologies for managing the uncertainties of the future"*

As has already been indicated, scenario planning should result in a few contrasting scenarios, which can be used to shed light on uncertain parameters related to the future development of specific decisions (Peterson et al., 2003). However, the method of scenario planning is not solely based on uncertainties. According to Schoemaker (1995), such an approach would lead to paralysis in most organizations. Thus, in addition to relevant uncertainties, fundamental trends should be included in the development of scenarios. By combining fundamental trends with relevant uncertainties, it is possible to derive multiple scenarios that compensate for errors in decision making (ibid). According to Schoemaker (1995), such usual errors are overconfidence and tunnel vision. This reasoning is further developed by Schwartz (1996), who indicates that scenario planning, and more specifically scenarios, is one of the most powerful methods for questioning our established mental models of the world. By the use of scenarios, such limitations could be challenged, and our ability to think more creatively about the future could be enhanced.

In relation to other planning methods, scenario planning differs with regards to some specific aspects (Schoemaker, 1995). According to Schoemaker (1995), there are at least three important aspects for which scenario planning differs from alternative planning methods. The first difference is that scenarios take the joint impact of relevant uncertainties into consideration. Secondly, variables constituting the basis of the scenarios could be changed simultaneously, which implies that certain variables do not need to be kept as constants when developing alternative future scenarios. Finally, the third aspect indicates that subjective interpretations should be included in the analysis and thereby be a part of the development of scenarios. Hence, when conducting a scenario planning, it is possible to include variables that are usually difficult to modulate in more precise models. Some examples of this kind of variables mentioned by Schoemaker (1995) are new regulations, innovations or value shifts.

Definition of a scenario

A scenario is a description of a possible and plausible future (Peterson et al., 2003). However, since a prediction of the future cannot be done with absolute certainty, the purpose of a scenario is to describe a situation that could possibly turn out to be the future (ibid). In his definition of a scenario, Porter (1985) has further elaborated on the fact that the future cannot be predicted with certainty. This definition of a scenario, which also is relevant for a scenario planning, reads:

> *"An internally consistent view of what the future might turn out to be - not a forecast, but one possible future outcome"*

In addition to this definition, Schwartz (1996) advocates a definition that includes the meaning of a scenario and how this can be used in order to facilitate decision making, which reads:

> *"A tool for ordering one's perceptions about alternative future environments in which one's decisions might be played out"*

According to Schoemaker (1995), scenarios are supposed to be described as simplified stories, based on an extensive amount of data that have been composed into a limited number of alternative shapes of a potential future. For each scenario, several elements might interact in different ways, which creates alternative storylines for each scenario. This view is shared by Schwartz (1996), who further describes scenarios as stories of how the development of the future might progress, and that this kind of stories can be used to facilitate the adaptation to a changed future reality.

There are several reasons for why stories have been considered an appropriate method of describing possible future scenarios. One of the reasons is that a detailed and realistic story has the potential to help the practitioner to focus on aspects that would otherwise have been ignored (Schoemaker, 1995). Another reason is that stories have the ability to psychologically impact the person exposed to a scenario. In contrast to graphs and equations, stories are an effective way to communicate how alternative futures could be evolved (Schwartz, 1996).

Purpose of scenario planning

One of the reasons for performing a scenario planning is to facilitate decision making for corporate managers, when being faced with uncontrollable uncertainties (Peterson et al., 2003). By providing an enhanced understanding of important drivers of change, scenario planning has the potential to reveal alternative options for action and to evaluate following implications.

As already mentioned, overconfidence and tunnel vision are common characteristics for managers when making decisions. However, with a successful scenario planning it is possible for managers to expand their imaginations and to assess alternative futures (Schoemaker, 1995). Furthermore, Peterson et al. (2003) indicate that a practitioner of scenario planning could benefit from an enhanced ability to effectively respond to alternative developments of the future. With this enhanced ability, the practitioner should be better prepared to avoid potential traps, as well as to take advantage of upcoming opportunities.

Suitable circumstances for scenario planning

Scenario planning is a suitable method in many different situations. According to Peterson et al. (2003), scenario planning is most suitable in situations for which the level of uncertainty regarding the future is high, and the possibility to impact the development is at the same time low. The range of situations for which scenario planning could be applicable is further extended by Schoemaker (1995), who argues that the technique could be used in merely any situation for which a decision maker would like to get a better understanding of potential developments of the future. However, some situations that are mentioned by Schoemaker (1995) as especially suitable for scenario planning are when any of the following conditions prevail:

- *"Uncertainty is high relative to managers' ability to predict or adjust"*
- *"Too many costly surprises have occurred in the past"*
- *"The company does not perceive or generate new opportunities"*
- *"The quality of strategic thinking is low"*
- *"The industry has experienced significant change or is about to"*
- *"The company wants a common language and framework, without stifling diversity"*
- *"There are strong differences of opinion, with multiple opinions having merit"*
- *"Your competitors are using scenario planning"*

How to perform a scenario planning

A scenario planning can be conducted in many different ways (Peterson et al., 2003). Depending on the context and stated goals, the approach to scenario planning can be modified and adapted. This view is shared by most sources describing different methods for conducting a scenario planning. However, there are some general aspects to consider for a successful scenario planning, which will be elaborated on below.

It should be kept in mind that the purpose of a scenario planning is not to cover all possible scenarios. According to Schoemaker (1995) it is sufficient to derive just a few simplified scenarios. The purpose is to widen the practitioners' perspectives of possible futures, which can be done with just a couple of scenarios.

Another general aspect to consider is that a scenario planning should be conducted as an open process, where a variety of opinions and perceptions are allowed (Peterson et al., 2003). The main reason for this is to limit the risk of acting on incorrect assumptions, and not understanding potential negative consequences of these assumptions. According to Peterson et al. (2003), this is the biggest trap when conducting a scenario planning.

Together with the ambition of maintaining an open process, a scenario planning should be conducted by a diversified group of people (Peterson et al., 2003). Furthermore, this set of people should share the same ambition with the scenario planning, and work for a clearly stated common purpose.

In addition to these more general guidelines, more detailed process steps have been developed by Schwartz (1996), Peterson et al. (2003) as well as Schoemaker (1995). These authors have all developed their own sets of process steps, which further indicates that the approach to scenario planning is not strictly defined. However, when studying the different sets of process steps in detail, it becomes clear that there is a common understanding regarding the essentialities of scenario planning. In order to facilitate the understanding of how a scenario planning could be conducted in detail, it is only the set of steps presented by Schwartz (1996) that will be described in this study. These steps have been considered easiest to understand by their names, and have been perceived as relatively comprehensive. The set of steps presented by Schwartz (1996) are as follows:

- *"Step One: Identify Focal Issue or Decision"*
- *"Step Two: Key Forces in the Local Environment"*
- *"Step Three: Driving Forces"*
- *"Step Four: Rank by Importance and Uncertainty"*
- *"Step Five: Selecting Scenario Logics"*
- *"Step Six: Fleshing out the Scenarios"*
- *"Step Seven: Implications"*
- *"Step Eight: Selection of Leading Indicators and Signposts"*

The previous steps will shortly be discussed in the following paragraphs. In general, the steps will be described based on how they are explained by Schwartz (1996). However, since several of the steps coincide with the understanding of Peterson et al. (2003) and Schoemaker (1995), relevant aspects concerning specific steps will be included from these sources as well.

1. Identify Focal Issue or Decision - A scenario planning should be focused and relate to a specific issue or decision (Schwartz, 1996). The choice of a focal issue or decision could be facilitated by considering aspects that will be important for management in the near future. This view is shared by Peterson et al. (2003), who indicates that a scenario planning needs to be focused in order to be effective. In addition to the scope of the research, the time frame should be settled early in the process (Schoemaker, 1995).

2. Key Forces in the Local Environment - The second step implies an identification of local key factors that are likely to determine whether the development of the focal issue, or the outcome of a specific decision, is successful or not (Schwartz, 1996). As an example, this kind of key factors could be related to competitors, customers or suppliers. This is further elaborated by Schoemaker (1995) who argues that the interests of major stakeholders should be identified.

3. "Driving Forces" - The most research-intensive part of a scenario planning is to identify driving forces in the macro environment, which is the aim of the third step (Schwartz, 1996). The local key factors identified in the previous step are likely to be affected by this kind of macro driving forces, which is why these driving forces are important to explore. To make sure to be comprehensive in this research, Schwartz (1996) indicates that the STEEP framework could be used, which include social, technological, economic, environmental as well as political areas. Furthermore, the reasoning concerning what kind of data that is relevant to collect during this phase is extended by Schoemaker (1995). Instead of referring to driving forces Schoemaker

(1995) uses the word factors, which has been considered an extension to what could be seen as relevant data to include in this step.

4. "Rank by Importance and Uncertainty" - When the factors and driving forces have been collected, considering both local and macro environments, the next step is to determine the level of importance as well as uncertainty (Schwartz, 1996). The ambition is to identify those factors or driving forces that are both highly important, as well as either relatively certain or uncertain. Schoemaker (1995) indicates that it is crucial to identify those factors that could either be classified as "basic trends", or "key uncertainties". In relation to the ranking of factors and driving forces, as advocated by Schwartz (1996), the basic trends constitute of those factors or driving forces that are considered both important as well as certain, while key uncertainties constitute of those factors or driving forces that are both considered important as well as uncertain.

5. "Selecting Scenario Logics" - Selecting scenario logics means, according to Schwartz (1996), to conclude which uncertainties that make most sense to constitute the base of the scenarios. As clarified by Peterson et al. (2003), the scenarios should be based on the key uncertainties, thus the most important and uncertain factors or driving forces. However, as indicated by Schwartz (1996), there is a possibility to analyze and regroup the set of key uncertainties in order to reach an appropriate number of variables that will differ between the scenarios. Depending on the number of variables, scenarios can be created in a varying number of dimensions (ibid). If only one variable is selected, scenarios will be created in one dimension along a continuum where this single variable is changing. Correspondingly, if two or three variables are selected, either a matrix or a cube could be created, and scenarios created in two or three dimensions. Hence, each variable constitutes one axes in a coordinate system. The goal is to end up with just a few contrasting scenarios. A suitable number of scenarios are three or four (Peterson et al. 2003). Too few scenarios would not lead to a sufficient extension of perceptions regarding the future, while too many scenarios would lead to confusion. This understanding is shared by (Schwartz, 1996). However, he points out that there is a risk with just developing three scenarios, since people have a tendency to be attracted by the scenario constituting the middle ground.

6. "Fleshing out the Scenarios" - When the scenario logics have been determined, it is time to describe the scenarios in the form of stories (Schwartz, 1996). As already mentioned, there are several advantages with this approach, which is why the use of stories is encouraged by most sources. As indicated by Peterson et al. (2003), it is essential that the stories have their base in the past and that they evolve into a realistic future. Except for the key uncertainties selected to constitute the basis of the scenarios, the stories should be made up by remaining key uncertainties and basic trends (Schwartz, 1996). According to Schwartz (1996), the outcome of the remaining key uncertainties is supposed to differ between the scenarios. The basic trends, on the other hand, are by definition supposed to reoccur in each scenario, although some minor variations could be motivated (Schoemaker, 1995). The developed scenarios should be tested for consistency as well as plausibility (Schoemaker, 1995; Peterson et al., 2003).

7. "Implications" - When the scenarios have been developed, it is time to investigate what implications each scenario is like to have on the focal issue (Schwartz, 1996). Suitable aspects to investigate could for instance be whether the current strategy is likely to be successful for all scenarios, or how a strategy could be altered in order to be more robust. This view is shared by Peterson et al. (2003). In addition, they indicate that there is a possibility that this investigation of implications could lead to new questions or variables that need to be considered. Hence, another iteration of scenario planning may be relevant.

8. "Selection of Leading Indicators and Signposts" - As the future unfolds, it is useful to be able to conclude which of the developed scenarios that seem to be most in line with the reality (Schwartz, 1996). For this reason, it is appropriate to identify and select leading indicators and signposts, which could be used for determining which scenario that correlates the most with the reality.

3. Method

This chapter describes how the research has been designed, how the data has been collected and how this data has been analyzed. Furthermore, the chapter is ended with an explanation of how the authors have strived for conducting a valid as well as reliable study, and how ethical aspects have been handled.

3.1 Research design

The research has been designed as a scenario planning. This means that considerations have been taken to the recommendations and guidelines presented in the theoretical framework, for how a scenario planning should be conducted. The reason for this design is that scenario planning has been considered a suitable technique in order to increase the understanding of how the Swedish heavy-duty truck industry might evolve until the year of 2030. In addition, the result in form of scenarios has been regarded as an appropriate base from which to further explore how the industry value chain might change in the future.

As indicated by Peterson et al. (2003), a scenario planning is suitable when the future of an industry is characterized by high level of uncertainty, as well as high level of uncontrollability. These conditions have been argued to be consistent with the heavy-duty truck industry, which is why a scenario planning has been considered a suitable technique for exploring the future development of this industry. However, that the industry is actually going to change is considered likely by most industry actors, although the perceptions regarding how the industry is going to develop differ. This made a scenario planning an even more attractive option when designing the research. The reason for this is that scenario planning is an appropriate technique whenever an industry is about to experience a significant change, but there is not yet any common understanding of how the industry is going to evolve (Schoemaker, 1995).

The main reason for why scenarios were considered an appropriate base to use for further exploring changes of the future industry value chain, was that a successful scenario planning enables for managers to expand their imagination and to assess alternative futures (Schoemaker, 1995). Furthermore, scenarios imply a relatively simple illustration of how the future might evolve, which was considered suitable when exploring changes of the industry value chain. A simple illustration of the future was considered sufficient, since the ambition with this research has not been to accurately predict the future, which neither is the ambition of a scenario planning. The ambition was rather to provide a realistic illustration of the future, in order to facilitate a relevant discussion regarding the future changes of the industry value chain.

Peterson et al. (2003) has implied that a scenario planning tends to make use of both quantitative as well as qualitative methods. However, it is also indicated that a scenario planning can be conducted based solely on qualitative methods and data, which is the case for this study. The main reason for why the study has been based on qualitative data is because the prior research within the field, referring to the future Swedish heavy-duty truck industry, has been assessed to be nascent, meaning that the prior research is limited (Edmondson & McManus, 2007). According to Edmondson and McManus (2007), it is important to reach a methodological fit when designing a research. In the case of a nascent level of prior research, it is appropriate to focus on qualitative data. The underlying logic for this reasoning is that rich and detailed data is needed when the aim is to explore new research areas, which quantitative methods and data provide (Edmondson & McManus, 2007). This reasoning is supported by Easterby-Smith et al. (2015), who indicates that the nature of a qualitative research usually is explorative.

3.2 Data collection

Primary data as well as secondary data has been collected for this study. The primary data has been gathered through semi structured interviews, performed with actors engaged in the heavy-duty truck industry. This primary data forms the basis of the development of scenarios, and the reasoning for how the industry value chain might change for each of these scenarios. The secondary data has mainly been used as a complement for the primary data. The reasons for choosing this kind of approach for data collection, and the procedure for how the data has been collected, will be further explained in the following subchapters.

3.2.1 Primary data collection through interviews

The collection of primary data can more easily be customized to support the research questions (Easterby-Smith et al., 2015), which is the main reason for basing the study on primary sources. Thus, In the case of this study, the focus has been on collecting data that is relevant for the future development of the areas of autonomy, connectivity and electrification, as well as implications for the industry value chain.

The main reason for why interviews were considered a suitable inquiry method is that a scenario planning should be conducted by a diversified group of people, as indicated by Peterson et al. (2003). However, for obvious reasons, this is not possible to arrange for a master's thesis. Therefore, in order to compensate for the lack of diversified opinions and expertise, interviews have been used to widen the spectrum of sources utilized for the scenario planning. Moreover, in order to limit bias, numerous interviews should be conducted based on persons with different perspectives (Eisenhardt & Graebner, 2007). Therefore, 30 interviews have been conducted with people from different organizations and focus areas. Finally, interviews were considered a suitable method since this enables a collection of rich and detailed data (ibid). As already described by Edmondson and McManus (2007), this kind of data is needed when exploring new research areas and topics.

For a number of reasons, the most suitable approach of the interviews was considered to be semi-structured interviews. One of the reasons is that semi-structured interviews are appropriate when trying to understand the context of the interviewee and the underlying reasons for its specific opinions (Easterby-Smith et al., 2015), which can be argued to be the case when conducting a scenario planning. Another reason for the choice of semi-structured interviews was the inherent level of flexibility, which was found appropriate for a scenario planning. For instance, semi-structured interviews can be centered around selected topics rather than detailed questions (ibid), which facilitated the exploration of topics within the areas of autonomy, connectivity and electrification. Finally, compared to other kinds of interviews, such as highly-structured and unstructured, the approach of semi-structured interviews was considered most appropriate. The judgement of the authors was that there is a risk that highly-structured interviews would limit the ability to explore new topics, while unstructured interviews would risk leading to irrelevant discussions.

The primary data has been collected during two rounds of semi-structured interviews, with the ambition to contribute to answers to the first as well as the second research question. The first round of interviews was carried out in order to gather data for the creation of scenarios, while the second round of interviews aimed to get a better understanding of how each scenario potentially could impact the industry value chain. These two rounds of interviews were conducted in slightly different ways and with different kinds of actors. The two interview procedures are further described in the following paragraphs.

Procedure of orientational interviews

The first round of interviews has been referred to as "orientational interviews". The main purpose of these interviews was to gather information regarding how the Swedish heavy-duty truck industry might develop until 2030, within the areas of autonomy, connectivity and electrification. Hence, these interviews were supposed to extend the authors' understanding of which factors that should be included in the scenario planning. The interview template used during these semi structured interviews can be found in appendix 1.

The orientational interviews were conducted with 21 actors which are not directly linked to the industry value chain. Instead, actors classified as "transport-related association", "research institutions", "actors within the public sector" and "potential new players", were interviewed during this phase. These actors are all familiar with and engaged in the heavy-duty truck industry, but are not a part of the current value chain as defined in chapter 1.4. The reason for focusing on actors surrounding the value chain, rather than actors that are a part of it, was to get a relatively unbiased understanding of the future development of the industry. The logic behind this argument is that the businesses of the actors that are currently being a part of the industry value chain are likely to be affected by future changes, which implies a risk that this kind of actors would share an optimistic perception of the future which would favor their own businesses.

Suitable actors for this first round of interviews were found through own investigations, trade fairs and recommendations from interviewees. Common to all interviewed actors is that they all are engaged in the future development of the areas of autonomy, connectivity or electrification. A compilation of the orientational interviews can be found in table 1.

Orientational interviews		
# and gender	***Organization name***	***Classification***
1 Man	AEOLIX	Transport-related association
1 Man	Chalmers	Research institution
1 Woman	CLOSER	Transport-related association
1 Man	Einride	Potential new player
1 Man, 1 Woman	Fordonskomponentgruppen (FKG)	Transport-related association
1 Man	FORES	Research institution
1 Man	Göteborgs Universitet	Research institution
2 Men	iSEA	Transport-related association
1 Woman	Northvolt	Potential new player
3 Men	RISE	Research institution
1 Man	Roadmap Sweden	Research institution
1 Man	SAFER	Research institution
1 Man	Swedish Electromobility Centre	Transport-related association
1 Woman	Sveriges åkeriföretag	Transport-related association
1 Man	Trafikkontoret	Public sector
1 Man	Trafikverket	Public sector
1 Man	Transportföretagen	Transport-related association
1 Man	Transportindustriförbundet	Transport-related association
1 Man	Vattenfall	Potential new player
1 Woman	Vinnova	Public sector
1 Man	Zenuity	Potential new player

Table 1. List of orientational interviews and related organizations

Most of the orientational interviews were held by telephone, and lasted about one hour. However, some of the interviews were carried out in person, usually at the workplace of the interviewee. All the orientational interviews were carried out together by the two authors, where one was responsible for leading the discussion while the other was responsible of taking notes. In addition, all the orientational interviews were recorded and later transcribed.

Procedure of interviews with industry value chain actors

The second round of interviews has been referred to as interviews with industry value chain actors. In contrast to the orientational interviews, the interviewed companies could all be argued to be a part of the industry value chain, as defined in chapter 1.4. For these interviews, the developed scenarios were used as a base for the discussion. The actors were all shown the developed future scenarios, and asked to speculate on how each scenario would impact the structure of the industry value chain. The interview template used during these semi structured interviews can be found in appendix 2.

In order to get a representative image of how the industry value chain could have evolved by 2030, the ambition of the authors was to interview actors related to all the different parts of the value chain. Hence, actors defined as either component suppliers, OEMs, haulers or freight forwarders were interviewed. In total were nine different actors interviewed, relatively equally distributed among the different parts of the value chain. In addition, consideration was taken to find companies with diversified product and service offerings in order to get an even better understanding of potential implications. A compilation of the interviews with industry value chain actors can be found in table 2.

Interviews with industry value chain actors		
# and gender	***Organization name***	***Classification***
2 Men	Autoliv AB	Component supplier
2 Men	Bror Tonsjö	Component supplier
1 Woman	DHL	Freight forwarder
1 Man, 1 Woman	Göteborgs Lastbilscentral (GLC)	Hauler
1 Man	PostNord	Freight forwarder
1 Man	Scania	OEM
2 Women	Schenker	Freight forwarder
2 Men, 1 Woman	Schenker Åkeri	Hauler
3 Men	Volvo AB	OEM

Table 2. List of interviews with industry value chain actors

In contrast to the orientational interviews, all of the interviews with industry value chain actors were conducted at the offices of the corresponding companies. Since the developed scenarios had to be presented in order to discuss potential changes of the industry value chain, more time was needed for these interviews compared to the orientational interviews. Therefore, most of these interviews lasted for about two hours. Both of the authors were actively participating in the discussion of the future scenarios. In order to compensate for the absence of detailed meeting notes, the interviews were recorded and later transcribed.

3.2.2 Complementary collection of secondary data

According to Easterby-Smith et al. (2015), secondary data is often collected for the reason to complement the primary data, which is the case even for this study. Whenever a new relevant concept or reasoning was encountered during the interviews, for which the authors' knowledge was limited, secondary data was used to increase the understanding regarding the matter. The collection of secondary data has also served to discover topics that could be further explored during the interviews.

In addition to the continuous collection of secondary data in order to complement the interviews, an initial collection of secondary data was performed during the early phases of the study. This initial collection of secondary data was performed to narrow down the focus of the scenario planning. Given the scope of the study, it would not have been appropriate to consider all possible aspects that potentially are going to impact the future development of the heavy-duty truck industry. Therefore, an initial investigation of relevant focus areas was conducted, which led to the actual focus on the technological areas of autonomy, connectivity and electrification.

The secondary data has mainly been collected through digital resources, by browsing the web. A selection of types of sources that have been used are industry reports, ranging from consultancy to governmental reports, websites of companies or associations engaged in the heavy-duty truck industry, or magazines focusing on the technological development of autonomy, connectivity or electrification. In addition, subscriptions to newsletters concerning the development of the truck industry, or the automotive industry in general, proved to be an efficient way for keeping up with ongoing changes in the industry.

3.3 Data analysis

In this section it is described how the collected data has been analyzed, and how the scenario planning has been conducted step by step. The analysis of the collected data is mainly based on comparisons between the findings from the orientational interviews, which is described in the first of the two following subchapters. A detailed description of how the study has been conducted step by step is found in the second subchapter. The first two of these steps (step 1-2), and the final step (step 8), are not analytical in themselves. However, these steps are presented in this chapter, along with the remaining steps, in order to represent a coherent overview of how the scenario planning has been performed.

Throughout the study, the analyses performed by the authors have been verified by the professional service firm Triathlon Group, and the professional service organization ISEA. Provided feedback has led to several refinements and extensions of the analyses.

3.3.1 Comparisons of findings from interviews

What is essential when conducting a scenario planning is to determine which factors that could impact the future development of a specific issue, and the corresponding level of certainty and importance of these factors. This identification and assessment of the level of certainty and importance constitute the main area of analysis for this study. The analysis is based on comparisons between the findings from different interviews. The underlying logic of these comparisons will be further explained in the following paragraphs. However, how these comparisons have been performed practically will be described in detail in the next subchapter.

In order for a specific piece of information to be considered as a relevant factor, and to be further analyzed, it must have been proposed independently by several interviewees. To identify these repeated occurrences, interview transcripts were systematically compared.

The level of certainty has been assessed based on the extent for which the different interviewees share the same expectations for how a specific factor is going to develop. This implies that if a majority of the interviewees expected a specific factor to develop in a certain way, this factor has been considered as relatively certain. Similarly, if the expected development for a specific factor differs between the interviewees, this factor has been assessed to be relatively uncertain. Thus, it is possible that a specific factor has been assessed as relatively uncertain since the expectations of how the factor will develop have differed among the interviewees, even though individual interviewees have had a firm and certain understanding of how this specific factor is going to develop.

The level of importance has been assessed in a similar way. In order for a factor to be considered as relatively important, this must have been indicated by the majority of the interviewees. Moreover, if the level of importance has been motivated as less important by most interviewees, the considered factor has been paid less attention.

3.3.2 Applied steps for scenario planning

The applied steps are based on the methodology for scenario planning, as described in chapter 2. However, as indicated by Peterson et al. (2003), a scenario planning should be adapted to the specific context and goals. Hence, the steps described below are not identical to the ones described in the theoretical framework. The main difference and adaption of the procedure is related to the gathering of information, which constituted the base for the identification and analysis of factors. In many situations, the individuals that are about to perform a scenario planning are already familiar with the industry and factors that might impact the future development. However, in that case of this study, the authors needed to collect a relatively extensive amount of information from interviewees, since the prior knowledge of the industry was limited.

In addition to the description of how every step has been performed, the relevant steps will be linked to different chapters of the study in order to facilitate the reading. The scenario planning has been conducted according to the following steps:

1. *Identification of the focal issue and the main stakeholders*
2. *Information gathering concerning the future development of autonomy, connectivity and electrification*
3. *Identification of factors and ranking by importance and uncertainty*
4. *Verification of mutual consistency of basic trends, and possible coexistence of key uncertainties*
5. *Clustering of key uncertainties and creation of scenarios*
6. *Naming of each scenario and checking for consistency and plausibility*
7. *Development of static descriptions and dynamic stories for each scenario*
8. *Investigation of possible changes of the industry value chain, based on created scenarios*

1. Identification of the focal issue and the main stakeholders - The focal issue for the scenario planning was selected during the early stages of the study, namely how the industry value chain potentially would change for each scenario. The decision to limit the study to the three technological areas of autonomy, connectivity and electrification was taken together with Triathlon and ISEA. As already described, this decision was based on the initial screening of the industry. The argumentation for the decision of the focal issue, as well as the selection of the technological areas, has already been clarified in chapter 1, and more specifically in the purpose of the study as well as the research questions.

The stakeholders of this study are numerous. Since the study will be publicly available, the stakeholders were considered to be any organization or individual who is interested in the future development of the heavy-duty truck industry. However, the most important stakeholders have been considered to be all the organization that have participated in the study. These organizations could be argued to be most familiar with the context of the study, and therefore appropriately prepared to make use of the findings of the study.

2. Information gathering concerning the future development of autonomy, connectivity and electrification - The information that constitutes the basis of the scenario planning has been gathered through the semi-structured orientational interviews as well as secondary data. How this data was gathered has already been described in more detail above, which is why this will not be further elaborated in this section. The gathered information can be found in chapter 4, structured according to the three technological areas of autonomy, connectivity and electrification.

3. Identification and ranking of factors by importance and uncertainty - The identification of factors was done based on the information that was gathered in the previous step. In literature, both the terms “factors” and “driving forces” has been used to describe what kind of aspects that are relevant to consider in a scenario planning. However, we have chosen to refer to these aspects as factors, since factors has been considered a collective name for all kind of aspects that could impact the future development of the heavy-duty truck industry. Hence, what has been identified is relevant factors related to the three areas of autonomy, connectivity or electrification.

However, although these three areas could be argued to be technological, the development of the areas will be dependent on a number of factors that could be either societal, technological, economic, environmental or political. Hence, the STEEP framework was applied during the identification of factors. More specifically, the framework was used in order to make sure that all areas of the framework were being covered during the orientational interviews. Thus, step two and three should be seen as an iterative process. In addition, similarly to the ambition to cover all areas of the STEEP framework, the identified factors have been classified as either to belong to the micro- or macro environment, in order to extend the analysis and thereby performing a more comprehensive scenario planning. For this study, micro-factors have referred to those factors that could be influenced by industry actors, while macro-factors have referred to those factor that are beyond the control of the heavy-duty truck industry.

The ranking of the identified factors was done according to the assessed certainty and importance for each factor, as already described. More precisely, the factors were placed in a coordinate system where the x-axis constituted the level of certainty, while the y-axis constituted the level of importance. The scale for the two axes covered a spectrum between -5 and 5, where -5 was considered highly uncertain/unimportant and 5 was considered highly certain/important. The level of certainty refers to the certainty that a specific factor will come true in the future, while the level of importance refers to the potential for a specific factor to impact the structure of the industry value chain. See figure 2 for an illustration.

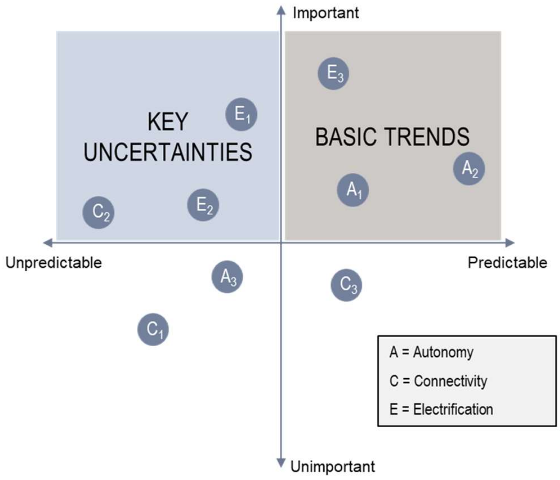

Figure 2. Illustration of classification of factors

Practically, this positioning of factors into the coordinate system was done with post-it notes and a whiteboard. This procedure was chosen since it enabled for the authors to discuss the judgement of certainty and importance, and to easily reposition factors when considered being placed incorrectly. In addition, the procedure facilitated the visualization and comparison of different factors, which led to some factors being merged if considered too similar and to reach a manageable number of factors.

The identification and ranking of factors were conducted by the authors of the study. However, both the identified factors and the corresponding ranking were discussed together with Triathlon and ISEA in order to verify the reasoning and to take more opinions into account. The identification and ranking of factors eventually resulted in a formulation of basic trends as well as key uncertainties. The identification, ranking, resulting basic trends and key uncertainties can be found in chapter 5.

4. Verification of mutual consistency of basic trends, and possible coexistence of key uncertainties - The verification whether the formulated basic trends were mutually consistent, as well as whether the key uncertainties could coexist, was done during a workshop with representatives from ISEA. To make sure that this was the case, the following questions advocated by Schoemaker (1995) were asked:

- Are the main future trends mutually consistent?
- Can the presumed outcome of the uncertainties all coexist?
- Are the presumed actions of the stakeholders compatible with their interests?

This step is not represented in any specific chapter of the study. However, the basic trends and key uncertainties formulated in chapter 5 have all been verified. Thus, this step was done in conjunction with the previous step.

5. Clustering of key uncertainties and creation of scenarios - The authors' ambition was to create scenarios based on two dimensions. Hence, four scenarios were supposed to be developed by letting each of the two axes be represented by a key uncertainty, which indicates that two key uncertainties needed to be selected of created. In fact, the previous steps had led to a formulation of five different key uncertainties. In order to reach two uncertainties to represent the axes in the creation of scenarios, these five key uncertainties were clustered to just two aggregated factors.

When formulating the four scenarios, the basic trends have been considered a more or less common basis that will hold true for all scenarios, while the variation of key factors has been considered the reason for why the scenarios differ from each other. This construction of the scenarios has been visualized in figure 3 below. The clustering and creation of scenarios can be found in chapter 6.2.

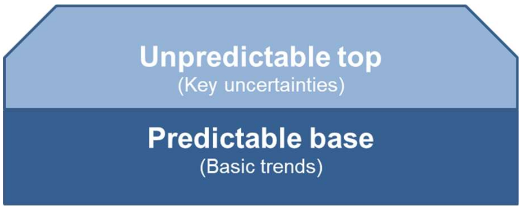

Figure 3. Illustration of scenario construction

6. Naming of each scenario and checking for consistency and plausibility - To make the scenarios as understandable and appealing as possible, quite a lot of effort was put on the naming of the scenarios. The ambition was to formulate names that caught the essence of each scenario. This procedure was done by the authors, and later verified with ISEA. The names of the scenarios are found in chapter 6.3.

7. Development of static descriptions and dynamic stories for each scenario - Each story has been described with a static endpoint as well as a dynamic story for how the future has evolved to reach this endpoint. The endpoint represents how far the development of the areas of autonomy, connectivity and electrification has reached by the year or 2030. The static representation has been formulated by answering the following six questions:

- What AV level will be commercially available?
- How are different AV levels utilized?
- To what extent will data be gathered?
- How will data be utilized commercially?
- What mix of powertrains is sold?
- What mix of fuels is used?

The dynamic stories for each scenario has been developed with respect to the state of selected key uncertainties as well as the basic trends. The stories have been formulated to be as plausible and understandable as possible. Each story shows one of many possible paths of development up until the year 2030 for each scenario. The static descriptions as well as the dynamic stories can be found in chapter 6.3.

8. Investigation of possible changes of the industry value chain, based on created scenarios - The scenarios have been used to investigate possible changes of the industry value chain. This investigation is based on the second round of interviews with industry value chain actors, as already described in previous sections. The purpose of this investigation is to gain a better understanding of how these actors expect the value chain to change for each scenario, in order to answer the second research question of this study. Thus, no analysis concerning the plausibility of the reasoning by the interviewed companies has been conducted by the authors. Such an analysis has not been considered to be within the scope of this study. The compilation of how the industry value chain actors expect the value chain to change depending on key uncertainties will be found in chapter 7, together with a visualization of which new value chains might develop for each scenario. In chapter 8, a discussion of findings not directly related to the research questions is given together with a proposal of future research. This discussion is mainly based on the findings derived from this second round of interviews with industry value chain actors. Chapter 9 concludes the study and answers the research questions.

3.4 Research quality

The quality of the research will be discussed in the two subsequent subchapters. In order to cover different aspects of how the quality work of the researched has been performed, the two topics of reliability and validity will be discussed.

3.4.1 Reliability

Concerning the level of reliability, it is relevant to discuss whether the research could be argued to be replicable as well as transparent (Gibbert et al., 2008). In the case of this report, it will be argued that both of these two criteria are met.

In order for this kind of research to be considered as replicable, it should be shown that the same kind of observations would be reached by other researchers if a similar research was to be performed (Easterby-Smith et al., 2015). The authors' understanding is that this would be the case considering the information gathered for the development of scenarios. The reason for this stance is that the level of consistency among the interviewed organizations seemed to be relatively high. Particularly, the same kind of topics and reasoning were frequently recurring during the orientational interviews, which implies that most of the relevant factors were covered. However, there is an infinite number of scenarios that could have been developed based on these factors, which implies that the final result could vary between different researches. But, since this is due to the inherent flexibility of a scenario planning, it is argued that the level of replicability should be judged based on the gathered data rather than the development of scenarios and the subsequent findings for how the industry value chain might change.

According to Easterby-Smith et al. (2015), it is especially important to prove that a sufficiently high level of transparency has been maintained regarding how the data has been collected, and how this data has been analyzed. The ambition of the authors has been to keep as high a level of transparency as possible concerning these matters. For instance, even such factors that have been considered as relatively unimportant have been presented and analyzed for the sake of transparency, although these factors were not used for the development of scenarios. However, some information has not been shared due to ethical aspects, which will be discussed further below.

3.4.2 Validity

When determining the level of validity of a research, it becomes relevant to question the integrity of the conclusions (Bryman & Bell, 2003). Hence, this means that the findings should provide a representable and accurate view of the matters being studied (Easterby-Smith et al., 2015). However, the ambition of a scenario planning is not to provide an exact prediction of the future, but plausible descriptions in the form of scenarios. Thus, since the development of the future is uncertain, there is more than one way of illustrating this development. This means that it is possible to develop many different scenarios, which all could be argued to be valid. However, according to Bryman and Bell (2003), there are several dimensions of validity that could be considered. In the case of a scenario planning, it could be argued that it is more appropriate to discuss whether or not the collection of data could be regarded as valid, which refers to what is called external validity (ibid).

According to Easterby-Smith et al. (2015), the researcher should make sure that a sufficient number of perspectives have been considered during the collection of data, which in this case refers to the number of interviews. The initial ambition was to conduct about 10 orientational interviews, and about 15 interviews with value chain actors. However, this was changed during the process, with the result that quite a few more orientational interviews were conducted, while a lesser number of interviews with value chain actors were performed. These changes were made in order to meet the first of these two requirements, to make sure that a sufficient number of perspectives had been considered. That a sufficient number of interviews had been reached was based on the amount of new relevant information that could be gathered. In the case of the orientational interviews, the amount of new information was started to saturate after about 15 interviews, while two interviews for each part of the value chain was considered enough for the second round of interviews.

It is also important to consider whether the interviewees have been in possession of the most relevant data (Easterby-Smith et al., 2015). In the case of this research, it can be argued that the choice of the orientational interviews was the most crucial, since these are constituting the base of the analysis. Similarly, to the previous reasoning, the judgement that most of the knowledgeable persons had been interviewed was based on the number of interview recommendations. These recommendations, from already interviewed individuals, also started to saturate when approaching about 20 interviews.

3.5 Ethical aspects

According to Wallén (1996), researchers of today need to take responsibility for their actions and results of their study. This ethical responsibility is necessary since the modern science has the potential to greatly impact the society and actors affected by the study. Therefore, ethical aspects have been considered throughout the research, which will be further described in the following paragraphs.

In the case of this research, there are mainly three different aspects that have been regarded as especially relevant to consider, which are all frequently recurring in the literature. Firstly, individuals that are potentially going to participate in a study should be appropriately informed about relevant aspects in order to make an informed decision whether to participate or not (Bryman & Bell, 2003). Secondly, individuals and organizations participating in a study should have the right to privacy, and the anonymity should then be protected by the researcher (Bryman & Bell, 2003; Easterby-Smith et al., 2015). Finally, the confidentiality of the research data should be ensured (ibid). These three aspects have been considered as especially relevant since the research has been based on quite a few interviews. Hence, it has been considered the authors' responsibility to treat these interviewees in an ethically correct way.

In order to fulfill this commitment, the participants were informed about the fact that the shared data would be used in the master's thesis and thereby publicly published. As a response, several of the interviewees expressed their reluctance of being quoted. Therefore, it was decided that the research would not contain any direct citations. In addition, it was decided that the individual interviewees would be kept anonymous throughout the research. However, in the case of the orientational interviews, the related organizations have been used as references rather than the interviewed individuals. On the contrary, concerning the interviews with the industry value chain actors, it was decided that not even the company names would be used as references in order to not disclose any company secrets and to protect confidential data.

4. Expectations on development and diffusion of technologies

In the following subchapters, the different expectations regarding the future development and diffusion of autonomy, connectivity and electrification is discussed. The opinions underlying these expectations are based on findings from the orientational interviews. Thus, the aim of this chapter is to share relevant findings from these interviews, and to demonstrate common understandings, as well as disagreements, among these interviewees. In order to understand their reasonings, each of the three subchapters are initiated with a more detailed description of the concerned technological area.

The technology area referred to as electrification has been divided into two subsequent subchapters. The reason for this is that the interview discussions have included several alternative technologies, which all need to be initially explained. In order to provide a thorough understanding of the different alternatives of powertrains and fuels, chapter 4.3 aims to give an orientational overview of these alternatives, while chapter 4.4 is where the different opinions expressed during interviews are being discussed.

4.1 Development and diffusion of autonomy

An Autonomous Vehicle is one that can drive itself from a starting point to a predetermined destination in "autopilot" mode using various in-vehicle technologies and sensors (Gartner, 2017). An international standard for classifying different levels of automation is the six levels presented in SAE J3016™ (SAE International, 2016). These six levels will be used to describe the characteristics of autonomous vehicles in this thesis. The levels are technical rather than legal in nature, and are descriptive and informative, rather than normative (ibid). The standard describes how driving-related functions is divided between the driver and the system for the six levels. One significant division in overall responsibility is between level 3 and 4. For level 3, the driver has the main responsibility to step in and handle situations if needed, whereas for level 4 autonomous vehicles, the system is expected to handle situations by itself if the driver if does not take control of the vehicle. The standard helps to eliminate confusion regarding the meaning of autonomous vehicles, and acts as a reference framework for the industry when developing the technology (ibid).

Levels of vehicles automation					
SAE-level	***Name***	***Execution of Steering and Acceleration/Deceleration***	***Monitoring of Driving environment***	***Fallback Performance of Dynamic Driving Task***	***System Capability (Driving Modes)***
0	No Automation	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	System	Human driver	Human driver	Some driving modes
3	Conditional Automation	System	System	Human driver	Some driving modes
4	High Automation	System	System	System	Some driving modes
5	Full Automation	System	System	System	All driving modes

Table 3. Summary of levels of driving automation according to SAE J3016 (SAE International, 2017)

The SAE framework has served as a guiding framework for policy making, as the U.S. Department of Transportation chose to adopt the SAE J3016™ as a policy guidance for vehicle manufacturers wanting to develop autonomous vehicles (NHTSA, 2017). Also, in Sweden policy making regarding autonomous vehicles have taken up speed. The 1st of July 2017, Sweden passed legislation to allow for trials of all levels of autonomous vehicles (Regeringskansliet, 2017a). The Official Reports of the Swedish Government found that the Swedish Transport Agency is to be responsible for granting the right for trials of autonomous trucks on public roads, setting the scope for the permit in terms of geographical location, duration of the permit and allowed types of vehicles. High emphasis is placed on the requirement for proper data protection and cybersecurity by the test organization (Statens Offentliga Utredningar, 2016). The interviewee at CLOSER stated that companies are eager to test their solutions in real environments, but that they experience that the process for getting a permit to perform a demonstration is slow.

In terms of legal framework, most national legislations are undeveloped. Only in some countries, an automated vehicle is considered a defined entity, and only a few insurers have adopted policies regarding autonomous vehicles (Tatcham, 2017).

Autonomous trucks are not yet available commercially, and the technology for autonomous trucks is still under development. OEMs and independent technology providers have mostly focused on testing autonomous trucks in controlled and restricted areas such as harbors and mines. However, projects involving autonomous trucks for public roads are under development. One such project is the Hub-2-Hub project by Volvo Trucks, which is a project involving a truck that would travel on a dedicated highway lane (Volvo Group, 2017a).

Volvo Trucks is currently working on several automation projects in Sweden, including an automated truck in a mine in Kristineberg (Volvo Trucks, 2016a). Furthermore, they are involved in a research project running 2017-2020 under the name Autofreight, aimed at automating high-capacity transports between a harbor and a logistics hub (Trafikverket, 2017a). Volvo unveiled another project on autonomous trucks in semi-restricted areas with their Hub-2-Hub project, displaying the potential of trucks in a future autonomous logistics system (Volvo Group, 2017a). Volvo also tests an autonomous waste refuse truck for urban areas (Volvo Group, 2017b). Scania is also working on developing autonomous trucks. Under the IQMatic, Scania have developed autonomous trucks for the mining industry in collaboration with KTH Royal Institute of Technology in Stockholm (Scania Group, 2017a). Under their Autonomous Transport Systems program, Scania has demonstrated two autonomous trucks in collaboration (Scania Group, 2017b). Another area of application for automation technology is platooning, meaning several trucks driving in a trail, mainly to gain fuel efficiency. Both Scania and Volvo partake in the project Sweden4Platooning, to explore the possibilities of multi-brand platoons (Vinnova, 2016).

Except for the traditional OEMs, there are also potential challengers in the Swedish autonomous truck segment. At the startup Einride, they see themselves as a system integrator that wants to provide a transport solution based on level 4 autonomy. The trucks will only be remotely controlled during specific circumstances, such as the truck leaving the highway, and when docking. Therefore, a single remote driver can control 8-10 trucks at the same time according to the interviewee at Einride. Einride plans to have 200 autonomous vehicles operating the stretch between Gothenburg and Helsingborg by 2020.

The potential benefits of automating road vehicles are many, and are to a large extent the same for trucks as for cars. A few areas where automation have the potential to have a positive impact are within the areas of user safety, energy efficiency, air quality, congestion, user comfort and asset utilization (European Commission, 2017a). While these areas were mentioned during interviews, most arguments for the benefits of autonomous vehicles were connected to either the potential for lowering vehicle TCO (Total Cost of Ownership), or increasing vehicle productivity, which will be further elaborated upon in the chapters below.

4.1.1 Implications on Total Cost of Ownership

Removal of the truck driver for trucks with level 4-5 AVs unlocks large cost benefits, as the driver currently account for between 35% and 45% of operating costs of road freight in Europe (Panteia, 2015). Furthermore, a truck that is not bound to the human's need for rest can lower its speed and still reach the target on time, reducing fuel consumption. In general, an automatic truck can consistently adopt a more fuel-efficient driving technique than a human driver, opening up for an additional potential fuel saving of 15% of total fuel consumption according to the interviewee at SAFER.

One way to reduce the spending on maintenance and repair is to reduce the number of accidents. A widely debated topic is the impact of autonomous vehicles on traffic safety. Several of the interviewees cited the figure that approximately 90% of accidents being caused by human error. One of the interviewee from RISE Viktoria stated that it is a mistake to believe that 90% of the accidents can be avoided if we remove humans as drivers. There are yet too few studies exploring the human-machine interaction aspect of the transport system becoming increasingly autonomous, with some initial studies suggesting that overconfidence of pedestrians in the safety of AVs could be a new source of accidents according to the interviewee at RISE Viktoria.

Another possibility for fuel efficiency unlocked by automation technology is platooning. Platooning is technically possible for level 1 AVs, but the main restrictions for a wider adoption are legal and regulatory (Capgemini, 2016). The more autonomous and accepted the trucks get the better, as today the driver still has to hold the steering wheel according to an interviewee at Vinnova. The interviewee also stated how there might exist social barriers to platooning. During a test project they found that some truck drivers had a negative perception of driving in a platoon, because they didn't like the driving style of the person leading the platoon. With more trucks adopting platooning in the future, and platoons including more vehicles, it will not be a problem if one truck breaks out of the platoon according to an interviewee at SAFER, making platoons a flexible solution. Furthermore, as indicated by the same interviewee, platooning could be a way to work around the length and weight restrictions imposed on many European countries. However, a disadvantage of platooning is that several vehicles driving in a platoon over utilizing HCT (High Capacitive Transports) is that each vehicle needs an investment in powertrain, tractor and as of today separate drivers. On the other hand, platooning provides flexibility according to the interviewee. The interviewee at Swedish Electromobility Centre stated that the demand for HCT transports is fueled by the will to distribute the driver salary over a large load, but with autonomous trucks this driving force is removed.

4.1.2 Implications on transport efficiency and productivity

Level 1-3 AV technology can enable the driver to increase productivity by being able to perform administrative tasks during driving. Depending on the legal framework in place, the automatic driving could also let the driver take mandatory breaks while driving, which would increase overall vehicle uptime (EUCAR, 2016).

When level 4-5 AV technology is implemented, and the human can be removed from the truck, the practical bottleneck that comes with breaks and sleeping times is removed completely, according to the interviewee at SAFER. In Sweden, a driver of a vehicle over 3,5 tons needs to take a 45-minute break every four and a half hour of driving, and as a standard do not drive more than 9 hours per day (Transportstyrelsen, 2017). Driverless trucks would only have to stop for charging, refueling and maintenance. In addition, driverless trucks could drive during night time, which is currently not favored by human drivers, which would be beneficial in terms of congestion. Higher uptime of a truck enables it to drive further during a single day, making high uptime important for enabling quick long-haul deliveries. From a logistics perspective, as described by the interviewee at SAFER, the management of a system based on driverless trucks becomes easier compared to what it is today, as the limitations of rest and sleeping time currently must be taken into consideration when attempting to optimize efficiency.

4.1.3 Influencing aspects on autonomy diffusion

During the interviews, it became clear that opinions regarding the speed and to which extent autonomous trucks will diffuse differs. Some interviewees thought that autonomous vehicle would cause large disruption in the industry, while others were humble towards the challenges that needs to be overcome in order for large scale diffusion of autonomous trucks to take place. However, most of the sceptics towards the impact of autonomous trucks still believed that autonomous trucks will find wide adoption in market niches until 2030.

Especially five areas of uncertainty were frequently mentioned. All interviewees agreed that autonomous trucks at some point in time will be an integral part of the logistics system, but the main difference in opinion regards when the technology will have large scale adoption. The identified areas of uncertainty that will impact the diffusion rate of automated truck technology include technical challenges, legal framework and regulations, the political and industrial attitude towards autonomous vehicles, difficulties in collaboration and infrastructure and usage barriers.

Areas of uncertainty
Technical challenges related to safety
Legal framework and regulations
Societal and industry attitude towards autonomous vehicles
Difficulties in collaboration
Infrastructure and usage barriers

Table 4. Compilation of uncertain areas affecting autonomy diffusion

Technical challenges related to safety

The technical challenge concerns the development of safe autonomous driving technology for trucks. According to the interviewee at Zenuity, trucks are technically more difficult to automate than a car due to heavier weight, larger inertia and often more driveshafts. This leads to a truck requiring a longer distance to come to a halt than a car, and having a lower possibility to perform maneuvers to avoid collisions. This complication puts higher demands on fast response time from autonomous truck systems and sensors with a long range of vision. Furthermore, according to the interviewee at Zenuity, trucks are more varied in terms of design, using stiff trucks versus tractor trucks as example, making it harder to standardize sensor placement.

Once the technical difficulties of automation are overcome, the challenges also concern validating the safety of the technology. Validating the safety of AV-technology is difficult, as the number of possible traffic situations that a vehicle can encounter is close to infinity. Many interviewees claimed that the bare minimum for accepting autonomous vehicles in public traffic is that they cause less accidents than human drivers.

In order to prove the safety of the technology, a great amount of data is needed, as AV technology is AI-based, and validated statistically. The interviewee at Zenuity indicated that one of the most difficult parts to validate is the sensor technology, for which it is needed to make sure that they identify what they should. For the vast number of situations that a vehicle can encounter, depending on weather, time of the day and so forth, this is a difficult task. The interviewee adds, that the relatively low sales volume of trucks compared to cars, will be an aspect hindering fast development of autonomous trucks. This puts pressure on companies to conduct simulations and physical demonstration, with the latter being subject to a rigorous approval process at the Swedish Transport Administration.

It is not enough to have a system that works in ideal situations, it needs redundancy and fallback functionality. In order to reach level 5 of automation, a reliable fallback mechanism is needed, and we are not there today according to the interviewee who is part of AEOLIX, a European project for digitalization of European logistics. The interviewee at Einride indicated that the technology is already safe enough for level 4 adoption with a remote driver. In case of emergency, the autonomous driving system will signal to the driver to take control, and if the driver does not assume control fast enough, the vehicle itself will make an attempt to come to a safe stop.

Legal framework and regulations

The interviewees being skeptical to the commercialization of level 4-5 trucks by 2030 mainly pointed out regulatory and legal frameworks as the main bottleneck, which are limiting the development. Many of them pointed out, that the technical challenges have to be overcome, before a legal framework can be accepted. At the same time, politicians have to allow for testing of vehicles.

Creating a legal framework for allowing self-driving vehicles to share the traffic system with human drivers demands thorough work, and this is something that is under investigation from the Swedish government and other jurisdictions. According to the interviewee at Sveriges Åkerier, the main point of uncertainty regards who is responsible in terms of an accident. Is it the driver behind the wheel, the car manufacturers, or the programmers who wrote the decision-making algorithm? The interviewee at Einride stated that the critical issue was not the final decision itself, but at what point in time the legal framework itself is put in place.

One interviewee at Transportindustriförbundet expressed concern regarding that Swedish autonomous truck diffusion might be slowed down if we wait for a common legal framework to develop in the EU. On the other hand, the interviewee at Zenuity held the opinion that Sweden can and likely will act independently and progressively in developing the autonomy technology forward, based on that the Swedish politicians have understood the benefits of an autonomous vehicle fleet. The interviewee at Transportindustriförbundet stated that if Sweden does not relate themselves to a common legal framework from EU, we will not see autonomous trucks driving across borders.

Some interviewees described that the current political developments around the world in favor of automated cars will act as a tailwind to speed up legal developments for trucks as well. If a legal framework and regulations are put in place for cars, it is likely easier from a political standpoint to vote through regulations regarding trucks as well.

Societal attitude towards autonomous vehicles

The society's standpoint regarding autonomous vehicles is mixed, but have improved the recent years according to the majority of interviewees. The interviewee at SAFER stated that a major turning point came three to four years ago, when the public started viewing autonomous vehicles as a comfort function. In addition, as well as a source of increased traffic safety, and an enabler for disabled people to more easily access transport. For these reasons, the interviewee argues, it has become more politically accepted to work with development of the technology. The interviewee at Vinnova stated that the public in general is more skeptical to autonomous trucks than autonomous cars, as the consequences in case of an accident is likely to be more extensive. The majority of interviewees were of the opinion that public perception of autonomous vehicles is improving, as more and more successful demonstrations on both public and private roads are demonstrated. Also, the possibility of having autonomous trucks remotely controlled is something that the interviewee at Zenuity expects could facilitate a further acceptance for a further development of AV. When level 5 AV technology is ready for adoption, the function of remotely controlling the vehicle could be phased out.

Depending on the outcome of more complex demonstrations on public roads in the coming years, the societal standpoint regarding autonomous vehicles is likely to change. There are already several cases of successful demonstrations in restricted areas such as harbors and mines and on low-traffic public roads, such as the mining truck tested by Volvo Trucks in Kristineberg mine in Boliden (Volvo Trucks, 2016a). But driving in bad conditions in heavily trafficked areas has proved to be more difficult. The interviewee at Vinnova stated that the public is uneducated regarding the benefits of autonomous vehicles in traffic, and therefore less accepting towards the technology. The challenge for the industry becomes to educate the public about AVs. However, as indicated by the interviewee, a problem is that the government has little interest in investing resources for this purpose. According to the interviewee at Zenuity, the media has an important role in promoting or counteracting the public acceptance of autonomous vehicles, by either portraying autonomous vehicles as being a threat, or improving traffic safety. Also, the interviewee stated that the general acceptance of autonomous vehicles will increase, as other industries increasingly replace human labor with autonomous robots.

Personal integrity is another important aspect that has sparked a lot of debate regarding autonomous vehicles. Autonomous vehicles rely on sensors that gather data about the surroundings and location of the vehicle, and many are worried about the potential risks that such data could pose. Personal integrity for trucks refers to both the driver in level 1-3 and in some cases level 4 autonomous trucks, and for fellow road-users and pedestrians. The interviewee at AEOLIX stated that personal integrity mostly is a concern as long as there is a driver present in the vehicle, while other interviewees stated that the personal integrity of other road users will be important enough to make personal integrity a core issue, even if the driver is removed. However, the interviewee at Zenuity believed that the debate regarding personal integrity will continue, but not be a barrier for progression as long as the data is anonymized. The interviewee added that our smartphones are already tracking most people, so the relative difference from autonomous vehicles is small. Conclusively, the debate regarding personal integrity in relation to AVs is still ongoing.

The political attitude in Sweden towards autonomous vehicles is regarded as positive amongst the interviewees. There is a political will to explore the technology, exemplified by the Drive Me, which is a governmentally supported project for autonomous cars, and progressive regulations for allowing demonstrations, according to the interviewee at AEOLIX. The politicians are more likely to promote progress, rather than limit it. The interviewee stated that one likely step in the coming years will be to dedicate a lane on highways specifically to autonomous vehicles. Sweden is part of the European TEN-T (Trans-European Transport Network), and the interviewee at Trafikverket stated that the involved roads in Sweden are likely to be a platform for experimenting with new technologies. In addition, the interviewee at CLOSER stated that the TEN-T roads could be a realistic implementation area for AVs, from which the technology can spread.

Industry attitude towards autonomous vehicles

The interviewees who expected a substantial diffusion of level 4-5 trucks by 2030 tended to point towards the aggressive investments into autonomy from incumbents in the automobile industry as a source of quick development. These aggressive plans were argued to be stimulated by the fear of becoming irrelevant as incumbents if they were not in the forefront of the AV technology. Also, from a geopolitical standpoint, several interviewees experienced that progress of AV-technology is sped up by an ongoing race between different regions, mainly the U.S., EU and Asia, who all wants to be first with the integration of AVs in society. The interviewee from Zenuity stated that once a successful implementation of AVs is made in one country, the rest of the developed world is soon to follow.

According to the interviewee at AEOLIX, premium OEM brands are likely to face challenges if the industry transitions into a transport system predominantly based on driverless trucks, as one key competence today for premium truck brands is to create a good driver environment. According to FKG, the vehicle industry is a mature industry not used to significant changes. However, in order to be successful in the future, the actors have to build a relatively new area of competence around AVs and ICT. At the same time, the interviewed transport-related associations all stated that the industry sees automation of trucks as an inevitability that the OEMs have to prepare for. The same type of challenge relates to suppliers delivering cabin-related components.

According to most interviewees, professional driving as an occupation risk disappearing with the adoption of AV-technology. Many interviewees have questioned what value that hauling companies actually provide once the driver is removed. Hence, most interviewees expected some kind of disruption of the hauler function, with a further development of the AV-technology. However, the interviewee from Sveriges Åkerier argues that it is difficult to replace the driver, since driving is only part of the job. The administrative and social aspects of the job are also important functionalities of the driver. Some interviewees even argued that the hauling companies could become more cost efficient by replacing drivers with AV-vehicles, and thus continue to exist.

There are approximately 100’000 active truck drivers in Sweden according to the interviewee at Sveriges Åkerier. The societal impact of implementing highly automated trucks may be disruptive, as automated trucks could reduce the demand for drivers with up to 70% by 2030 (ITF, 2017). Some of the interviewees speculated that the decrease in jobs could lead to retaliation from the trucking worker unions, but the majority of interviewees pointed out that automated trucks serve as a relief for hauling companies to the large lack of truck drivers. According to TYA, a joint committee in the Swedish transport sector, the Swedish transport industry could lack 50´000 drivers within the next decade (Sveriges Åkerier, 2017).

The interviewee from Sveriges Åkerier argues that it is difficult to replace the driver, since driving is only part of the job, and the administrative and social aspect of the job also an important functionality. The drivers manage client contacts and solve problems.

The freight forwarders were seen as least likely by the interviewees to oppose to the development of AV, as they still saw a need for a network operator in an autonomous logistics system. Actually, freight forwarders could benefit from the cheaper transports that AVs could bring. However, to benefit from autonomous vehicles, freight forwarders need to change their routines in terms of loading and unloading, according to the interviewee at Vinnova. On the contrary, the interviewee from AEOLIX pointed out that even if freight forwarders might be more profitable with more autonomous vehicles in the logistics system, adjusting to the technology is likely to take a long time because of inertia in the organizational systems. The interviewee from SAFER, on the other hand, believed that freight forwarders would utilize the AV-technology if there was a business case for it.

Difficulties in collaboration

When it comes to developing AV technology, the interviewee at Zenuity argued that a lot of data is needed to prove that the technology is safe. Thus, if researchers and actors in the industry collaborate and share data effectively, the development of the technology can progress more quickly. However, there are practical and social barriers to collaboration within AV development. Practicalities such as vehicles used for testing having different designs, means that it is difficult to share sensor data. On the other hand, it is possible to share research methodologies for AV development amongst developers according to the interviewee at Zenuity. Even if the data practically could be shared, competitive behavior holds industry actors back from doing so according to the interviewee at SAFER. According to the interviewee at Zenuity, OEMs and other actors in pursuit of putting the technology on the market, they want to be first in commercializing a fully autonomous truck. The interviewee also pointed out that collaboration further decreases with the influx of ICT companies into the vehicle industry, as the ICT industry is less collaborative than the vehicle industry.

In terms of adoption of platooning, development is slowed down because of a lack of business models, where a business model is defined in line with Björkdahl's (2009) definition as "the link between how firms create and capture value", and payment models according to the interviewee at SAFER. A collaboration framework is needed to ensure fair and mutual benefit from platooning, as today the trucks further back in the platoon benefit more than the lead truck. Therefore, platooning is currently only frequently used amongst trucks in the same company according to the interviewee. The interviewee also stated that collaboration is held back because of the haulers' unwillingness to contribute to cheaper transports for competitors.

Infrastructure and usage barriers

The initial use of automated trucks is likely to be for standardized terminal to terminal distribution according to the interviewee at CLOSER. For this setup, as already indicated, the possibility to remotely control the truck is seen as a needed transition into full AV. Remote driving will be used to take control of the vehicle when it is about to exit the highway and drive the last stretch to the terminal. To safely control a truck remotely, the connection to the truck must be reliable. Some interviewees stated that 5g technology is a prerequisite for autonomous vehicles, while the interviewees from Einride and Zenuity stated that they would benefit from a rollout of the 5g-technology, but that their solutions are not dependent on it. Other connectivity-related challenges that partly relate to AV-technology, such as Vehicle-to-Infrastructure, will be discussed in the chapter that follows.

It was by many interviewees identified that a larger proportion of trucks operate in areas with low complexity and traffic, compared to cars. This was identified to speed up diffusion of autonomous trucks, as they can be tested in their natural environments. The areas where autonomous trucks are expected to spread first is in restricted areas according to the majority of the interviewees. Unlike cars, autonomous trucks have many use cases in restricted and semi-restricted areas such as mines, harbors and industrial areas. Compared to cars, trucks have a relative advantage when it comes to finding use cases within controlled environments, according to the interviewee at Zenuity.

The next area to be pointed out as applicable for autonomous trucks is highways. Highways have favorable conditions for an implementation of AV, such as long and straight stretches and a low amount of traffic according to the interviewee at Vinnova. Especially highways with no oncoming traffic would be favorable for AV implementation according to the interviewee at Zenuity.

After technical and legal challenges are overcome, it will probably take an additional 5-7 years to phase out the old vehicle fleet, and even longer for the logistics system to adjust to the autonomous vehicles, according to the interviewee at AEOLIX.

4.2 Development and diffusion of connectivity

Connected vehicles can exchange information wirelessly with the vehicle manufacturer, third-party service providers, users, infrastructure operators and other vehicles (ACEA, 2016). One benefit of connected vehicles is the potential for increasing traffic safety and logistics efficiency (EUCAR, 2016). In-vehicle technologies enabling connected trucks include sensors, processors, operating systems, actuators, internet connection and detailed maps (ITF, 2017). The sensors monitor the driving environment, processors and the operating system utilize algorithms to respond, actuators implement the commands, and the internet connection and maps are used to gather external driving environment information (ibid).

The following subchapter will describe the current state of connectivity, followed by an in-depth explanation of vehicular communication technology. The subsequent subchapter describes how some aspects of vehicle connectivity is likely to be seen as an order qualifier. The two last subchapters elaborate on the possibilities and challenges of utilizing connectivity for increased transport efficiency and as a new revenue source.

4.2.1 Current state of connectivity

Ten years ago, connectivity was a technical problem, but not today, according to the interviewee at AEOLIX. Connectivity-enabling technology is expected to be standard equipment in trucks by the year 2020 (Frost & Sullivan, 2014). Both Volvo Trucks and Scania are having separate connectivity offerings, with Scania reaching 250’000 connected trucks in early 2017 (Scania Group, 2017c). In other words, the challenge of connectivity today does not consist of connecting the vehicles, but to utilize the connectivity to its full potential, according to the interviewee at Vinnova. As with most emerging technologies, some innovators and early adopters are already advanced in their usage of vehicle connectivity, but the long tail are not yet there, and the marketplace for connectivity-services is still underdeveloped, according to the interviewee at AEOLIX. According to the interviewee at Sveriges Åkerier, connecting the trucks is not enough for reaching the potential of logistics, we also need to connect the goods that lie inside the trucks.

The 4g network in Sweden is widespread, and 5g is under development. Also, on an European level, vehicle connectivity is an area brought to attention. Under the name Cooperative

Intelligent Transportation System, EU adopted a strategy the 30th of November 2016 to harmonize legislation and provide funding for cooperation regarding vehicle connectivity (European Commission, 2017b). Another European initiative to promote connectivity utilization in the region is AEOLIX, a program with the goals whose goals are to firstly enable different connectivity ecosystems to communicate with each other, secondly make it easier for more people to easily access the connectivity ecosystem, and thirdly provide a platform and toolkit for connectivity services, according to the interviewee at AEOLIX.

4.2.2 Vehicle communication

Part of the field of vehicle connectivity is vehicle communication technologies. The common term used for vehicle communication currently is road telematics, which represented the vehicles' ability to communicate with the environment by sending, receiving and storing information (Vin Basics, 2017). Such applications could be vehicle localization by GPS, notification of vehicle collision and automatic emergency calling in case of an accident (ibid). Road telematics have been used for over 20 years to improve traffic efficiency and safety (European Commission, 2017b).

A new field of vehicle communication under development is V2X, meaning Vehicle-to-Everything. It is a local form of communication technology based on WLAN, which enables instant communication with low latency, that is functional without supporting infrastructure (Electronic Design, 2017). This technology enables vehicles to communicate with other vehicles (V2V), and surrounding infrastructure (V2I) such as traffic lights, and other connected units. The V2X technology can be used to increase efficiency and safety in the local traffic environment. One way of adopting V2I technology is to install digital speed limit signs that adapt to the current traffic, states the interviewee at Vinnova. An example of how V2V technology applied is by letting autonomous vehicles communicate and thereby more efficiently pass a crossing, the interviewee continues.

In terms of development of V2V and V2I communication functionality, most interviewees were skeptical, as they saw the incentive for OEMs to invest in the technology as low. Some interviewees saw connectivity as a prerequisite for AV, but interviews showed that most developers focus on making the vehicle independent of the surroundings by improving sensors, rather than developing communication functionality. Therefore, V2V and V2I is not seen as a deal breaker for realizing commercialization of AV, but something that can be added at a later stage. The reason for not wanting to depend on V2V and V2I as an enabler, is according to the interviewee at SAFER, standardization and development of a legal framework would slow down the development too much.

Furthermore, the whole incentive structure regarding V2I development is flawed according to the interviewee at Zenuity. With low diffusion of autonomous trucks, there will be little incentive to develop the V2I infrastructure, and vice versa. Furthermore, it would be too bothersome for AV developers to adjust their connectivity systems if different V2I solutions become dominant in different countries. The interviewee adds that V2V has been under discussion for several years but have not been adopted because of a lack of network effects. The marginal benefit of being the first actor adding costly V2V technology to the vehicle is close to zero.

4.2.3 Connectivity as an order qualifier

This subchapter explains how connectivity-services successively are required by customers in the industry, and they potential problems that the spread of connectivity-services create.

Impacts of connectivity becoming an order qualifier

Increased overall digitalization in the transport industry has led to actors in road transport actors expecting sophisticated connectivity services, according to the interviewee from the Gothenburg University. The haulers are starting to expect their vehicles to be connected, and the logistics customers expect a high degree of traceability, according to the interviewee at Sveriges Åkerier. In addition, freight forwarders expect the vehicle connectivity systems to be interoperable with other logistics systems, meaning that it should be able to exchange information with the these, according to the interviewee at AEOLIX. The reason for these increased expectations is the growth of B2C transports and e-commerce, since these customers place higher demands on their transport, the interviewee continues. Also, according to the interviewee at AEOLIX, B2B customers place higher expectations on transport providers to allow for real-time information, to be able to work more just-in-time and to plan less for the long term.

As the supply of connectivity-enabled services in the transportation industry increases, and since the OEMs already provide sophisticated connectivity platforms, eventually connectivity will become a commodity in the industry, according to the interviewee at AEOLIX. As of today, the companies compete to provide the best services in order to differentiate themselves from each other, but over time it is likely that the supply of services will become standardized, according to the interviewee. Eventually, companies that do not provide at least a minimum level of connectivity-services will not be able to survive, the interviewee adds.

Problems with connectivity becoming an order qualifier

The growth of connectivity-services is inhibited by some unsolved issues. Robust connectivity systems and IT security are two areas granted much attention, according to the interviewee at Vinnova. The transport system must be robust enough to endure an electricity blackout, and connected trucks cannot risk being hacked, the interviewee adds. However, the interviewee at Zenuity states that connectivity and AV developers already work actively with designing the vehicles to be able to function without being connected, and safety-critical systems have backup-systems.

Another problem regards standardization of connectivity. The interviewee from AEOLIX stated that standardization of connectivity systems would slow down the development progress too much, and that the focus rather should be to facilitate interoperability. One interviewee from RISE Viktoria added that the industry is more likely to go towards a solution becoming the de-facto standard, without having to go through a lengthy standardization process. The interviewees from Vinnova and AEOLIX stated that currently the industry have not come far in creating an overarching system enabling wide-spread communication for V2V and V2I, but that this is something that we are likely to have reached by the year of 2030. The interviewees from CLOSER and Vinnova pointed out that the development of a digital infrastructure is hampered by the lack of a centralized financing. The interviewee from CLOSER stated that the

Swedish Transport Administration owns the physical infrastructure, but that the government expects private companies to finance the digital infrastructures such as cloud services.

4.2.4 Connectivity for transport efficiency

When inquired regarding the benefits of connectivity, most interviewees focused on how it could enable a high efficiency of internal activities for all actors in the transport industry. Table 5 compiles mentioned benefits for different industry actors in terms of efficiency gains.

Efficiency gains from connectivity	
Component Supplier	Connected components enabling circular economy
OEM	Analyzing engine performance
	Over-the-air-updates
Hauler	Improved fleet management
	Route optimization
Freight Forwarder	Real-time data reduces the need for planning processes
	Reduced slack in the logistics system
	Cheaper capital due to lower risk for goods
	Improved joint loading

Table 5. Efficiency gains for industry actors mentioned during interviews

Another area of benefits frequently discussed is the unlocked efficiency potential from collaboration opportunities that is enabled by connectivity. The key to efficient goods management is to have the right information at the right time, according to the interviewee at AEOLIX. The more actors that are participating in data sharing, the more the system benefits as a whole. This type of sharing economy is made possible by connectivity systems, as it would be too complex for humans to handle and share this amount of information manually, according to the interviewee. An example of such collaborations could be to reduce the amount of empty transports, since connectivity could make easier to connect transport buyers with drivers, the interviewee commented. The interviewee at CLOSER commented that there are practical limits to the possibilities of collaboration, since many trucks are designed for a specific purpose.

To make external collaboration through connectivity successful, interoperability of the systems is a must, according to the interviewee at AEOLIX. This is because information is spread out, bound to people in certain organizations, to infrastructure or to the goods itself. There is a lack of reliable access to this data in the transportation system, the interviewee continues. Instead of trying to technologically standardize the market for connectivity, focus should be to enhance interoperability between the systems. Currently there is a lack of IT and ICT system interoperability, inhibiting this type of collaboration, according to the interviewee at Vinnova. The interviewee at SAFER that interoperability is lacking because of too regulations that inhibiting collaboration.

Another barrier mentioned during interviews regards the current skepticism amongst actors to share data, resources and business models. One reason for this behavior, the interviewee at

SAFER speculates, could be a lack of trust between the logistics actors. The interviewee from AEOLIX states that these actors want to control the flow of goods and restrict access to their clients. A solution to the problem of trust is to use a neutral data broker, meaning a third party that stores all data, and distributes it fairly based on contribution, according to the interviewee at CLOSER. In addition, the interviewee states that it is not only a lack of trust that inhibits organizations from collaborating through sharing of data, but also the organizational models themselves which are not structured for this kind of collaboration.

Another inhibitor to transport collaboration is the current behavior of transport buyers. Business contracts between haulers or freight forwarders and transport buyers are often formulated as such that a customer purchases the whole transport capacity of the truck, regardless if they intend to fill it or not. The logic behind this is that customers want the flexibility to add more cargo with short notice if they need to, and sometimes to block competitors from accessing cheap transports, the interviewee continues. The interviewee at CLOSER stated that many transport buyers would collaborate, but they lack the insight about goods flow and opportunities for collaboration. Another reason for current transport buyer behavior, as stated by the interviewee at FORES, is that many organizations don't incorporate transport policies in their sustainability policies.

In the future, the incumbents will have to share data in order to stay competitive, according to the interviewee at AEOLIX. The underlying reasoning is that if a company does not share any data, it will not receive any data, and thus suffer a competitive disadvantage. According to the interviewee at CLOSER, such collaborations could also be institutionally driven, as the responsible authorities could require industry actors to share data, if the actors want to access the traffic system. However, the interviewee at Vinnova were skeptical towards the idea that the government would manage such a digital infrastructure. On the contrary, one interviewee at Transportindustriförbundet stated EU have recently started to investigate how they could solve issues with cabotage by tracking vehicles through connectivity, and how geofencing can be used to govern the emissions of vehicles.

4.2.5 Connectivity as a revenue source

This chapter will dwell specifically into how connectivity can enable new technologies or customer interaction, opening up new revenue sources.

Possibilities for utilizing connectivity as a revenue source

Even if connectivity is not a prerequisite for autonomous vehicles, it can be utilized to realize remotely driven autonomous trucks, and thus unlock a new source of revenue, according to the interviewee at Zenuity. Furthermore, once fully automated, connectivity will ensure that autonomous trucks receive updated maps and current traffic information.

By utilizing truck-generated data, OEMs can learn more about the needs of a specific customer, and tailor their offerings accordingly, according to the interviewee at Zenuity. Furthermore, with the right analysis capabilities, an OEM can turn vehicle data into valuable insights that can be sold to customers. The interviewee also stated that OEMs could also turn data about the goods being transported could be into a revenue source, by making it available to transport customers, according to the interviewee at Zenuity.

Challenges for utilizing connectivity as a revenue source

However, when dealing with data as a resource, the challenges of cybersecurity and personal integrity comes into questions. According to one interviewee at RISE Viktoria, cybersecurity will be the most crucial question during the coming years, regarding the development of further automated and connected trucks. This is argued to be the case since cybersecurity needs to be guaranteed in order for the society to permit connected and automated vehicles.

By connecting the truck to the surroundings, it becomes a potential security threat in terms of cybersecurity. It is a danger to society if a truck would be hacked and used as a weapon against the public (Capgemini, 2016). A problem yet to be solved is validating that trucks with remote driving functionality operating on public roads can withstand cyber-attacks, according to the interviewee at SAFER and RISE Viktoria.

On the other hand, the interviewee at Zenuity stated that cybersecurity is not a problem, since the connected vehicles will have sufficient protection, and, in case of a cyber-attack, it will be possible to disconnect the truck. Moreover, the interviewee at AEOLIX also did not see cybersecurity as a problem for the continued pursuit of connected trucks, on the basis that cybersecurity is an ongoing challenge in other industries as well, but that this challenge has not slowed down development.

Personal integrity concerning the data collected from truck and goods could become a problem in the future, according to one interviewee at RISE Viktoria. Especially sensor data about people surrounding the vehicle can be sensitive. Furthermore, as long as trucks are operated by a driver, data about the driving behavior can be considered as discriminatory. According to the interviewee at Zenuity, the problem with personal integrity can be managed by anonymizing the data. In addition, as stated by one of the interviewees at RISE Viktoria, companies can quickly ruin their brand if they do not store and use data properly, which should lead to an appropriate handling of such sensitive data.

Some final business challenges mentioned during interviews, concerning utilization of gathered data as a revenue source, involved developing the right competences for selling knowledge-based products, transforming the current business model, and to compete with third party connectivity service providers.

4.3 Overview of electrification paths and alternative fuels

In the following subchapters, the areas of alternative powertrains and fuels are contextualized. The first of the following three subchapters aims to explain how the societal development towards sustainability has led to the internal combustion engine and the fossil fuels being increasingly questioned. In the last two subchapters, the alternative future combinations of powertrains and fuels are explained for the orientational purpose.

4.3.1 Sustainable development as driver of change

Sweden has adopted ambitious climate goals, which are heavily affecting the transport industry. Until 2030, the goal is to reduce the emissions of greenhouse gases from domestic transports with 70%, compared to the levels of 2010 (Regeringskansliet, 2017b). In addition, the ambition is to have reached a level of zero net emissions of greenhouse gases by the year of 2045.

Compared to other countries, these adopted goals are among the most ambitious, which indicates that Sweden has a will to be seen as an international role model regarding sustainable development (Regeringskansliet, 2017c). Considering the heavy-duty truck industry, the interviewee at Transportindustriförbundet argues that this strive for an international leadership for sustainability is important. The fact that two of the most influential truck manufacturers are Swedish implies that such a leadership could lead to a considerable impact and positive change of the industry.

Moreover, the interviewee indicates that the strive towards sustainability is the single most important aspect affecting the development of the industry. However, this change is not just fueled by the communicated goals, the experience of the interviewee is that the transport buyers are increasingly demanding sustainable alternatives. These aspects have made sustainability a central question for the truck industry, including the heavy-duty trucks. Nevertheless, which technology these heavy-duty trucks will primarily utilize to become less dependent on fossil fuels is still being debated.

In order to reach the communicated goals, and to meet the increasing demand of sustainable transports, there are mainly two different approaches that are being discussed. Firstly, an alternative is to increase the use of sustainable fuels for the internal combustion engine (ICE). Secondly, the ICE could successively be substituted by the electric engine, provided that the electricity consumed has been sustainably sourced. According to most interviewees, one could expect that these two alternatives and powertrains are going to coexist during a considerable amount of time. However, eventually it is probable that any of these two alternatives are going to dominate the heavy-duty truck industry. The two alternatives will be further described in the following subchapters.

4.3.2 The internal combustion engine and alternative fuels

Even in the long term, pure electric vehicles are unlikely to totally replace the conventional vehicles and the ICE (ERTRAC, 2017), which is currently the dominating powertrain for heavy-duty trucks. Hence, in order to reach carbon-neutral heavy-duty truck transports, the ICE needs to be fueled with CO2-free or CO2-neutral energy sources (ibid). The ICE can be fueled by a number of alternative energy sources. The following paragraphs aim to give an orientational overview of the most common alternatives to fossil diesel, namely biofuels and natural gas.

Biofuels is one important group of fuels that could be used as a complement, or as a substitute, to fossil diesel (International Energy Agency, 2017). Depending on different factors, including the raw materials used and the choice of production chain, a number of different biofuels can be produced (Börjesson et al., 2016). Biofuels by themselves are not by definition sustainable. Whether a specific biofuel is sustainable or not depends on the whole process chain, ranging from cultivation to final use (ibid).

Two of the most frequently mentioned biofuels are “biodiesel” and “hydro-treated vegetable oil” (HVO), which will serve as examples of how these biofuels are used. Both of these biofuels can be mixed with fossil diesel in order to decrease the carbon footprint (International Energy Agency, 2017). The HVO can be used as a “drop-in fuel”, meaning that an unblended mix of

100% HVO could be used by the ICE and related infrastructure for fuel distribution. Biodiesel, on the other hand, require modifications to the vehicle and powertrain in order to be used in higher concentration (ibid). Some other substances that can be produced as biofuels are “biomethane”, “ethanol” and “hydrogen” (Börjesson et al., 2016). The most common biofuels are all produced by raw materials derived from the forest, ocean and agriculture.

The ICE can also be powered by natural gas (International Energy Agency, 2017). More specifically, the ICE can run on a mix of a small amount of diesel and the remaining part of methane, where most of the methane is currently being extracted from natural gas. However, as already mentioned, methane can also be produced from biological sources as “biomethane”. For natural gas to be used as fuel for heavy-duty transports, the gas is usually compressed and liquefied into what is called liquefied natural gas (LNG) (ibid). The use of LNG, compared to fossil-diesel, could result in a considerable reduction of CO2 emissions. For instance, Volvo Trucks claims that their newly released FH LNG truck emits 20% less CO2 during usage (Volvo Trucks, 2017a). However, according to the International Energy Agency (2017), the overall reduction of greenhouse gases could be questioned when considering a number of other aspects, such as leakage issues during the whole process and variability in gas production.

4.3.3 The electric powertrain and alternative electricity supplies

The electric powertrain is expected to progressively become a valid alternative to the ICE (ERTRAC, 2017). According to the interviewed organizations, the main reason for this is that an electric powertrain, running on sustainably sourced electricity, could reduce the level of emissions as well as fuel costs. Another frequently mentioned advantage is that the electric powertrain comes with a higher torque, which enables quicker acceleration and conveniences when driving uphill. There are several options for how the electric powertrain could be used as the single powertrain or in conjunction with the ICE. In addition, there are different alternatives for how the electricity is being transferred to the engine. The different applications of the electric powertrains that are going to be described below are “Hybrid Electric Vehicles” (HEV), ”Plug-in Electric Vehicles” (PHEV), “Battery Electric Vehicles” (BEV), “Road Powered Electric Vehicles” (RPEV) and “Fuel Cell Electric Vehicles” (FCEV).

Hybrid technologies

An electric hybrid solution means that an electric powertrain is combined with an ICE (ERTRAC, 2011). However, there are basically two different types of hybrids, which are named HEV and PHEV. The difference is that the PHEV could be plugged into the electric grid for static charge, while a HEV truck only charges during driving by storing spare energy. Furthermore, the electric driving range usually is longer for a PHEV (ERTRAC, 2011). Common for both types is that the combination of powertrains enables the truck to drive long distances on the ICE, as well as to be operated without any emissions when switching to the electric powertrain. According to Trafikanalys (2017), as well as ERTRAC (2011), the general level of emissions is reduced with a hybridized truck, compared to a truck powered only by an ICE.

As indicated by Trafikanalys (2017), the current share of hybrid trucks in the Swedish truck fleet is almost non-existent. At the moment, both Volvo and Scania offer hybridized solutions for city distribution and regional distribution (Volvo Trucks, 2013; Scania Sverige, 2017).

According to Volvo Trucks, there are at the moment about 50 hybridized trucks of their model Volvo FE Hybrid in operation. However, Volvo Trucks is currently developing a hybridized truck for long-haul with the ability to lower the CO2 emissions by 30% (Volvo Trucks, 2017b).

BEV technology

Battery electric vehicles, with the acronym BEV, refers to vehicles with a single electric powertrain which is powered by electricity stored in batteries in the vehicle (International Energy Agency & Electric Vehicles Initiative of the Clean Energy Ministerial, 2013). Thus, for a BEV truck the ICE has by definition been totally replaced by an electric powertrain, which is necessarily not the case for other types of electric vehicles.

The current use of BEV trucks for long-haul transports is insignificant. However, several truck manufacturers have recently announced that they are about to release heavy-duty BEV truck alternatives. Some of these manufacturers are Tesla, Daimler and Einride, with the corresponding truck models Tesla Semi, E-FUSO Vision One and T-pod (Tesla, 2017a; Daimler, 2017; Einride, 2017).

RPEV technology

An alternative infrastructure to static charge of batteries is an electric road system, where the vehicles are continuously being charged dynamically while moving (International Energy Agency, 2017). A common name for vehicles connected to such a system that is sometimes used is Road Powered Electric Vehicles (RPEV), which will be used throughout this study.

Different designs for electric road systems are currently under development around the world, with no clear dominant design. There are basically two different technologies for transfer of electric energy to consider when developing an electric road system, conductive and inductive transfer (eRoadArlanda, 2017a). Conductive transfer means that the truck is somehow attached to the electric grid, either through an overhead contact line or through an electric rail in the roadway. The inductive solution implies that the energy is being transferred magnetically from the system to the vehicle.

Sweden currently has two ongoing demonstrations of conductive electric roads, driven by the Swedish Transport Administration in collaboration with additional participants (Trafikverket, 2016). In Sandviken, the Swedish Transport Administration, Scania, Siemens and a number of other Swedish authorities are financing a demonstration of electric roads where the electricity is supplied through an overhead contact line (Region Gävleborg, 2016). The second demonstration is carried out in Arlanda, where a technical solution based on an electric rail attached to the roadway is being tested (eRoadArlanda, 2017b). Some of the involved organizations are NCC, Elways and the Swedish Transport Administration. In addition, Sweden recently signed a contract regarding collaboration with Germany regarding electric road systems (Trafikverket, 2017b).

In addition to demonstrations of conductive solutions, inductive solutions are being tested and developed around the world. However, according to some of the interviewees, the inductive technology is not as mature as the conductive alternatives. An example is the demonstration in Mannheim, Germany, where Bombardier and Scania have been testing an inductive solution since the year of 2013 (Bombardier, 2017).

FCEV technology

Another future alternative to the ICE are fuel cells. A fuel cell electric vehicle (FCEV) is powered by an electric motor, where the electricity has been converted from chemical energy, usually hydrogen, by a fuel cell (International Energy Agency & Electric Vehicles Initiative of the Clean Energy Ministerial, 2013). The technology is currently not used in any greater extent in heavy-duty trucks, according to the interviewee at the Swedish Electromobility Centre, but has the potential to become an attractive alternative in the future.

There are some indications of a future extension of the use of fuel cells in heavy-duty trucks. For instance, the American truck manufacturer Nikola has announced that a fuel cell powered truck will be released in the near future (Nikola Corporation, 2017). In addition, the Swedish fuel cell developer PowerCell has recently delivered fuel cells for the use in trucks in Switzerland, which are operated by the Swiss company named COOP (PowerCell, 2016).

4.4 Future roles of electrification and alternative fuels

Here, the different opinions and expectations on the future use of the alternative powertrains and fuels will be discussed. In the first of these subchapters, the opinions gathered during orientational interviews regarding the future attitude towards sustainability is presented. Similarly, the opinions regarding the future role of the ICE and electric engine are discussed in the last two subchapters.

4.4.1 Implications of future attitude towards sustainable development

Throughout the interview process there has been consensus regarding the expected endurance of the highly ambitious climate goals proclaimed by the Swedish government. The general perception of the interviewees is that the industry is preparing to change in order to meet the goals for 2030 and 2045. The demand for sustainable transports from transport purchasers is increasing, while transporters are trying to offer solutions in line with these demands. However, there are still numerous of areas where the political positions are not yet settled, especially concerning potential future EU-policies and increased independent governance of cities.

EU policies

The European Union is currently trying to steer the development of the heavy-duty truck industry to become more sustainable. According to the interviewee at the Swedish Electromobility Centre, the control mechanisms that are currently applied on EU-level are twofold, namely truck efficiency and level of renewable fuels used. However, according to the same interviewee, these policies are likely to change into being stricter. In addition, the EU is trying to find additional ways of making the industry more sustainable, by exploring and evaluating alternative areas other than trucks efficiency and level of sustainable fuels. According to the interviewee at the Swedish Electromobility Centre, the reason for this stricter regulation is that the EU is falling behind the US and Japan in terms of regulating the heavy truck industry towards sustainability.

Even though Sweden has most of the ingredients for taking the lead in the change to a more sustainable transportation industry, the ability for Sweden to act is sometimes hampered by the EU. According to some of the interviewees, this is because Sweden has to adapt to the laws of competition that have been adopted by the EU. An example is that the Swedish production of domestic biofuels is limited by the EU, since legislation on EU-level is restricting the ability to design control mechanisms for an extended production (Energimyndigheten, 2017). In addition to this, some criticism towards Sweden's ambition of being a role model for a sustainable transport sector were expressed during some interviews. The criticism has considered the fact that Sweden is promoting sustainable solutions which requires specific prerequisites that not all countries have, such as sustainably sourced electricity or an abundance of forest. Hence, some interviewees stated that Sweden's ambition of being a role model should be adapted to take into account the current conditions and prerequisites of other EU member states.

City policies
Although most heavy-duty trucks are not operating in the vicinity of cities, they are occasionally passing these areas. Hence, another important aspect to consider is how city policies are going to impact the heavy-duty truck industry.

Some interviewees have indicated that it is likely that many cities will create strict transport policies in the future, as a way to profile itself as sustainable. Especially harder restrictions regarding noise and particle emissions are to be expected. In some cities, as indicated by several interviewees, all kinds of vehicle traffic could be banned. As expressed by one of the interviewees, this development is a trend that we can see in many influential cities in the EU. The cities are increasingly establishing local rules in favor of a sustainable development, which are more extensive than the corresponding rules on the European or national level. As stated by the same interviewee, there is a tendency that these influencing cities are competing of being the most sustainable city in the EU. An example of this development is Stockholm, where heavy-duty trucks are just allowed to operate on specific roads during the nights, in order to reduce noise (Trafikkontoret, 2017).

As already mentioned, the future urban policies will mainly affect trucks engaged in city distribution of goods. However, even though the long-haul trucks are not driving through the city, some interviewees have indicated that it is possible that similar restrictions will be applied in the near vicinity of the city. As has already been stated, these restrictions could in the future be enforced by connectivity solutions and geofencing. Another example of how new policies could influence the transport industry, and thereby the heavy-duty truck industry, is when public procurements require that eventual transports should be sustainable. According to one of the interviewees, this is becoming increasingly common for public procurements made by the city of Gothenburg.

4.4.2 The future role of the internal combustion engine
ERTRAC (2016) recently stated that the conventional ICE will still be dominating the heavy-duty truck industry by the year of 2030. This perception is shared by most of the actors that have been interviewed for this study. The common opinion is that it will not be possible to totally replace the ICE until the year of 2030. However, the opinions regarding to what extent the ICE will be dominating the heavy-duty truck industry differ. The following paragraphs will elaborate on the reasons for the continued dominance of the ICE and discuss which fuels that are likely to be used in the future.

There are numerous of reasons for why it would take a long time for the heavy-duty truck industry to make a transition to all electric powertrains. One of the most important factors is that electricity in itself is not sustainable by definition. This issue has been raised by several interviewees, but was especially highlighted by the Swedish Electromobility Centre and Vattenfall. The Swedish electricity is relatively sustainable, but this is not always the case for other European countries. According to Vattenfall, the trend is that European electricity is in general becoming more sustainable. However, the transition to sustainable production of electricity will not be completed by the year of 2030.

Another reason for the preservation of the ICE that has been mentioned during the interviews is that the energy density is higher in hydrocarbons compared to electricity. This leads to batteries being a heavy energy carrier compared to ICE-related fuels. Low vehicle weight is important, as it allows the vehicle to consume less energy during transport. In some cases, weight limits are a restriction when transporting goods, and a lighter vehicle can thereby transport more goods. In addition, the infrastructure for fuel distribution of varying hydrocarbons is already developed, which motivates a continued usage of the ICE (ERTRAC, 2016).

Finally, as stated by RISE Viktoria, there is a resistance among the component suppliers and the OEMs to totally replace the ICE with electric powertrains, since this is a threat to current business models, prior investments in R&D and developed competence related to the ICE. In addition, some of the trucks being sold during the coming decade, with an ICE installed, will still be in use by the year of 2030.

Even though the ICE is expected to play a significant role in the future, the goal is to still reach a 70% reduction of CO2 emissions by 2030 compared to the levels of 2010. This means that the fossil diesel needs to successively be phased out. As indicated by FKG, the fossil diesel is not yet dead, but production of new fuels needs to be developed in parallel the coming years if we are to meet the emission goals by 2030. The most heavily discussed alternatives to fossil diesel are biofuels and natural gas. However, both of these alternatives come with benefits as well as drawbacks.

Biofuels

During the interviews, the general opinion of biofuels as such has been positive. The majority of the interviewees think that biofuels will be a part of the solution for a sustainable development. Transportföretagen states that biofuels probably will be more important than electrification until 2030. The main reason for why biofuels have received a positive response by the transport industry is because these fuels can utilize the same infrastructure and truck designs, meaning that the different actors within the industry do not need to significantly change their behavior. Sveriges Åkerier confirms that the purchase of a truck is a long-term investment, which means that the truck owner wants to be sure that associated fuels will be available and competitively priced during the lifespan of the vehicle. Especially HVO is expected to be a significant fuel for decades even after 2030, since no alterations of the engine are needed even though high concentrations of HVO is being used.

The main issue with a transition to more consumption of biofuels is that the supply is limited. There is a common concern that it will not be possible to satisfy the growing demand of sustainable fuel with biofuels alone. In addition, there are significant regulations from the EU limiting the potential future production of biofuels. According to Transportföretagen, Sweden is currently importing 80% of the HVO being consumed, even though the potential of domestic production is substantial.

According to the Swedish Electromobility Centre, the attitude towards biofuels is not as optimistic on an European level as it is in Sweden. This is because Europe in general do not share the Swedish preconditions for production of biofuels. As a result, an increased consumption of biofuels in Europe would imply an increased reliance on import of biofuels into the EU, which policy-makers are not in favor of. Furthermore, from a sustainable point of view, there is a risk that a potentially increased foreign production would give rise to new challenges. An example of this is what is usually called “indirect land use change”, which means that new land needs to be used for production of food and feed as current existing land is increasingly used for production of biofuels (European Commission, 2012). In addition, biofuels have been accused for draining the soil from nutrients. Other interviewees have highlighted the conflict in crops being used for production of biofuels instead of production of food.

The view of the EU being more skeptical to an increased use of biofuels is shared by Transportbolagen, which indicates that the legislation concerning production and use of biofuels is probably going to be even more limiting in the future. This means that even though Sweden has favorable conditions for production of biofuels, it is reasonable to think that the exploitation of these resources will be limited. According to Swedish Electromobility Centre, Sweden will probably not be allowed to have an extensive domestic production of biofuels which supplies the Swedish market with competitive sustainable alternatives. This would be considered a subsidization of domestic production, which will not be tolerated by the EU.

Natural gas

It is possible that the current international trend towards an increased use of natural gas is going to influence the diffusion of gas-powered trucks in Sweden (Trafikanalys, 2017). As already mentioned, it is possible to reduce the amount of CO2-emissions by substituting diesel with natural gas, which is the main reason for the increased use. Furthermore, natural gas is price competitive with diesel, at least in areas where the supply of natural gas is less limited (ibid). Many of the interviewees stated that it is possible that the use of natural gas is going to increase in the future. Most of these interviewees have referred to the newly released Volvo FH LNG truck, and have thereby indicated that the substitution of diesel for natural gas has somewhat already started.

However, some restraining aspects for an increased use of natural gas have been raised during the interviews. According to the interviewee at Sveriges Åkerier, the most obvious drawback is that there is not yet any well-developed infrastructure for distribution of natural gas for trucks. In addition, during the interview with the Swedish transport administration, it was argued that the fact that the powertrain needs to be adapted in order to be powered by natural gas is a considerable competitive disadvantage compared to biofuels.

Finally, a common perception shared by several of the interviewees is that natural gas probably will be used as a transitional product. The main reason for this perception is that natural gas is not an all sustainable alternative. The level of emissions can be reduced, but this reduction is not enough in order to meet the environmental goals.

4.4.3 The future role of the electric powertrain

The general perception among the interviewed organizations is that the truck fleet will eventually become electrified, even if this is not likely the case by 2030. However, the perception regarding when and how this electrification will become reality differs. The newcomer Einride, that aims to have launched 200 electrified and autonomous trucks operating the route between Gothenburg and Helsingborg by 2020, envisions a large-scale adoption of electric trucks already by 2030. On the other hand, the Swedish Transport Administration argued that this transition will take several decades, since new infrastructure for transmission of electricity needs to be developed, which is a time-consuming process.

Most interviewees conclude that urban and short range heavy truck traffic would be the first to become electrified, and that these trucks could be operated by electricity stored in battery packs onboard, or possibly fuel cells driven by hydrogen. However, how long-haul heavy-duty trucks would be electrified is somewhat uncertain. The Swedish Transport Administration is convinced that battery packs will not be enough for operating these trucks with the technology available in the foreseeable future, and that some kind of assistance such as electric roads will be needed. On the other hand, Tesla has recently announced that their BEV truck “Tesla Semi” will be released in 2019 and that the range will be about 500 miles on a single charge (Tesla, 2017b), which if achieved could make long-haul heavy-duty traffic possible. Hence, the future electrification of trucks is uncertain. The following paragraphs will describe the opinions raised during interviews regarding future application areas of combinations of powertrains and related infrastructures.

Possible diffusion of hybrid electric trucks

According to Swedish Electromobility Centre, many of the future trucks will probably be hybrids, both in the form of HEV and PHEV. In the absence of a sufficiently developed charging infrastructures, static as well as dynamic, hybrid trucks could play an important role during the time that these potential infrastructures are being constructed. Trafikanalys (2017) expects that the share of hybrid trucks in Sweden could range between 3% to 15% by the year of 2030, which is an increase compared to the current almost nonexistent share of hybrids. Another aspect highlighted by the Traffic Office of the city of Gothenburg is that it is possible that new legislation will prevent trucks to operate near cities if not driven on electricity, forcing long-haul trucks to become hybridized. This argumentation is supported by Trafikanalys (2017), that indicates that hybrid trucks will probably be used in areas that are sensitive to pollution. Within these areas, the ICE could be turned off and the truck could be operated on electricity.

The main issue that has been raised regarding hybrid solutions is that these trucks are more expensive, since two different powertrains need to be installed. Therefore, some interviewees have questioned the long-term survival of the hybrid solutions when alternative more fully electrified alternatives are available. As an example, Northvolt stated that hybrid solutions are just a transition product that will disappear when an alternative charging infrastructure has been developed.

Possible diffusion of BEV trucks and static charging infrastructure

The opinions regarding the likelihood of BEV trucks as electrification path have differed heavily throughout the interviews. The range of opinions spans from the perception that there will never be an application of long-haul heavy-duty BEV trucks, to the perception that BEV trucks will be widely spread by the year of 2030. The following paragraphs will elaborate on the different aspects that are in favor of a wider use of BEV trucks, as well as those factors that are hampering the development.

Comparing a BEV truck with a conventional truck that runs on diesel, one of the most frequently mentioned differences during interviews was the driving range. This is usually considered a significant disadvantage of a BEV truck. However, during the interviews it became clear that this is an aspect of less importance for many transports. The reason for this is that many transports are not as far as one would expect, which is discussed in more detail later in the study.

According to Swedish Electromobility Centre, a reason for the delusion that all trucks need to be able to travel far distances on a single tank is because most trucks have been designed to do so. The price of the truck does not change much depending on the volume of the conventional fuel tank. Therefore, for convenience most trucks have been equipped with a sometimes oversized fuel tank. In contrast, battery packs used in a BEV truck will have a significant impact on the price, which means that the amount of batteries needs to be adjusted depending on how far the truck is supposed to drive. However, as indicated by Swedish Electromobility Centre, this should not constitute a major problem since many transports are standardized.

Although battery packs would be the source of a significant cost increase for electric trucks, FKG indicates that these costs could be compensated by electric powertrains being cheaper than the conventional ICE, which is used as another argument in favor of the electric powertrain. According to them, it is the simplicity of the electric engine compared to the ICE, that leads to the low cost.

Another aspect that has been discussed during interviews is whether the time it takes to charge the batteries would limit the diffusion of BEV trucks. Many interviewees have indicated that as long as the trucks require drivers, the wages of these drivers will be considered a waste during charging times. On the other hand, both Northvolt and Transportindustriförbundet have opposed to this argument since the drivers are supposed to take regular breaks. If the charging stations are strategically positioned, these breaks could be combined with the truck being charged.

As has already been discussed, the main reason for a transition to electric powertrains is to make the transport industry more sustainable. However, some of the interviewed organizations have been questioning the sustainability of BEV trucks. For a BEV truck to be sustainable, both the production of the battery packs as well as the electricity consumed while driving need to be sustainable. Even Northvolt admits that there are ethical and environmental challenges that needs to be managed and avoided during mining of specific metals, especially cobalt from African countries. Moreover, Northvolt has a positive approach to future development regarding recycling of batteries and what is usually referred to as circular economy. As the production of electricity in Europe is becoming more sustainable, and recycling of batteries is being more efficient, the BEV trucks could be a sustainable alternative in the future.

Finally, the need of improved battery technology has been mentioned by several organizations. According to Transportindustriförbundet, the main problem is that batteries based on current technology would lead to heavy battery packs, which are negatively impacting the freight capacity of the truck. Furthermore, the Swedish Transport Administration confirms that the battery technology is a decisive factor for the future diffusion of BEV trucks. They consider this development to be very uncertain, but admits that future technologies other than lithium-ion could revolutionize the adoption of batteries in trucks. Other actors, such as Northvolt and Swedish Electromobility Centre, are more optimistic towards the development of battery technology. Northvolt indicates that just as we were skeptical to the use of batteries in cars some ten years ago, we are now skeptical to the application of batteries in trucks. However, they think that this skepticism is going to fade away as the technology is becoming more mature. According to Swedish Electromobility Centre, it is reasonable to think that the development of battery technology will be hardly pushed going forward as China is investing in sustainable electricity and electrification of the vehicle fleet. This could result in technology leaps as well as economies of scale in production of battery cells. Such a development could lead to lighter and more price competitive batteries entering the market in the near future.

Reasons for the Swedish engagement in electric roads

Some interviewees who did not believe in BEVs as a likely development for electric heavy-duty trucks, instead believed in a widespread development of electric roads in Sweden. The most obvious reason for why Sweden is engaged in the development of electric roads is because of the ambitious climate goals that Sweden has committed to for 2030 and 2045. Both Transportföretagen and the Swedish Electromobility Centre pointed out that electric roads may be a future necessity in order to reach these goals. As has already been discussed, Sweden has got relatively sustainable production of electricity, which makes electric roads an even more attractive alternative here than in other countries.

Another reason for the engagement in electric roads is that Sweden has a lot of commodities that need to be transported. According to the Swedish Electromobility Centre, it would be financially unreasonable to expand the railway network to be able to reach all relevant parts of Sweden. However, an electric road system could suit this purpose to a greater extent. Then, the future transports could become both more affordable as well as sustainable.

Finally, the fact that two prominent truck manufacturers are Swedish, Volvo and Scania, is another reason for why Sweden is engaged in demonstrations and a potential extension of an electric road system. According to the Swedish Transport Administration, the two OEM manufacturers want to position themselves for the future. By testing and developing electric road systems, the manufacturers can both steer the development of the industry as well as prepare themselves for a potential expansion of electric road systems in Europe.

Drawbacks of electric roads

On the contrary, there are interviewed organizations that argue for electric roads being an unnecessary investment. The representative of Sveriges Åkerier believes that an electrification of selected highways will not make any significant difference for the environment, nor the haulers. According to Sveriges Åkerier, the Swedish haulage industry is usually operating locally, within an area of just a few kilometers. Their statistics show that 92% of the transports are shorter than 300 kilometers, while 50% of the transports are below 50 kilometers. This means that an electric road system as range extender should be unnecessary.

Another concerning aspect of an investment in electric roads is that these could become a stranded asset, as expressed by the Swedish electrification center. As other technological developments are progressing, electric roads could become obsolete in the future. If it becomes more affordable to operate the truck on alternative technologies, such as cheap battery packs, hydrogen or biofuels, there is a risk that the electric roads will not be utilized.

Possible diffusion paths of electric roads

Assumed that electric roads prove to be a favorable solution, the opinions regarding which roads that should be electrified differ significantly. In essence, the interviewees have mentioned two different development paths for electrification of the road system. The electrification could start locally, by focusing on short standardized routes which are important for specific industries. Or, the electrification could start with selected key highways in order to act as an electric range extender. Representatives for Transportföretagen, Rise Viktoria and the Swedish Electromobility Centre have all expressed their belief in a local electrification of the road system. In contrast, the representatives from the traffic office of Gothenburg, Fores, Vattenfall and Roadmap Sweden have argued that the electrification might as well start with key highways. However, some of the organizations have concluded that one alternative does not exclude the other. The developments could occur simultaneously, the local expansion being pushed by industry actors for cost efficiency, while the electrification of key highways would be pushed by the government in order to meet the environmental goals.

Options regarding technical standards for electric roads

At the moment, it is uncertain which technology for electric roads that will be dominating in the future. As already mentioned, different kinds of conductive as well as inductive solutions are currently being demonstrated and evaluated. The interviewed organizations have highlighted different influential aspects, which all relates to specific advantages as well as disadvantages for each of the alternative technologies.

One aspect that has frequently been discussed is the possibility for cars to make use of the same infrastructure for electric roads. The person interviewed from Roadmap Sweden was convinced that the government would not invest in an infrastructure that would not allow cars to be dynamically charged. This attitude is shared by some of the interviewees from RISE Viktoria, who expressed that it would be unfortunate if an electric roads system was developed just for trucks. This is the main disadvantage of the conductive solution where the electricity is supplied through an overhead contact line. An inductive as well as a conductive solution attached to the roadway have an advantage in this regard, since these solutions could also be utilized by cars.

Another aspect that has been raised is that the infrastructure needs to be operational independent of weather conditions. According to Vattenfall, this is the main disadvantage of a conductive solution attached to the roadway. In case of heavy snowfall, or the roadway being flooded, this kind of system is vulnerable. Concerning weather conditions, conductive overhead contact lines as well as inductive solutions have an advantage.

Finally, efficiency in energy transfer has been discussed as a disadvantage for inductive solutions. Compared to the two conductive solutions discussed, the loss of energy is considerable in the case of an inductive transfer of energy.

Technical standardization of electric roads

In addition to the different aspects discussed above, there is an ongoing discussion whether Sweden, together with remaining countries in the EU, should adopt a technical standard of electric roads. Some of the interviewed organizations have concluded that a common standard within the EU is necessary in order to create an efficient transportation industry. However, some other organizations do not regard standardization as an important issue.

The main argument for why there is a need to standardize future electric roads is that many of the long-haul transports are international. Both the representatives from the Swedish Electromobility Centre and Roadmap Sweden have highlighted the inefficiency of transshipment of goods at the country borders if different standards were to be used. In addition, according to the interviewed person at Roadmap Sweden, the absence of an European standard could delay the development of electric road systems in Europe. The reason for this is that an absence of a standard could lead to a situation where governments do not dare to invest in electric road systems, since there is a risk of investing in a system that will not be used by foreign trucks.

In contrast, the main argument for why a standard is not necessary is that most of the transports are domestic and local. According to the Swedish Transport Administration, it would not be devastating for Sweden to invest in an electric road technology that would not become dominant internationally. According to the interviewee, Sweden has a big enough domestic transport demand to develop its own electric road system. To a great extent, the imported goods reaches Sweden by sea, and is then managed locally. As an example, a cargo port investing in local electric roads should not need to be restricted by a standard set by the EU. Furthermore, one of the representatives of RISE Viktoria argued that a standard for electric roads is more important for a transit country, which is not the case for Sweden.

Regardless of the different arguments described above, Sweden and Germany have decided to collaborate in the development of electric roads (Trafikverket, 2017a). According to the Swedish Electromobility center, it is reasonable to think that this collaboration will result in a standard at least between these two countries. Furthermore, several of the interviewees believe that Germany is strongly favoring the conductive solution with an overhead contact line developed by Siemens. However, it was pointed out by the interviewee from Roadmap Sweden that the German car manufacturers probably will argue against this solution, since this technology is not suitable for cars.

Another aspect influencing whether a standard will be developed or not is the interest of the truck manufacturers. As admitted by both the Swedish Transport Administration and the Swedish Electromobility Centre, the truck manufacturers are pushing the development of a standard for electric roads, as this would facilitate and favor their business.

Financing of electric roads

The interviewed organizations agree upon the fact that an expansion of an electric road system would come with a considerable investment. However, how this investment is going to be financed is still uncertain. Most interviewees agree that such an investment needs to be at least partly funded by the government. When Vattenfall was interviewed, it became clear that it will be difficult to make the development of electric roads a profitable business. However, during the interview with Vattenfall it was also argued that investments in electric roads would be a cheaper alternative than expanding the railway system. Since we are already considering expanding the railway system, the interviewee expressed that it is not unreasonable to think that the government could invest in electric roads in the future.

That the government alone would finance a potential electric road system is considered likely by most interviewed organizations, at least when considering electrification of highways and other public roads. Nevertheless, one of the interviewees form RISE Viktoria argued that such an investment could partly be funded by the government together with industrial actors. For instance, there could be economical incentives for freight- as well as power companies to partly invest in such a system. What matters for the freight companies is how much that could be saved by switching to electricity powered trucks, while power companies will have the opportunity to distribute and sell electricity to a greater extent.

Considering more local environments, such as roads within restricted areas, it was expressed by some interviewees that an electrification is more likely to be financed by related local actors. Some examples that was mentioned are harbor areas, mining areas or goods terminals.

Time required for diffusion of electric roads

The potential expansion of an electric road system by the year of 2030 is expected to be rather limited by most of the interviewed organizations. However, they found it relevant to discuss whether such an expansion has been initiated or not at this time. Regarding this matter, the interviewed organizations were of different opinions.

Interviewed representatives from RISE Viktoria, Vattenfall and the Swedish Transport Administration expressed that we probably will see operational electric roads in Sweden by 2030. However, it is likely that most of these roads will be found in local areas, rather than public roads. In order for public roads to be electrified, the government needs to have concluded that an infrastructure for electric roads is a favorable investment.

Some other organizations, for example the traffic office of Gothenburg and Transportföretagen, are more skeptical to an initiated development of electric roads by the years of 2030. The person interviewed at the traffic office of Gothenburg expressed that we would probably have many statically charged trucks operating in the urban environment, but that electrified public roads will become more relevant for the year of 2050. This was further discussed during the interview with Transportföretagen, where the interviewee concluded that the upcoming sub-processes, such as evaluation of demonstrations, decision making and later the construction of the infrastructure will probably take a considerable amount of time. Therefore, it is more likely that an electric road system will contribute to the environmental goals set for the year of 2045 rather than 2030. In addition, it was pointed out by one of the interviewees from RISE Viktoria that the political determination is crucial for the development. According to the interviewee, it is uncertain whether concerned governments dare to invest in an electric road system during their period of mandate.

Potential diffusion of FCEV and hydrogen gas infrastructure

Generally, the knowledge regarding fuel cells among the interviewed organization is limited. Most of the organizations are aware of the technology, and that there is potential in substituting large battery packs or conventional fuels with hydrogen gas to power fuel cells. But the common perception is that this is a more futuristic technology than batteries, electric roads or biofuels. However, the Swedish Electromobility Centre is more optimistic to an application and diffusion of fuel cells for trucks by the year of 2030. According to the interviewee, the most obvious application segment is for trucks that are operating in a regional environment. With a range of 100 - 200 kilometers it is possible to fill up the hydrogen tanks in the morning, perform the daily transports, and refuel the next day. For this kind of transports, the FCEV have the potential to be an even more attractive alternative than BEV. Furthermore, as argued by the Swedish Electromobility Centre, fuel cells are suitable for combinations with other powertrains and technologies, such as the ICE or electric roads. This view is shared by the representative from Northvolt, who indicated that FCEV trucks could be a complement to BEV trucks in those areas where static charge stations or electric roads have not yet been constructed.

The main uncertainty with fuel cells is the validity of the technology. According to the interviewee at the Swedish Electromobility Centre, as for the battery technology, the developers need to prove that the lifespan of the fuel cell is sufficient. In addition, during the interview with the Swedish Transport Administration, it became evident that the technology needs to become more mature in order for the price to drop to a reasonable level. Except for the technical barriers and the price, hydrogen as fuel needs to become more accepted by the population general and especially the drivers. According to the interviewee at Einride, hydrogen gas has sometimes got a bad reputation, because of it being explosive. In order for hydrogen to become an accepted fuel, the safety needs to be proved.

Another barrier for a future use of fuel cells is the current absence of an infrastructure for distribution of hydrogen. According to the interviewee at the Swedish Transport Administration, such an infrastructure is not to be expected until the technology for fuel cells have been proved to be valid. However, the representative from the Swedish Electromobility Centre added to the discussion that compared to cars, trucks running on hydrogen comes with an advantage with regards to the infrastructure. The operation of long-haul trucks is more predictable, which makes it easier to position the refueling stations strategically. This means that fewer fuel stations will be needed for serving trucks than cars, which means that a potential future expansion of the infrastructure will more quickly become sufficient for trucks than for cars.

Finally, the production of hydrogen needs to become more efficient and to be scaled up in order for the price to be reduced to a competitive level. This issue was highlighted during the interview with the Swedish Electromobility Centre, where the interviewee stated that this could be an even more important enabler for the application of fuel cells than the price for the fuel cell itself. According to the interviewed person, the total cost of ownership (TCO) is the final deciding factor of a truck purchase, of which the initial purchase price is small in comparison to the fuel price.

Future combinations of the electric vehicle types

Many of the interviewees have argued that combinations of the different types of electric vehicles are likely to exist in the future. For instance, both hybrids, BEV and FCEV truck could make use of electric roads if appropriately equipped for this transfer of electricity. It is also possible that fuel cells could be used as range extenders for any of the other kinds of electric vehicles. The possibility that electric roads could act as an enabler for BEV trucks was most frequently discussed during the interviews, which will be discussed in more detail in the following paragraph.

Several of the interviewed organizations have indicated that a strategic development of electric roads could support a potentially increased amount of BEV trucks in the future. One of the interviewed at RISE Viktoria argued that if some selected key highways would be electrified, the driving range of BEV trucks would not need to be more than 100 kilometers. The logic in this argument is that the truck will never be further away from the next electric road than approximately 100 kilometers, which enables the truck to reach its destination and to get back to the electric road without any need of static charging. This would mean a reduced need of energy storage onboard the vehicle. According to Roadmap Sweden, this would be a favorable development since there is a risk that the battery packs would otherwise be far too heavy, especially for long-haul transports. Furthermore, a reduced need of battery packs would reduce the price of the truck. Even the representative from Northvolt admitted that electric roads could be a healthy development for the society. Instead of regarding a potential development of electric roads as a threat to sales of batteries, this could be seen as an enabler of BEV trucks.

5. Identification and ranking of factors

This chapter has been divided into two different parts. Firstly, the information presented in chapter 4, which was based on the findings from the orientational interviews, will be analyzed in order to identify and rank relevant factors. Secondly, an illustration of this analysis will be presented with the purpose to provide an overview of the analyzed factors.

As already described in chapter 3, the analyses of the identified factors are based on comparisons of interview responses. Hence, the identified factors and the corresponding ranking regarding the level of certainty and importance should be regarded as an analytic extension of chapter 4.

The identified factors have either been classified as macro- or micro-factors. As explained, this was done in order to perform a comprehensive scenario planning. For an illustrative purpose, this division will be used throughout the chapter.

5.1 Description and motivation of ranked factors

The following sections aim to describe the identified factors, as well as to motivate the ranking of the corresponding level of certainty and importance. As already described in chapter 3, the level of certainty refers to the perceived likelihood that a specific factor will come true in the future, while the level of importance refers to the potential for a specific factor to impact the industry dynamics and the industry value chain.

Regarding the identification of the subsequent factors, the factors have been identified and formulated through combinations of different pieces of information, which have all been presented in chapter 4. The general procedure for this combination has been to combine aspects that share a common denominator, which is represented by the name of the factors. Hence, there are many alternative factors that could have been identified. However, the ambition has also been to combine aspects that share the same level of certainty and importance. With regards to this approach, the names and specific combinations of different pieces of information becomes less important, since what matters is that these are associated with an appropriate level of certainty and importance.

Thus, the focus of the following paragraphs is to reproduce the analysis of the corresponding level of certainty and importance for each identified factor. However, for an orientational purpose, the subsections for each factor will be introduced by a presentation of which pieces of information that are represented by the specific factor.

5.1.1 Description and motivation of macro-factors

Ma.1 - Sufficiently secure data management

The most uncertain as well as important macro factor covers aspects related to a secure management of data. More specifically, the related aspects are cyber security, data security and personal integrity. As has been discussed in previous chapters, the difference between these three aspects are that cyber security refers to the ability to protect the connectivity systems of trucks from external threats, while data security refers to safe management of stored data, and personal integrity issues refer to what data is gathered.

The main reason for why this factor has been considered uncertain, is because several interviewees have indicated that whether or not a system is sufficiently secure is determined by the public opinion, which could quickly change. If the population in general, and drivers and goods owners in particular, considers the connectivity systems and autonomous functionality of trucks as too insecure, it is likely that the technology will be subject to severe restrictions. Another reason for the uncertainty of this factor is that the attitudes differ between interviewees regarding the possibility of developing sufficiently secure systems, where some interviewees are more skeptical while others are more believing. Finally, new legislations need to be developed in order to make full use of autonomy and connectivity. The development of these legislations is uncertain in itself, with regards to time needed and outcome.

A secure management of data has been considered important by most interviewees, regardless of the attitude for whether sufficiently secure systems could be developed or not. This aspect, together with a reasoning that a changed public opinion towards a system that has turned out to be insecure could ultimately lead to a ban of the technology, is the basis for the judgement of this factor as being highly important.

Ma.2 - Societal engagement for sustainable transports

A continued societal engagement for sustainable transports has been considered the most certain, as well as important, trend for the future. This understanding is based on the common political agreement to favor a sustainable development, solidified by the announced environmental goals, Sweden's will to act as a role model and the influential power from the EU.

The main reason for why the authors have considered this factor as highly certain is the absence of industrial opposition towards mentioned political actions. The industry actors seem to have accepted the new conditions and are willing to adapt their offerings. Furthermore, it is considered unlikely that Sweden will deviate from the announced sustainability goals, since this would harm the international perception of Sweden as a leading role model regarding sustainability.

The importance of this factor is based on the legal power of future political actions with the objective to reach the announced environmental goals. Hence, it is likely that legislations will be designed in order to favor a sustainable development. As a consequence, the market dynamic is expected to change, since these legislations will have a direct impact on the choice of powertrain and fuel.

Ma.3 - Entrance of new players

The factor referred to as entrance of new players relates to the fact that new companies are currently being established in order to compete with or supply the current actors in the industry value chain. More specifically, players such as Tesla and Nikola are competing with alternative powertrains, while actors such as Zenuity and Einride aim to drive the development of new digital technologies, such as high level AV. In addition, the ongoing development of sustainable production of electricity and an enhanced focus on electrification in China, could result in new competition for established truck manufacturers.

However, the reason for considering this factor as just slightly certain is that the future success of these new players is not guaranteed. Since the concerned technical solutions have not yet been introduced in any greater extent on the market, no evaluations of the offerings have taken place. In addition, it is possible that many of these new players will be conquered by the incumbent firms. Hence, these players could potentially impact the industry in the future.

On the other hand, the level of importance is considered to be high. If the players offering alternative powertrains would succeed, the threat to incumbent firms that are currently being a part of the industry value chain is obvious. What makes this factor even more important is that these new players are all trying to develop technologies within the most important areas for the future, namely autonomy, connectivity and electrification. Hence, there is a risk that the incumbent truck manufacturers will be left behind with regards to this development.

Ma.4 - Maturing of sustainable technologies

Next to societal engagement for sustainable transports, a trend named maturing of sustainable technologies has been placed. This relatively certain and important factor basically refers to the general enhancements in battery technology, as well as the ongoing electrification in China, especially concerning the extended production of sustainable energy. Hence, the factor refers to the fact that mentioned technologies are improving, not that they necessarily will be used for long-haul transports.

With the announcement from Tesla of their BEV truck, the battery technology has somewhat already made its way to long-haul transports, although there are still many obstacles for a successful commercialization. However, it is reasonable to think that the battery technology will continue to improve, which implies that a future application of batteries in trucks could become an even more relevant alternative in the future. In addition, as the general production of electricity becomes more sustainable, the future application of electric powertrains in trucks is further motivated. Mentioned aspects constitute the basis for the factor being judged as relatively certain.

The level of importance has been considered to be relatively high, since the electric powertrain has the potential to substitute the ICE in the future and thereby significantly impact the industry. A shift to electric powertrains would probably imply massive competence destruction for incumbent truck manufacturers and concerned component suppliers, and change the economics of the logistics industry.

Ma.5 - Convergence of transport- and digital industries

As the digitalization proceeds, it is reasonable to think that digital technology becomes more applied even in the transport industry. This development implies further utilization of connectivity and automation in trucks, and digital processes replacing physical processes in the logistics industry, which is the reason for a factor that is highlighting this convergence.

The moderately high level of certainty is motivated by the general trend of the society becoming more and more digitized, and that most interviewees expect the development to continue. However, barriers related to a sufficiently secure management of data could potentially limit the adoption of digital technologies in the transport industry.

The reason for the judgement of a moderately high level of importance is that the digitalization of transports might result in considerable implications on the operations of the industry actors. For instance, incumbent actors will need to invest in new IT competencies. However, since this is a development that has been ongoing for several years, it is assumed that incumbents will be able to adjust and to drive the digitalization forward.

Ma.6 - Influence from bus- and automotive industry

The three main study areas, autonomy, connectivity and electrification, are also under development in the bus- and automotive industry. Even though there are differences between these industries and the truck industry, there are also similarities, and it is assumed that the development in one industry will affect the other industries. This is the reason for a factor related to the development within these adjacent industries. For instance, Zenuity, that currently develops AV technology for cars, deemed it possible that they would apply their AV-technology to trucks in the future. In addition, regional trucks could potentially be electrified if the technology is proved to be suitable for regional buses.

That the development within these adjacent industries are going to influence the truck industry has been considered as moderately certain. That cars and buses are going to be electrified to greater extent is relatively certain, which drives a development of charging infrastructures. Since such an infrastructure could also be used by trucks, the development of electrification for buses and cars is likely to drive a similar development for trucks where possible. In the same way could infrastructure for autonomy and connectivity, such as V2I and V2V technologies, make way for a quicker development of these areas for trucks. However, as mentioned, there are differences between different vehicle types, which slightly reduces the level of certainty.

The same kind of reasoning has been used for determining the level of importance, which has resulted in a moderately high level. The development in adjacent industries could enable a quicker penetration of new technologies, which is important to prepare for. However, a potential change of the industry structure will not be driven by these adjacent industries in itself, rather the consequences of a successful development of these.

Ma.7 - Influence from EU

As a member state of the EU, Sweden has to comply with regulations established for the union. The factor named influence from EU includes potential future regulations, regarding areas such as allowed sources of biofuels. Another example is a potential future regulation that requires trucks to use certain connectivity solutions, which could facilitate the governance of border controls, cabotage and geofencing in cities.

However, the level of certainty has been analyzed to be moderately certain. The reason for not giving this factor a higher certainty rating, is because some of the regulations discussed limits Sweden's ability to work for a sustainable development. For example, EUs influence on Swedish production of biofuels could be argued to limit the possibilities to make use of domestic resources for a sustainable transition. Hence, there is a conflict of interests for which the outcome is somewhat uncertain. The logic for this kind of regulation is to prevent subsidization of domestic industries as well as to limit undesirable side effects, but at the same time the EU has an ambition to favor a sustainable development.

Similarly, the level of importance has been assessed to be moderately important. Due to the legal force of EU regulations, the factor is of importance. However, the authors' judgement is that the interests of the EU usually coincide with those of Sweden. Therefore, it is reasonable to think that certain future regulations would be applied independently of the influence from the EU, which makes the factor slightly less important. Furthermore, it is assumed that many developments within autonomy, connectivity and electrification will not be dependent on EU regulations.

Ma.8 - Growing demand of transports

As already indicated, the demand of transports is increasing. The fundamental underlying aspect of the factor named growing demand of transports is the increasing e-commerce.

The reason for judging this factor as moderately certain is the absence of interviewees indicating a reduced need of transports. However, it could be reasonable to imagine a behavioral change if a continuous increase of transports turns out to be incompatible with a sustainable development, which reduced the level of certainty.

On the contrary, not even the current level of transports is compatible with a sustainable development. Hence, the main solution to the environmental problem caused by transports should be to make the transport in itself sustainable, rather than reducing the number of transports. In addition, an increased demand of transports is not likely to change the industry value chain by itself. This reasoning constitutes the base of the judgement of this factor as relatively unimportant.

Ma.9 - Sustainable and smart cities

A factor regarding sustainable and smart cities is motivated by the fact that certain cities have an ambition to profile themselves as sustainable, and that cities have some degree of self-governance. As already mentioned, local emission rules for cities that are more extensive than the national equivalents are starting to impact the truck industry.

The common perception among the interviewed organizations is that sustainable cities is a phenomenon that will increasingly impact local legislation in the future. This, together with the fact that cities are already starting to enforce specific rules, constitutes the basis for a moderately high level of certainty for this factor.

However, this kind of local rules are expected to mostly affect trucks operating in urban areas. Except for increased requirements regarding emissions and noise in the vicinity of cities, the long-haul transports are not expected to be affected by city policies in any greater extent. Therefore, the level of importance has been assessed to be rather unimportant.

5.1.2 Description and motivation of micro-factors

Mi.1 - Viability of electricity as substitute for hydrocarbons

The most uncertain, and at the same time most important, factor has been analyzed to be the potential substitution of fuels for the ICE for electricity. Hence, what is considered is to what extent the future heavy-duty trucks actually will be powered by an electric powertrain instead of the ICE. In addition to the following two factors, Mi.3 and Mi.5, concerning to what extent the electric powertrain has penetrated the heavy-duty truck fleet, this factor highlights the uncertainty whether these electric powertrains are going to be used or not. As already discussed, several of the different types of electric vehicles could be mixed with an ICE, which implies that there is a choice for the operator to run the truck on fuels for the ICE or electricity. The different types of electric vehicles referred to as HEV, PHEV, RPEV and FCEV, could all be operated in conjunction with an ICT. Thus, it is only in the case of a BEV that it is certain that the only powertrain installed is electric.

The motivation for the high level of uncertainty of this factor is that there is a number of different aspects impacting the future validity of electricity as fuel, which are all uncertain in themselves. To what extent a PHEV or a RPEV is run by electricity depends on factors such as the possibility to charge (statically as well as dynamically), if the electricity is produced by sustainable sources and future urban regulations. In addition to these factors, the diffusion of BEV trucks is heavily dependent on the development of battery technology, which impacts the price for battery packs as well as energy capacity. Concerning FCEV, the technological development as well as an eventual extension of a distribution network for hydrogen gas is what becomes relevant. At the same time, the relative competitiveness of hydrocarbons, referring to alternative fuels for the ICE, becomes relevant. There is a possibility that the attitude towards biofuels on an European level improves, which could increase the supply of biofuels.

The relative validity of electricity as fuel is essential for a continued diffusion of electric powertrains in trucks. The authors' understanding is that the industry has not yet reached a consensus regarding this validity. However, as the industrial development progresses, there is a possibility that a consensus regarding this matter has been reached by the year of 2030. Hence, in the case of a future where electricity is increasingly preferred over hydrocarbons as fuel source, a considerable transformation of the industry could be expected. Truck operators will increasingly demand trucks powered by electricity, which will result in new expectations on both truck manufacturers as well as concerned suppliers. These are the underlying reasons for the perceived high level of importance.

Mi.2 - Time until commercialized high level AV-technology

One of the most important and at the same time uncertain factor has been analyzed to be the time until commercialization of high level AV-technology. This factor refers to the technical, societal, political and legal aspects of the issue. Hence, for a successful commercialization, the technology needs to have reached a sufficiently high level, and the technology needs to have gained public, political and legal acceptance.

The perceptions among the interviewed organizations regarding the possibility of a successful commercialization of high level AV-technology have differed substantially. In addition, the technical development as well as the public, political and legal acceptance are in themselves uncertain. If any of these three aspects would fail or be delayed, the time to commercialization will be heavily affected. These are the circumstances constituting the basis for the factor being considered as highly uncertain.

Given that a high level of AV-technology will be available and commercialized at some point in the future, the industry structure will probably be strongly affected. A high level of AV-technology has the ability to disrupt the industry. The economics of logistics and the design of trucks could change significantly once the driver is removed. In addition, it is reasonably to think that such a technology will drive the development of new business models as well as new owner structures for trucks. Hence, the time factor for a commercialization of such a technology will be crucial for an appropriate strategic preparation for this transformation, which is the reason for the high level of importance related to this factor.

Mi.3 - Penetration of electric powertrains in regional transports

Unlike factor Mi.1, which considered to what extent the electric powertrain was in operation, this factor considers to what extent the electric powertrain has succeeded to penetrate the truck industry. Hence, what is in focus is the proportion of the truck fleet that consists of either a HEV, PHEV, BEV, RPEV or FCEV. Furthermore, this specific factor refers to the regional heavy-duty truck transports. The level of certainty has been analyzed to differ between regional and long-haul transports, which is why the penetration of electric powertrains are split into two different factors.

The level of certainty has been assessed as slightly uncertain. The penetration of electric powertrains is dependent on the progression of Mi.1, namely if electricity proves to be a valid fuel for heavy-duty trucks or not. Thus, since Mi.1 was considered highly uncertain, this factor also becomes uncertain. However, until electricity has potentially proved itself as a valid fuel, it is reasonable to think that the number of electric trucks is going to increase as opportunistic actors try to evaluate the technology and prepare for a potential shift to electric powertrains. An example of such an actor is Tesla that will try to penetrate the market in order to speed up the evaluation of their technology. Some other examples are Einride and Nikola. Moreover, it is reasonable to think that the Swedish incumbent truck manufacturers, Volvo and Scania, will extend their product range with additional electric alternatives, in order to prepare for the potential shift towards electrification. These kinds of actions are likely to increase the number of electric trucks on the roads. Finally, since urban policies probably are going to change in favor of powertrains with reduced levels of particle emissions and noise, the authors' judgement is that the penetration of electric powertrains in regional transports is be more certain than for long-haul transports.

Regardless of whether electricity in the end proves to be an appropriate fuel for trucks or not, it is reasonable to think that the demand for electric trucks will increase the coming years, even though it is still somewhat uncertain to what extent we will see this market penetration. Therefore, it becomes important for the industry to offer these kinds of trucks in order to strategically position themselves for a potential future shift to more electric powertrains. But what really matters, as has already been discussed, is whether electricity in the end proves to be a valid fuel. Hence, the level of importance has been set to relatively important.

Mi.4 - Penetration of electric powertrains in long-haul transports

As for the factor Mi.3, this factor refers to what extent the electric powertrain will have penetrated the truck industry by 2030. The difference between these two factors is that this factor focuses on long-haul transports. The penetration of electric powertrains in long-haul transports has been considered to be more uncertain than for regional transports. Hence, the following paragraphs aim to highlight this difference rather than once again explaining the common reasons underlying the assessed level of uncertainty and importance.

The penetration of electric powertrains in long-haul transports has been assessed as relatively uncertain. The reason for the higher level of uncertainty, compared to regional transports, is because long-haul transports are more demanding with regards to energy availability. Either the battery technology needs to be improved to a sufficient level, or the charging infrastructure needs to be considerably expanded. This expansion of the infrastructure could be in terms of electric roads, rapid chargers or both. Moreover, the reason for not giving this factor an even higher degree of uncertainty is that electric trucks for long-haul have already been announced to be available on the market in the near future. The most obvious example is Tesla Semi. Hence, it is reasonable to think that electric trucks for long-haul will be in operation to at least some extent by 2030.

Mi.5 - Demand for digital services

That the demand for digital services will be a central factor impacting the future truck industry has been indicated by several interviewees throughout the study. The aspects that are included in this factor are, for instance, the goods owners' will to be able to efficiently track their goods, as well as haulers and truck manufacturers ambition to more easily monitor the state of the trucks.

The main reason for the authors' assessment that the future progress of this factor is relatively certain is the general digitalization trend in the society. The digital technology has reached a level where this kind of services is possible and often expected by customers.

The level of importance has been judged to be moderate. The reason for this is that an offering of digital services will be more of an order qualifier than an order winner in the future, which makes it important for relevant actors to keep up with the development. However, since this is a trend that all actors are able to adapt to, this factor should not necessarily result in structural changes of the industry.

Mi.6 - Preservation of the ICE

The factor referred to as preservation of the ICE means that the conventional powertrain will be found in most of the long-haul trucks by the year of 2030. However, the fuel is successively expected to be substituted with more sustainable alternatives and the ICE will probably increasingly be combined with electric powertrains. As has already been discussed, the ICE may well be used in conjunction with new infrastructures for transfer of electricity as well as with fuel cells. In essence, what this factor signifies is that the ICE will most likely play an important role for long-haul trucks by 2030.

According to the absolute majority of all interviewed organizations, the ICE will be installed in the majority of all long-haul trucks by the year of 2030. This is a perception that is also shared by the authors of this report. As has already been discussed, the reasons for why a total replacement of the ICE is unlikely are numerous. For instance, the electricity in itself is not always sustainable, and hydrocarbons come with the advantage of high energy density. Furthermore, a total replacement of the ICE is a threat to already established business models, which is likely to spark resistance by incumbents. Hence, the level of certainty is considered to be highly certain.

The potential transition to a single electric powertrain is going to happen successively. Thus, the affected companies, especially the OEMs and component suppliers, will have to simultaneously offer and develop these both types of powertrains. The companies that do not successfully make this transition will suffer from a competitive disadvantage. However, the preservation of the ICE implies that the current structure of the industry will not be considerably changed because of this factor alone. Hence, the level of importance has been set to moderately important.

Mi.7 - Degree of cooperation regarding connectivity in logistics

As described in previous chapters, data sharing will be key to reach a higher efficiency in logistics in the future. However, currently there is a lack of trust between logistics operators, and several non-behavioral barriers to cooperation exist. Some examples are antitrust laws and uneven flows of goods in the country. Nevertheless, the future degree of cooperation regarding connectivity in logistics could change, which is why a factor regarding this matter has been analyzed.

Even though it makes sense for industry actors to cooperate in order to become more efficient, there are uncertainties to consider. In order to raise the level of cooperation, both behaviors in the industry as well as political attitudes need to change. Since the evolution of both of these two matters are uncertain according to most interviewees, the general level of certainty for the factor has been considered as moderate.

Increased cooperation within the logistics industry is of importance concerning a sustainable development of the industry. However, considering a potential structural change of the industry, this factor could be argued to be less important. Whether or not the industry becomes more efficient, this work for higher efficiency is expected to be driven by the current actors, which should result in minor changes if any.

Mi.8 - Need of standardization of new technologies

A factor regarding standardization of new technologies is relevant for all of the three studied technology areas, namely autonomy, connectivity and electrification. Regarding the first two areas, the factor relates to the potential need of a formal standardization in order for these technologies to develop. As for electrification, standardization of electric roads is what has been considered.

A future standardization with regards to autonomy and connectivity have been considered as unnecessary by most of the interviewed organizations. In addition, several interviewees have questioned the possibility of developing a common legislation for this kind of technology. On the other hand, the opinions regarding the need of a standardized technology for electric roads in the EU have differed. Hence, the level of certainty has been assessed to moderately uncertain.

A potential standardization of new technologies is mainly desirable from a sustainable point of view and the society at large. However, no matter if the technology has been standardized or not, the industry actors have to adapt to the future circumstances. Hence, considering potential structural changes of the industry, a standardization is of less importance.

Mi.9 - Lack of cooperation in development of AV-technology

The expressed lack of cooperation in development of AV-technology is based on the practical barriers to share sensor data, as well as the unwillingness to share this kind of data with competitors. This factor has been considered as moderately certain, but relatively unimportant.

The judgement is that cooperation within the field of AV will be limited even in the future. Like today, there could be some collaboration within research, but for commercial development most interviewees agree that different actors will develop separate solutions. Thus, the factor has been set to moderately certain.

As already discussed, the application of sensors needs to be adapted for each type and model of trucks. As a result, there is little to be gained on a potentially increased collaboration. Hence, the importance of this factor has been considered as most unimportant.

5.2 Illustration of ranked factors

The analysis of the data that was collected during the orientational interviews resulted in 18 factors, divided equally between the macro- and micro environments. The illustration of these factors consists of three different figures. The first two figures are structured lists, where the names as well as the corresponding classifications of the macro- and micro-factors are presented. In these lists, the factors have been ordered according to their perceived level of importance. Hence, the most important factors will be found at the top of the lists. In addition, the identified factors are visualized in the last figure as a coordinate system, representing the procedure used with post-it notes and a whiteboard.

The two lists will be found in table 6 and 7, while the coordinate system is presented in figure 4 below.

Macro-factors			
Code	***Description***	***Certainty***	***Importance***
Ma.1	Sufficiently secure data management	-4	5
Ma.2	Societal engagement for sustainable transports	5	5
Ma.3	Entrance of new players	1	4
Ma.4	Maturing of sustainable technologies	4	4
Ma.5	Convergence of transport- and digital industries	3	3
Ma.6	Influence from bus- and automotive industry	3	2
Ma.7	Influence from EU	2	2
Ma.8	Growing demand of transports	2	-1
Ma.9	Sustainable and smart cities	3	-2

Table 6. Identified macro-factors and corresponding classification

Micro-factors			
Code	***Description***	***Certainty***	***Importance***
Mi.1	Viability of electricity as substitute for hydrocarbons	-5	5
Mi.2	Time until commercialized high level AV-technology	-4	4
Mi.3	Penetration of electric powertrains in regional transports	-1	3
Mi.4	Penetration of electric powertrains in long-haul transports	-3	3
Mi.5	Demand for digital services	4	3
Mi.6	Preservation of the ICE	5	2
Mi.7	Degree of cooperation regarding connectivity in logistics	-2	-1
Mi.8	Need of standardization of new technologies	-3	-2
Mi.9	Lack of cooperation in development of AV-technology	2	-4

Table 7. Identified micro-factors and corresponding classification

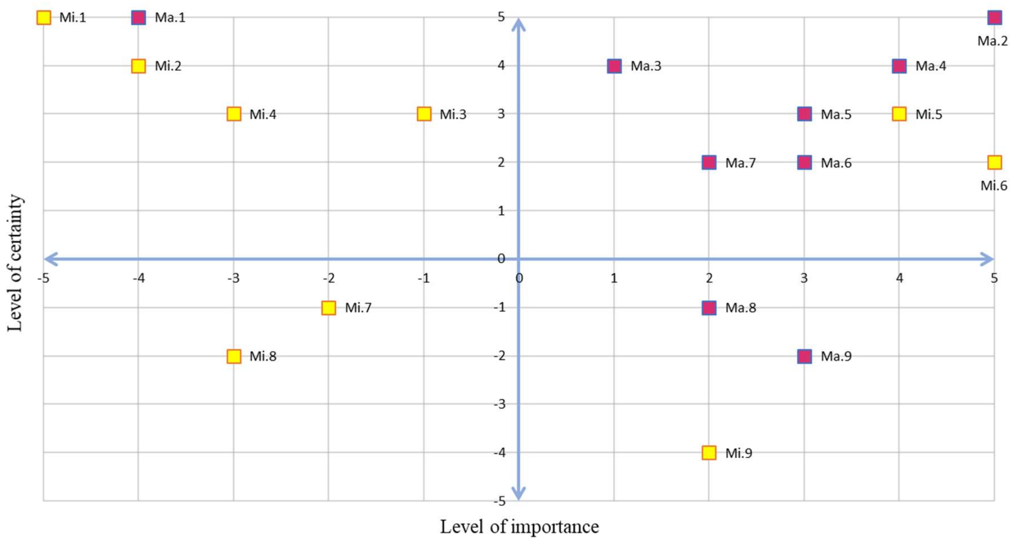

Figure 4. Visualization of identified factors

6. Development of scenarios

This chapter presents basic trends and key uncertainties, that together make the basis for four scenarios. The basic trends were created from combining important and certain factors, and give an overview of general directions in which the industry is likely to develop until 2030. The key uncertainties were created from selecting and combining important and uncertain factors, and presents the two uncertain areas that will be impactful for the future of the industry. The chapter concludes with the developed scenarios being presented.

The procedure for how the four different scenarios have been created has been visualized in figure 5 below. What should be understood by this visualization is that the basic trends are recurring for each scenario, while the key uncertainties constitute the axes of the coordinate system. Hence, the basic trends should be regarded as a common base for all scenarios, while different progress levels of the key uncertainties are the reason for why the scenarios differ from each other.

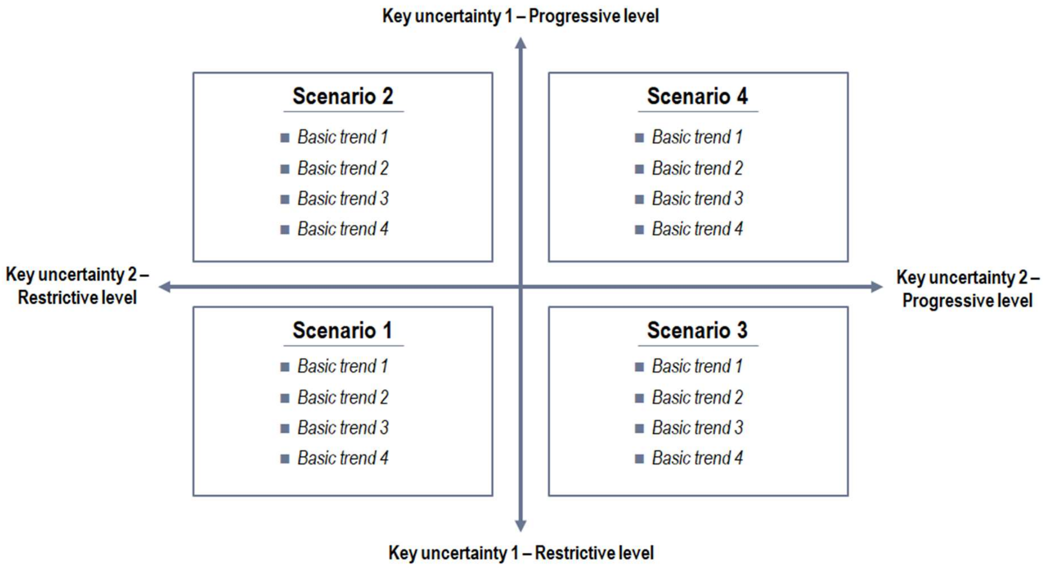

Figure 5. Visualization of the construction of scenarios

6.1 Clustering and presentation of basic trends

The eight certain and important factors identified during the interviews, have been combined into four basic trends expected to affect the industry until the year 2030. These general areas of development have, based on interview responses, been evaluated as certain enough, that they will affect the industry in all likely future scenarios. These trends will lay the foundation for the scenarios and the technology diffusion of autonomy, connectivity and electrification.

Trend 1: Digitalization of transports
The amount of data that newly sold trucks generate is already high today, and is expected to increase even further in the future. More importantly for the industry, the ability of different actors in the value chain to process this data into valuable information will increase. The competition regarding ownership of data will intensify, as data will constitute a significant revenue source and a prerequisite for conducting efficient business in the industry by 2030. As trucks become increasingly digitized, more and more companies with background in the ICT industry will try to expand into the commercial vehicle industry to utilize their short innovation cycles to provide connectivity services. It is up to the current industry incumbents to quickly develop the skill of working in the digital sphere and utilize available data. In the coming years, connectivity services will be seen as a premium product, but approaching 2030 the most relevant connectivity services will be standardized, and will thereby not be a source of competitive advantage.

Trend 2: Maturing of green technologies
With an increasing pressure to solve global warming, renewable sources of energy, such as solar- and wind energy, will make a great leap the coming years, both in terms of global investments and productivity of the technologies. The trend of quickly growing countries, such as China, investing in renewable energy sources as a way to solve pollution and be competitive in the future, will continue. The recent growth in electrification of the car and bus industries will spur electrification ventures in the truck industry. A growing acceptance for electric trucks will lower the barriers of entry to become a truck producer, since the electric powertrain is simpler. With increased taxation on non-renewable energy sources and increased supply of renewable energy sources, more and more application areas will reach a point where the renewable sources of energy break even with the non-renewable energy sources. Once investments in renewable energy sources are the best option from an economic and environmental perspective, development is likely to increase sharply. This will incentivize even further research and industrial investments into energy carriers such as batteries, leading to capacity improvement and falling prices. This will spur adoption of battery technology in several industries.

Trend 3: Increased political sustainability efforts
The seriousness of earth's environmental challenges is a top political priority of most developed nations. The agreed upon contributions from nations to combat climate change by the Paris Agreement will stimulate the development of new technologies and redirect financial flows to answer the environmental challenge. The global climate goals defined in Agenda 2030 have allowed countries to build a frame of reference for how to achieve a sustainable environment, and will increase the will from politicians to promote sustainable industries, including transport. With increased attention and pressure globally to create a sustainable society, the Swedish government is not expected to yield on their commitment to the sustainability goals for 2030 and 2045. In the years approaching 2030, this commitment will result in higher taxation of incompatible incumbent technologies, and subsidizations and funding for new technologies in order to reach the goal.

Trend 4: Continued survival of the ICE

Trucks are business assets which require large investments from companies in the transport industry. Furthermore, the society at large is accustomed to the fact that trucks have undergone few changes in design and type of fuel usage during several decades. The energy supply infrastructure network is designed primarily for trucks with an internal combustion engine running on diesel. For a new type of powertrain or energy carrier to outcompete the ICE-trucks, it has to outperform the current ICE-trucks to such a degree, that it becomes worthwhile to build a new energy supply infrastructure, and other restructurings in society, such as repair and service networks. The transition is easier if the new powertrain and energy carrier can utilize existing infrastructure, and if it implies just a minor change of behavior, which is the case with biofuels. Reaching the climate goals requires immediate action, and utilizing biofuels is an easily accessed way to reduce the climate impact from transports. By utilizing drop-in fuels, biofuels can be phased in at a controlled pace, which will make the adoption even less of a disruption. Biofuels are seen as a way to make heavy-duty long-haul trucks environmentally sustainable while retaining a long maximum driving range, and lock-in effects from existing infrastructure is likely to keep the internal combustion engine relevant also by 2030. However, with this said, it is not sure that the ICE will be as dominating as it is today. What is sure is that the ICE will survive and account for a considerable use in heavy-duty truck transports, not that it will be the only valid powertrain powering these kinds of trucks.

6.2 Clustering and presentation of key uncertainties

Based on the five uncertain but important factors, two key uncertainties were derived. The first key uncertainty relates to the political climate in Sweden and in related international contexts in terms of how vehicle- and transport related data is allowed to be used. This key uncertainty is a combination of the factors Ma. 1 (Sufficiently secure data management), and Mi.2 (Time until commercialized high level AV-technology). The logic behind this clustering, is that both factors will shape the political opinion regarding the viability of autonomous and connected trucks, and how the data that they generate is allowed to be used. The second key uncertainty relates to which fuel that will be dominantly used in the heavy-duty truck industry by 2030. This key uncertainty is a combination of the three factors Mi.1 (Viability of electricity as substitute for hydrocarbons), Mi.3 (Penetration of electric powertrains in regional transports) and Mi.4 (Penetration of electric powertrains in long-haul transports). The logic behind this combination is that Mi.1 represents the technological progress for battery and sustainable energy technology, while Mi.3 and Mi.4 captures the behavioral aspects of incumbents and new entrants, in their attempt to push new product to the market. Together, the factors are assumed to capture the core deciding factors for which fuel source will become dominant.

The development of both of these two key uncertainties are expected to have considerable impacts on the future heavy-duty truck industry. In what follows, a detailed description of each key uncertainty is given.

Uncertainty 1: Political approach to data utilization

Vehicle- and transport related data has, as previously mentioned, the potential to increase efficiency and to create new revenue streams for all actors in the value chain. The term that is used to reflect a restrictive political approach to data utilization is conservative, while the term liberal is used to describe a progressive political approach to data utilization. This uncertainty mainly relates to the development of connectivity and autonomy, which will be explained in the next two paragraphs.

For the future development of connectivity, interviewees singled out personal integrity and data security as the core issues, as connectivity gives companies access to potentially sensitive data about the driver and the surroundings of the vehicle. It is believed that the outcome of public perception of personal integrity and privacy, will shape the political approach to data utilization.

When discussing automation, interviewees singled out cybersecurity as the core issue relating to data. Data relates to cybersecurity in terms of being needed to validate the traffic safety of the autonomous vehicle technology, and to operate autonomous vehicles in hostile environments. Although many of the autonomous driving functions of such a vehicle will not rely on real-time data, most AV concepts are based on being continuously fed with data with updated map information, and some are based on remote driving. The sheer amount of data needed to statistically prove that an autonomous truck is as safe as if operated by a human driver, was during interviews deemed as difficult to attain. Many interviewees stated that public concern regarding potential terrorism involving remotely controlled vehicles will make the public skeptical towards autonomous vehicles. Conclusively, given the fact that it is hard to prove a sufficient robustness of AV technology in terms of cybersecurity, a fast deployment of the technology will be reliant on the willingness of politicians to allow for complex demonstrations, and to propose progressive legislation. The willingness to do so has been assessed as highly volatile, since this will depend on the public opinions towards autonomy during the years to come.

Uncertainty 2: Industry perspective on dominant future fuel

The opinions regarding how to best reach the goal of a fossil-independent vehicle fleet in Sweden by 2030 were fragmented among the interviewees. Some were in favor of electricity as fuel, while others promoted biofuels, natural gas or other fossil-independent fuel sources. Electricity and alternative fuels for the ICE come with different benefits and drawbacks, and the future diffusion of these are highly dependent on political decisions impacting the competitiveness of the different fuel sources.

Many interviewees believed that even if biofuels would be the dominant fuel by 2030, eventually the transport industry would turn to electricity as the main source of fuel. However, there are several uncertain aspects determining whether electricity, and the electric powertrain, would become a successful substitution to the alternative fuels for the ICE in the future. Some of the most important uncertainties are the supply of high-performing low-cost batteries, the construction and financing of electric roads or static charging infrastructures and a sufficient production of sustainable electricity.

Therefore, the industry perspective on the dominant future fuel from 2030 and forward was singled out as the key uncertainty, in order to reflect the importance of incumbents' and new actors' willingness to invest and commit to the different technologies. The industry perspective not only reflects what fuel is used by vehicles at the time, but also for which fuel the industry is moving towards. The high end of the key uncertainty is defined by electricity being regarded as the dominant fuel in the industry. The low end of the key uncertainty is defined by fossil-independent fuels other than electricity being considered the future fuel, such as biofuels and other fuels currently being researched.

6.3 Scenario descriptions

By combining the aspects of political approach to data utilization and industry consideration regarding dominant fuel, four scenarios for the Swedish heavy-duty truck industry were created. These four scenarios have been named “Locked-in potential”, “Offline powerline”, “Autonomous combustion” and “Force Unleashed”. For a visualization of the scenarios, see figure 6.

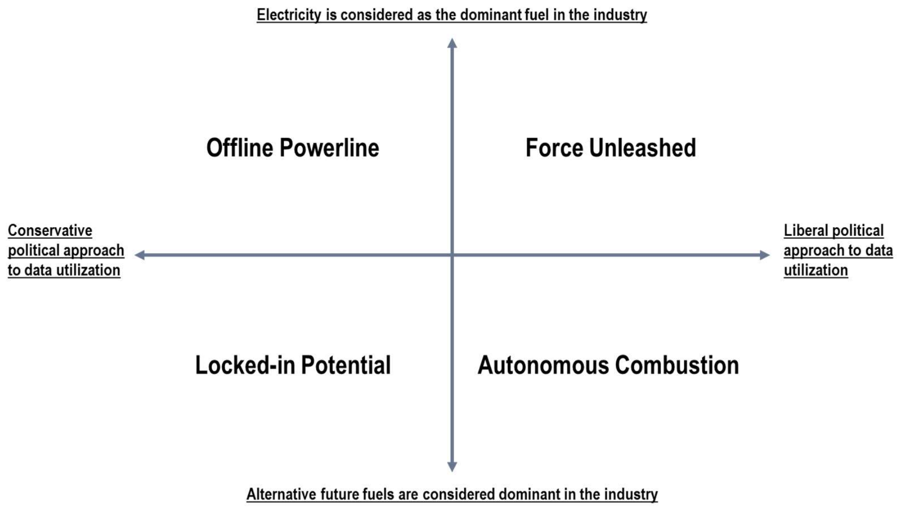

Figure 6. The four scenarios developed based on identified key uncertainties

Locked-in Potential is a scenario reflecting an industry where the political approach to data utilization is conservative, and alternative fuels other than electricity is considered the dominant fuel in the industry. Offline Powerline is a scenario consisting of a conservative political approach to data utilization, but with electricity being considered the dominant fuel in the industry. Autonomous Combustion constitutes a liberal political approach to data utilization, and alternative fuels other than electricity being considered dominant fuels in the industry. Finally, Force Unleashed is derived from a liberal political approach to data utilization, and electricity being considered the dominant future fuel.

Each scenario will be presented by a snapshot of the industry at the year 2030, by providing the answer to the following questions:

- *What AV level will be commercially available?*
- *How are different AV levels utilized?*
- *To what extent will data be gathered?*

- *How will data be utilized commercially?*
- *What mix of powertrains is sold?*
- *What mix of fuels is used?*

This snapshot aims to clarify what the scenario would mean in terms of progress of autonomy, connectivity and electrification by 2030. However, for the scenarios where the high or low version of a key uncertainty already has been explained, only a brief summary of that uncertainty will be given.

In addition, in order to provide an idea of how the development until 2030 could look like, a storyline will be presented for each scenario. The storyline represents one of many possible paths of progression for reaching the defined scenario by 2030, but are provided in order to facilitate the understanding of the future development and the plausibility of the scenario.

6.3.1 Locked-in Potential

Locked-in Potential reflects an industry environment where the technology for high level autonomous vehicles exist and connectivity could be used for more efficient collaboration and new services, but restrictions concerning data utilization prevent the technologies from reaching their potential. In terms of fuel, tough taxation of fossil-fuel and a skepticism towards electrification of heavy-duty trucks in Sweden, and the rest of Europe, have resulted in a quick adoption of biofuels. The concerned scenario has been visualized in figure 7.

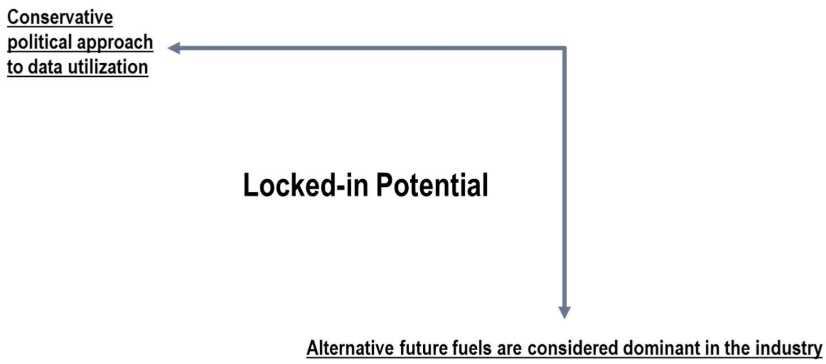

Figure 7. Scenario: Locked-in Potential

Level 2 AVs (Partial Automation) are allowed on public roads and is a technology implemented by almost all newly sold trucks on the market. The result is an overall increase in job satisfaction for the professional truck drivers, as less effort has to be expended when the need to manually perform the tasks of steering, accelerating and decelerating is reduced. With a firmer standing on skepticism towards autonomous vehicles in public traffic, more people see trucking as a future industry for employment. As a result, the acute lack of drivers in the industry is relieved for regional transports, while the recruitment problems for long-haul transport remains. In restricted areas, such as cargo harbors or mines, companies can, with special permission, be allowed to operate remotely controlled level 4 (High Automation) AVs.

Vehicle- and transport related data is mainly used for effective route planning and internal operations. Rigid and restrictive legislation regarding data utilization, with the purpose of mitigating potential data-related security threats, inhibit actors in the value chain from utilizing captured data as a revenue source or as a collaborative resource. The public considers data-exchange and connected vehicles as a threat. Since no driverless vehicles operate on public roads, the market for connectivity services focuses on enhancing the driver experience, and to support the driver.

Biofuels and alternative drop-in fuels are the main source of propulsion for heavy-duty trucks. Natural gas is increasingly utilized in the rest of Europe as a substitute for fossil diesel. Most long-haul transports utilize the ICE as the only powertrain, but in urban areas electric hybrids are becoming the standard for heavy-duty trucks, as most cities have placed strict regulations on local particle emissions

Storyline

Political policy regarding freedom of data utilization turns conservative, restricting OEMs from monetizing on gathered data. The need of AV technology is being questioned, due to the value that a driver provides other than simply the driving function. A legislation for AVs is delayed due to ongoing debates regarding data security. Until further notice, AV level 4 is just allowed in restricted areas. Thus, OEMs are focusing on developing high-end driver assistance, while waiting for AV legislation to allow level 4 on public roads.

New entrants offering BEVs are trying to penetrate the market of regional transports, but find it hard to live up to customer expectations due to short maximum range and high truck weight. Due to public skepticism towards electrified trucks, few goods owners and freight forwarders consider investing in solutions for charging BEV trucks during loading and unloading, as the technology is not considered to be extensively used in the future. As a countermeasure to the aggressive entrance of new BEV-focused OEMs, incumbent OEMs speed up development and commercialization of trucks utilizing biogas, and invest heavily into performance improvements for the ICE. With a wide range of developed biofuels, compatible trucks and a political pressure to reach the climate goals, the EU decides to promote the use of biofuels and to hold back on restricting certain sources of biomass for biofuel production. With more lenient European regulations, Sweden specializes in producing biofuels from forest products.

6.3.2 Offline Powerline

Offline Powerline reflects an industry environment where restrictions on data utilization inhibits the commercialization of high level AV and connectivity services, and electric roads have been implemented on several highly trafficked highways, with more plans in place for expansion for the years following 2030. The concerned scenario has been visualized in figure 8.

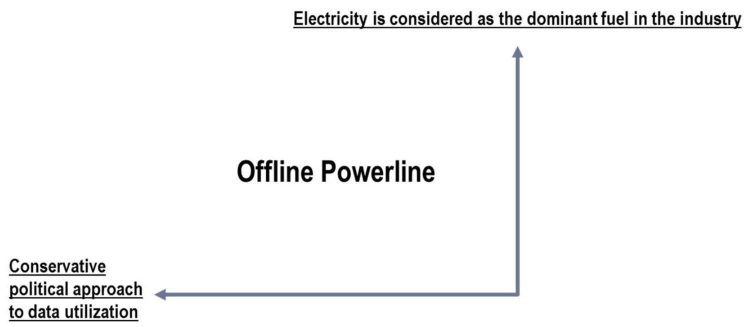

Figure 8. Scenario: Offline Powerline

Similarly, to the previous scenario, level 2 AVs (Partial Automation) is allowed on public roads, and level 4 AVs (High Automation) are allowed in restricted areas. Vehicle data is used for route planning and internal efficiency of operations.

The electric engine is increasingly used as the main powertrain for long-haul trucks. Electric road technology has been identified as the way to reach a sustainable transport industry in the long term, and the government supports the expansion of the electric road network. Electric roads are already implemented on major transport highways in Sweden, with plans in place for further expansion. For trucks that have the need to diverge from the electric roads frequently, hybrid powertrains with the ICE as range extender are favored, powered by biofuels.

Storyline

In the beginning of the 2020s the future for AVs seems optimistic. Progressive Swedish legislation make Sweden one of the first European countries to accommodate pioneering companies offering level 4 AV transports on public roads. However, during unclear circumstances, a serious accident occurs. An autonomous truck traveling on European Route E20 during highly trafficked Friday rush hours make an uncontrolled turn into another lane, colliding with several other vehicles, creating a pile up and several persons are injured. The accident gets major international media attention, as suspicions rise as to whether or not the crash was due to a programming error, or if it was a planned terror attack. The issue gives rise to debates in the EU regarding the security issue of remotely controlled trucks, eventually leading to a level 4 AV ban in the EU.

To cope with polluted city air, China continues the development of solar energy investments. China and neighboring countries ramp up BEV production, and start pushing BEV trucks on the domestic and the international market. The Asian offerings attempt to penetrate urban and regional distribution through LCV (Light Commercial Vehicle) and MCV (Medium Commercial Vehicle) offerings. More and more studies prove biofuels to be an inferior source of fuel to electricity when evaluated by the Agenda 2030 sustainability framework. The best case in terms of pollution reduction is concluded to be electric roads, and the related investments in infrastructure become a priority on a governmental level. Other movements towards electrifying roads for goods transport in the Northern part of the European transport network makes it possible for RPEVs in Sweden to drive internationally, and for international vehicles to drive in Sweden.

6.3.3 Autonomous Combustion

Autonomous Combustion reflects an industry environment where the societal acceptance of AVs is high, and there are policies and a legal framework in place to allow for level 4 and 5 AVs on public roads. Biofuels have become the dominant fuel in the industry for heavy trucks in regional and long-haul transport, and combined with the efficiency-increasing potential of AVs Sweden reaches the emission goals by 2030. The concerned scenario has been visualized in figure 9.

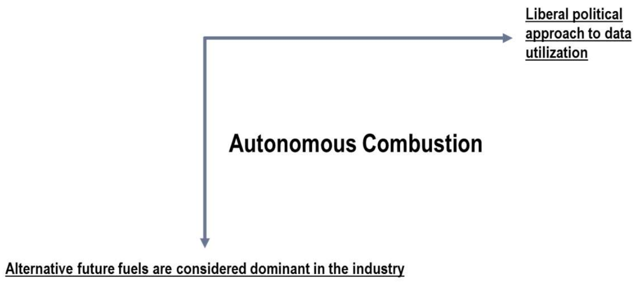

Figure 9. Scenario: Autonomous Combustion

Level 4 (High Automation) autonomous trucks with the possibility of remote control are commonplace on public roads, and tests with level 5 (Full Automation) are carried out frequently with positive results. The incorporation of AVs in logistics improve the profits while at the same time driving down the price of transport, and increasing the total amount of goods transported. Data sharing and coordinated loading between companies in the logistics system become more accepted and less of an anti-competitive issue, due to government promotions of an efficient transport environment. The whole truck industry and adjacent stakeholder become reliant to high-quality real-time data to operate their businesses, and the vehicle-generated data become a core asset to many businesses.

The ICE remains the main powertrain, powered by biofuels. Due to the complexity in certifying and producing an Internal Combustion Engine, and the fact that electric trucks didn’t become popular, completely new OEM competitors are few. New OEMs mostly compete on urban transport solutions, or on limited transport stretches, where they can operate BEVs and themselves support a charging infrastructure. Due to increases restrictions regarding local emissions in urban areas, most newly sold trucks are fit with a hybrid electric powertrain, while long-haul trucks tend to stick with the ICE as the only powertrain.

Storyline

In order to solve problems with cabotage and congestion, the EU starts to enforce sharing of localization from trucks over 3,5 tones operating within the border of the European Union. The location data is sent to an EU-operated connectivity platform, so that data-based intelligent transport systems can ease congestion problems, and that cabotage rules more easily can be governed. In an attempt to further digitalize and modernize the transport industry, the EU pushes for the introduction of AV lanes on main highways in the northern European road network. This creates a rapid growth in the level 4 AV (High Automation) segment. As a result of the increases demand of data sharing, follows a more liberal approach to data utilization. Thus, companies start to unlock the revenue potential that vehicle-data brings.

An aggressive taxation of fossil fuels on a national level, and from nearby countries, drive a high demand for alternative fuels. With the import of renewable fuels in Sweden already being high, the government makes large investments in biofuel production, in order to ensure biofuel supply for the coming years.

6.3.4 Force Unleashed

Force Unleashed reflects an industry environment where the power of automation, connectivity and electrification have come together to shape the transport industry. Level 4 (High Automation) AVs are commonplace on public roads and level 5 (Full Automation) are progressively implemented in progressively more complex areas. BEVs is outcompeting traditional ICE trucks on long-haul transport. The concerned scenario has been visualized in figure 10.

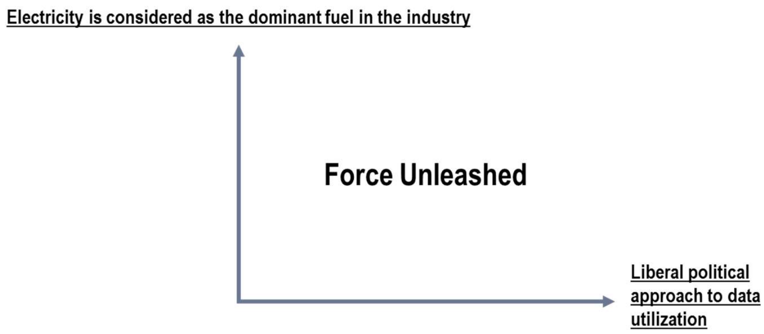

Figure 10. Scenario: Force Unleashed

With level 4 and 5 autonomous vehicles commercially available, the occupation as a professional driver for long-haul and regional transport is decreasing year by year, only held back by the organizational inertia in companies and the logistics system. The transport system becomes increasingly dependent on high-speed real time data.

With the removal of the driver, suddenly the industry experiences a large overcapacity of trucks, as the existing ones can drive both day and night in a cost-efficient manner. Due to the overcapacity, there would be only marginal benefit of building out a widespread electric road network. Instead, static charging becomes the industry standard for heavy-duty BEV trucks.

Storyline

Aggressive establishment of IT-based entrants in the commercial vehicle industry drive quick development of level 4 and 5 (High and Full Automation) autonomous vehicles. Removal of the driver and connected vehicles open up for OEMs to offer capacity as a service. Customers demand interoperability between trucks from different brands, creating a need for a market-standard data sharing platform.

Tesla Semi and other newcomers on the heavy commercial vehicle market surprise the incumbents with potent BEV trucks, and haulers' and buyers' perception of BEV trucks change into being more positive. Investors become increasingly willing to finance static charging networks for BEV trucks, as it is seen as the inevitable future technology. ICEs are mostly sold in new trucks as a range extender for long-haul trucks, driving in areas or countries where the charging infrastructure is underdeveloped. Falling battery prices eventually give BEVs a cheaper TCO than conventional alternatives on regional transports. Approaching 2030, pure ICE trucks still operate in majority on long-haul routes, but are increasingly challenged by autonomous BEV trucks, due to an expanding charge infrastructure.

7. Implications for industry dynamics and value chain structure

This chapter serves the purpose to reflect the findings from the nine interviews conducted with actors being part of the industry value chain. The intention with these interviews was to get a better understanding of how the industry dynamics and the structure of the value chain is expected to change for each developed scenario, which is in line with the second of the two research questions. The chapter has been divided into six subchapters.

In the first four of these subchapters, the findings with regards to the four extremes of the key uncertainties are presented. Thus, these subchapters include how the industry is expected to be affected depending on a conservative or liberal political approach to data utilization and whether electricity or alternative fuels would become dominant in the future. The reason for structuring these findings according to the extremes of the key uncertainties, and not by the scenarios themselves, is to avoid redundancy. The vast majority of the expected implications on the industry dynamics and value chain were shared by at least two different scenarios, and usually these scenarios shared one of the four extremes of the key uncertainties. Figures 11-14 below serve as visualizations for the concerned scenarios, with regards to the specific extremes of the key uncertainties.

However, in the fifth subchapter, the implications for the specific scenario of Force Unleashed is presented. The reason for including a separate subchapter for this specific scenario is that additional implications were expected to take place if a liberal political approach to data utilization was combined with a situation where electricity would become the dominant fuel. Figure 15 serves as visualization of the concerned scenario.

Finally, the sixth subchapter summarizes the expected implications presented in the previous subchapters by visualizing possible new value chains for the four different scenarios, and how these value chain structures are expected to impact the industry dynamics.

In general, the interviewees tended not to see any major impacts on the current value chain and the industry dynamics if the political approach to data utilization was to become conservative, or if alternative fuels other than electricity were to become the dominant fuel. On the other hand, interviewees saw the potential for several implications for the industry if the political approach to data utilization was to become liberal, and if electricity was to become the dominant fuel.

7.1 Conservative political approach to data utilization

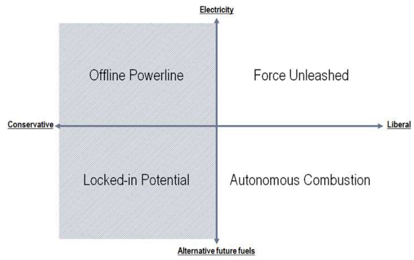

Figure 11. Illustration of concerned scenarios: Offline Powerline and Locked-in Potential

General impacts on the industry
Even with a conservative approach to data utilization, the industry is still expected to become more experienced and efficient in the utilization of data, according to a component supplier. It is impossible to stop the technological evolution, the interviewee continued. Maturity of connectivity technology will make the logistics system more efficient as a whole, according to an OEM. The growth in E-commerce will undoubtedly lead to more hub and spoke transports and increased need for consolidation of goods, the interviewee further stated.

Impact on component suppliers
Component suppliers are not expected to be impacted much, according all interviewees. One OEM mentioned that it is likely that we will see component suppliers transitioning into system suppliers, by instead of delivering complete modules instead of single components.

Impact on OEMs
OEMs will likely sell similar products as today, if they are restricted in terms of data usage, and instead try to innovate their offering by selling service contracts and guaranteeing uptime, according to an OEM. This is a trend that is seen already today, according to the interviewee.

Impact on haulers
Haulers are expected to fill the same function as today with a low data utilization, according to a freight forwarder. The freight forwarders are completely dependent on the haulers, as they only utilize their own vehicle fleet when an external hauler unexpectedly cannot fulfill a route, or in rural areas of Sweden where it is difficult to find drivers, according to the interviewee. The local haulers are said to possess local knowledge that the freight forwarder does not have, making them extra valuable.

Impact on freight forwarders
All interviewees agreed that freight forwarders would likely be able to continue their operation as usual in this case.

7.2 Liberal political approach to data utilization

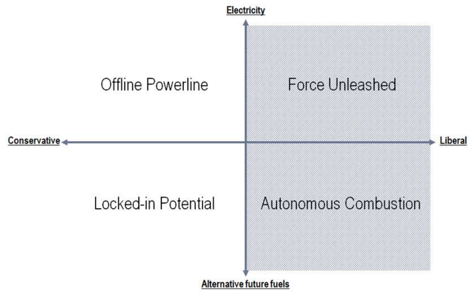

Figure 12. Illustration of concerned scenarios: Force Unleashed and Autonomous Combustion

General impacts on the industry
All interviewees agreed that a liberal political approach to data utilization will have a large impact on the industry as a whole.

The flow of goods and the traffic system as a whole will likely improve in terms of efficiency, according to a component supplier. With a liberal approach we are likely to see a more transparent and open market for transportation, similar to the development in the taxi industry, according to a component supplier. The component supplier envisioned a pool of circulating autonomous trucks trafficking different regions, with the possibility for automated swapping of trailers with trucks in pools of adjacent regions.

Many opinions regarded where it is feasible to implement autonomous vehicles. Consensus regarding autonomous trucks were that we will see an automation of terminal to terminal transports first, or in situations where the route, loading and unloading are standardized and simple. Transports to the end storage of end customers will likely require drivers by 2030, according to a freight forwarder, since the customer service that the driver provides in this case is critical. Regional distribution with several points of unloading can feasibly be automated, but it either takes smart unloading technology or that the customer takes increased responsibility of unloading.

One interviewed hauler had evaluated that only about 20% of their drivers could be removed if AVs were available on the market, given that the vehicle still would be unable to load and unload goods independently. The given reason, was that only a small proportion of their transports run terminal to terminal in a standardized fashion. On the other hand, the industry could very well see a strong growth in hub and spoke systems, if it suddenly became very cheap to operate terminal to terminal transports. Other transports are often less predictable and harder to automate according to the interviewee. For example, when delivering goods to building sites, these are often located in remote areas and are generally hard to access due to their temporary nature. This would make it hard to make use of automated unloading at these sites, due to the complexity and variance. Another hauler adds that the driver also tends to work with the transported goods in these cases, by performing related task such as stocking goods. Another example, mentioned by one of the haulers, was that the driver would deliver soil, and then shovel it into a flower bed. Another hauler stated that even if some routes are hard to automate all the way from departure to arrival, it should be possible to automate parts of the route.

Due to an increasing maturity in the industry relating to data utilization, many interviewees pointed out that this will likely change how transports are consumed. One component supplier stated that with liberal data utilization laws, and thereby more freedom in gathering data about the vehicle, it will be easier to ensure uptime. Therefore, the interviewee believed that it will be easier for OEMs to provide transport as a service, in the sense that the truck customer would pay per usage of the truck, or for transport capacity, or simply for uptime. One OEM stated that this is already under development today, but that selling trucks as a service still only constitutes a small fragment of the business in total.

Another implication from a liberal data utilization approach on consumption of transport is, according to the interviewee at AEOLIX, a strong growth of open transport markets, such as freight exchanges. This new way of operating in the transport industry would come with several challenges according to the interviewee. One of these challenges are that the involved actors will have to get used to short term business relationships. This puts increased demand on handling trust between buyer and seller. This is a problem solvable by utilizing a user-run rating system, which is common in other industries, according to a freight forwarder. Furthermore, haulers must trust that the freight exchanges can provide enough business opportunities to be worthwhile using, which is not the case today, according to a hauler. The freight exchange must also come with an easily accessible digital interface, without the need for large investments by the actors, if a large-scale adoption is to be seen.

The dynamics of competitiveness and industry growth were another area frequently discussed when faced with high automation. One component supplier stated that the financials of haulers are characterized by trying to lower salary costs by utilizing foreign workers with lower salaries. However, even if foreign drivers demand less salary, the vehicles are capital intensive and the capital could be utilized better. With the introduction of AV, enormous productivity gains can be made, since you feasibly could increase the current limit of approximately ten hours driven per day to approximately 22 hours. Then suddenly, long-haul trucks would approximately double their possible traveled distance in a day, and trucks could start to compete with the airline industry for some orders, where time is of importance. Furthermore, through connectivity the customer would get a better prediction of when the goods will arrive, enabling them to make their operation more efficient. In user cases where level 5 automation is possible, and the vehicle can be redesigned to remove the cabin, more of the weight and volume of the vehicle can be utilized for goods, increasing the efficiency of the transport. The interviewee concluded that automation and connectivity is likely to create growth in the road transport industry.

Impact on component suppliers

For component suppliers it will become increasingly important to connect and gather data from the delivered components, according to one component supplier. Connecting their components will be important for learning more about their own products in use, and from a maintenance perspective. With increased automation, the interviewee also argued that some categories of components will increase in importance while other are likely to decrease. Components related to driver safety and increased driving experience will be eliminated from high level AV trucks, while the importance of technological components for increasing data gathering and processing will increase.

Impact on OEMs

OEMs will experience several changes to their current value creation based on the changes that a liberal political data utilization approach would bring, in terms of sold trucks and profitability. One component supplier estimated that even if automation would lead to cheaper transport and enhance growth in transport demand, the potentially doubled uptime of autonomous trucks will ultimately lead to fewer trucks sold. However, an interviewed hauler stated that the perceived possible increase of uptime might be overestimated in the case of terminal to terminal distribution, since they already drive their trucks both during day and night, by utilizing several drivers. The sales price of the truck is likely to increase according to an OEM, due to the implementation of AV-enabling technologies. But one component suppliers stated that it is likely that by 2030, this new high-tech hardware will be cheap enough, that the total value of the software of a truck might outweigh the cost of the hardware.

The reduced reliance on professional drivers is likely to bring several other implications for the business of OEMs. An OEM states that in trucks designed to be driverless, they can't charge a premium for a high quality cabin. Furthermore, one component supplier speculated regarding that the branding of trucks will be less important, as they no longer will be an influencer when making truck purchases. Even if truck purchases are already primarily economic investments, the interviewee argues that what was left of the brand preference will dissipate and investors will instead value uptime and transport efficiency even further. Many interviewees envisioned that with level 4 and 5 AVs on public roads, we will see a consolidation of small-scale haulers into bigger fleet managers, who will be able to negotiate a lower price when purchasing large quantities of trucks, reducing the profit margin of OEMs.

The service network of OEMs will likely change according to a component supplier. Increased connectivity will enable them to work more effectively by predicting maintenance, which could be used to reduce costs from maintaining a lower storage of spare parts, and to increase customer service from having more vehicle knowledge. But they also will have the role of servicing and ensuring the traffic safety of the AV systems, which will make their job more difficult. Another component supplier stated that the higher uptime of trucks will lead to increased wear, and therefore more frequent need for service.

OEMs could gain new revenue sources by forwardly integrating towards haulers and freight forwarders according to several interviewees, enabled by connectivity and autonomy. As more and more trucks on public roads become autonomous, one freight forwarder believed that the OEMs will assume the role of current haulers, and sell transports directly to freight forwarders. The interviewee commented that previously, OEMs have focused only on the vehicle itself, but recently have opened their eyes for selling transports as well. A component supplier stated that this new way of conducting business would require OEMs to own the trucks themselves, and instead of selling products, selling transports to the freight forwarders. Another freight forwarder stated that due to the technical know-how of the vehicles, it would make sense that the OEMs own the trucks, and that the trucks are part of a fully autonomous logistics system.

That OEMs own the trucks for certain operations is nothing new, as many trucks are already assets of OEMs today. According to an interviewed OEM, they lease out trucks to haulers, a deal that includes a service contract. Leasing is preferred by many of the haulers, as it reduces the volatility of their costs, and that they do not have to worry about services or other uncertainties related to the truck. One inquired OEM said that they currently had no strategy of becoming a hauler, but that they saw that the hauler function likely will be disrupted in some way.

OEMs have the potential to also venture into activities currently performed by freight forwarders. One interviewed OEM stated that they are interested of increasing their knowledge about transports, and ultimately generate income from selling transport insight.

One freight hauler stated that OEM's venturing into freight forwarding will be hampered by their lack of a widespread distribution network and customer contact, but that they are likely to try to build this kind of network and to gain competence in transport-related services. One OEM saw it as likely that OEMs and freight forwarders are going to collaborate more in the future. This could be the case since it would then be possible to combine the vehicle data, currently owned by the OEMs, and the goods data, currently owned by the freight forwarders, in order to create better tracking services for customers. One interviewed freight forwarder was worried that such services could give the OEMs too much access to the end consumer of the transport, which in the long run could lead to OEMs circumventing freight forwarders. For example, one OEM stated that it is possible that they would be interested in goods-related data in the future, such as value of goods transported and the space and weight utilization of the truck. The interviewee speculated that the transfer of this data from freight forwarders to OEMs will be reliant on the political approach to data utilizations, and on the existence of transaction models for data between the OEM and the freight forwarder. The ownership of customer data is something that freight forwarders believe puts them in a control position, and they are likely to be restrictive with sharing this information with OEMs. Furthermore, their position is also secured by having well established insurance solutions and toll solutions in place for the goods, according to a freight forwarder.

Impact on haulers

Haulers are the actor in the value chain that will face the most risk of being disrupted with increased automation, according to an interviewed OEM. In the short term, replacing human drivers with autonomous trucks would likely be good for haulers according to all interviewed freight forwarders, as the haulage industry currently struggles with finding drivers. One interviewed hauler indicated, that the hauler function could become redundant once trucks are automated and the goods is connected. An OEM stated that as long as the data is freely transferable, the whole industry can become more profitable by replacing many functions performed by haulers with artificial intelligence. The interviewee stated that a large part of the value provided by haulers today is coordinating drivers and plan transports, which could be unnecessary or automated in the future. In addition, coordination of the vehicles could be centralized and performed on a large scale from a control tower.

Professional drivers being completely replaced by autonomous vehicles was deemed unlikely by most interviewees. But given the prospect that the industry by 2030 would have high level

AVs with advanced loading or unloading function, and the logistics flow being adjusted to account for autonomous trucks, many interviewees found it possible that the hauler function might disappear from the value chain. More likely according to the interviewees, would be terminal to terminal and parts of long-haul transports being automated by 2030, but that local and last-mile transports performed by haulers would remain. One hauler stressed that we currently see a strong trend of transport customers wanting to take less responsibility for loading and unloading, which makes it unlikely that they would want to take increased responsibility for handling goods even at a price discount. Another hauler was of the opposite opinion, and saw it very possible that transport customers would be willing to load and unload goods to a larger degree in the future. One OEM that was humble for the complexity of automating loading and unloading, speculated that haulers would be more or less unaffected by automation by 2030, and that they instead could increase their profit margin of incorporating some autonomous vehicles in their workflow. Another OEM stated that big haulers will exist, but will have to change their activities due to connectivity and automation.

Impact on freight forwarders

Freight forwarders are likely to benefit from automation of the hauling function, by being able to acquire cheaper transport of goods according to an interviewed hauler. On the other hand, freight forwarders will become increasingly challenged by other actors trying to circumvent or replace them in certain business segments. One potential threat to the market power of freight forwarders is increasingly open transport markets. In an open transport market, the exclusivity of customer networks would disappear, opening up for small and specialized freight forwarders to enter the market, according to the interviewee at AEOLIX. Efficient open markets where goods can be matched directly between transporters and end customers would be a threat to the business of freight forwarders according to an interviewed hauler. The transport buyers could in this case turn directly to the haulers, and cut out the middleman. This is already happening on a small scale of freight exchanges online. Another case where incentives would exist to try to connect the hauler directly to the customers for goods that is not time sensitive and of large quantities, where joint loading would not be of interest, stated an interviewed hauler. One interviewed freight forwarder saw the threat of backward integration from big e-commerce players, such as Amazon, as they might want to reach big enough volumes to find it worthwhile to manage their own freight forwarding operation. With the growth in popularity of block-chain technology, and thereby an alternative way of creating safe transactions, part of the value that freight forwarders provide will disappear, according to the interviewee at AEOLIX.

However, there are some limitations to the potential of replacing the function of the freight forwarders. Firstly, one OEM stated that not all of the transport industry could be operated with an ad-hoc open market model, with one example being the delivery of post. Secondly, the freight forwarders control much transport-related infrastructure, such as transfer stations, which constitutes a high barrier of entry for new actors, according to a freight forwarder. Even if fully autonomous vehicles exist and the logistics industry is transparent, it is still their infrastructure that needs to be used. Thirdly, even with full transparency of data, an ad-hoc transport market would lack the economies of scale that incumbent freight forwarders can reach in their operations, according to an interviewed hauler. On the same note, one freight forwarder argued that the logistics knowledge bound to the large international incumbent freight forwarders would be difficult to compete with. Conclusively, most interviewees didn't see the business of freight forwarders to be threatened by 2030. Furthermore, freight exchanges were not seen as a solely negative development for the freight forwarders, as they could, if they position themselves properly, utilize the freight exchanges to extend the reach of their current networks.

Freight forwarders will most likely continue to exist in a similarly as of today, according to an interviewed freight forwarder. In addition, it is unlikely that we will see any consolidation of the market either, because of current competition laws. A negative aspect of this is that the competition laws are reducing the possibility to utilize connectivity for further collaboration, the interviewee continued. Even if collaboration were more freely allowed, the interviewee saw the potential of connectivity to increase the degree of filling as limited. The underlying argument was that transport specific transport routes tend to have an uneven flow of goods, meaning that goods flow more in one direction than the other. Therefore, some trucks are bound to run empty.

Freight forwarders might take the role of coordinating autonomous vehicle fleets, as stated by component suppliers, haulers and freight forwarders. However, one OEM suspected that freight forwarders will not want to own the assets themselves, and that it will be up to OEMs to own and maintain the fleet.

Challenges for reaching high data utilization

The identified challenges for reaching a high data utilization were identified as technical capability for managing data, willingness to cooperate in sharing data, and taking responsibility for and daring to invest in connected and autonomous vehicles.

Both an OEM and a freight forwarder stated that they currently gather much data from vehicles and their activities, but that some data is unstructured or unused, while other data is not used to its full potential. They saw it as a critical area of competence development, to be able to turn the data into information and further into knowledge, since this data can be utilized for increased internal efficiency, increased loading efficiency, or as a valuable resource to trade.

The willingness to share data with other actors is still low, especially between OEMs and freight forwarders, according to a freight forwarder. The interviewee stated that OEMs want to own the vehicle data, in order to sell insights to freight forwarders. Freight forwarders, on the other hand, have the goods owners as customers, and are skeptical towards allowing the OEMs to access the goods data, as that this would lessen their competitive position in the value chain. One OEM speculated that freight forwarders will be successful based on the reach of their networks, and are therefore interested in interchanging data, as long as it increases the reach of their network. One interviewed freight forwarder stated that they do not see data sharing ultimately as a threat, when comparing to what value that could be brought through this sharing. Therefore, they are currently working on a platform for open data sharing.

Taking responsibility and daring to rely on autonomous and connected vehicles was a frequently mentioned issue, and it was presented as a behavioral and organizational issue. One component supplier argued that all actors in the value chain will face challenges when implementing autonomous and connected vehicles in their operations. These challenges include addressing the threats of data security, system risk and traffic security. According to a hauler, they currently take responsibility for their drivers to drive safely, but it was uncertain whether they could take responsibility for the safe driving of an AV. An OEM also saw it as complex to reach a conclusion regarding who will take responsibility for the performance of the vehicles, when they will be intertwined in a complex connected traffic system. A component supplier also saw a threat to the wellbeing of the society when relying on a connected and autonomous vehicle fleet that could suddenly stop functioning, and because of the increased cybersecurity threat.

Challenges related to logistics

Haulers and freight forwarders presented several logistical challenges for realizing the potential of autonomous and connected vehicles. One challenge regarded the fact that autonomous vehicles do not create autonomous logistics, according to a freight forwarder. The industry is still operated manually to a high degree, and goods are still mostly sorted by hand in terminals. For investments in autonomous technologies to be financed, the payback period needs to be short if they are only supposed to increase internal efficiency, or the end customer must be willing to pay higher prices. The interviewee saw that freight forwarders have struggled with succeeding to automate several of their core activities, and the autonomous trucks can only reach their potential if other functions than the transportation itself would become automated.

Another challenge related to logistics brought up by a freight forwarder, was that a truck being connected doesn't mean that the goods is also connected. The interviewee argued that in time, the data gathered about the goods will be more valuable than the vehicle data. This is the case since the visibility of goods for the customers and freight forwarders would be incredibly valuable. As of today, the components suppliers, OEMs and haulers are mostly interested in data regarding the truck, and not the goods. To benefit from connectivity in logistics, the goods need to be connected as well, the interviewee argued. Currently the technology for digitizing goods is too expensive to implement, but connected goods is essential for an effective collaboration between logistics providers.

Potential new actors

During the interviews, several potential new actors in the road transport industry was identified. Some were related to the implementation of autonomous vehicle fleets, and some to the perspective of an open data market.

For the development of an autonomous vehicle fleet, most interviewees agreed that the market for AV- and connectivity technology providers will become significant. One component supplier mentioned that companies specialized purely on AV-technology, such as Zenuity, would be needed to overcome the technical challenges of autonomous vehicles for public roads. For an effective operation of an autonomous road transport system, the role of a control tower will be of importance, according an interviewed OEM. The control tower will manage the vehicle fleet and the traffic system, by for example assigning deliveries to vehicles, and monitoring that the delivery arrives as planned. Vehicle owners will have to pay a fee for participating in the overarching traffic system, according to the interviewee. The role of a traffic tower can be taken by either an incumbent actor, a new actor, or by the government, the interviewee continues. Another player, similar to the control tower, that will be of essence once V2V and V2I technology becomes more utilized, is the system integrator, according to an interviewed OEM. One function of such a player could be to own and run a service that enables vehicles of different actors to cooperate through platooning.

In order to maintain an autonomous vehicle, the role of a maintenance hub is needed, according to an OEM. Autonomous vehicles will be complex, and uptime will be even more critical, which mean that the spare parts and repair part of the industry will change. One component supplier speculated that autonomous vehicles will be more reliable and easy to control than with a human driver, and therefore banks might see autonomous vehicles as an interesting investment. One freight forwarder saw it as likely that we will see a strong increase of new transport solution providers entering the market. These companies are likely to be based in the IT industry, and have competence in working with digital products and short innovation cycles, the interviewee stated. This type of actor would capture business from both the haulers and freight forwarders, and possibly even OEMs. With enough financing, they could become an integral part of the industry.

For an open data market to be trusted and for transactions to be safe, governance is needed. One freight forwarder mentioned that a neutral data broker could provide this function. The interviewee at CLOSER referred to a conducted project where a neutral broker collected transport data in order to coordinate transports. The result showed that a neutral data broker could act as an intermediary between competing businesses that would otherwise not share data with each other. Another role of the neutral data broker could be to standardize, and be responsible for, the digitalization of goods.

Another frequently discussed topic was the possibility of backward integration of large transport customers. As already mentioned, large e-retailers might try to overtake responsibility for the transportation of goods from terminals to terminal, while local actors would solve last-mile delivery. One OEM stated that large e-retailers are interested in gaining more control over the logistics operations relating to their businesses, since they could use their data-management skills and economies of scale to succeed in this arena. Other large transport buyers, such as international construction companies, might be interested in owning and operating autonomous trucks to suit their needs, according to an interviewed hauler.

7.3 Alternative fuels considered dominant in the industry

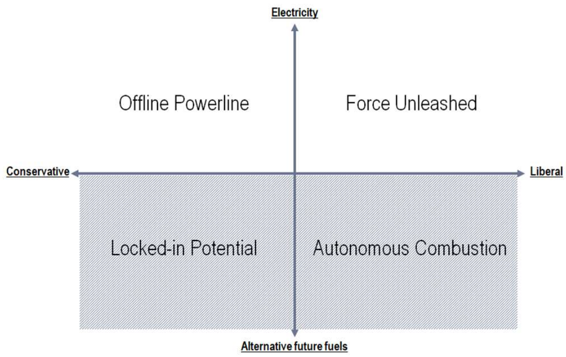

Figure 13. Illustration of concerned scenarios: Locked-in Potential and Autonomous Combustion

General impacts on the industry
If developments of electric roads are slow, and if statically charged trucks doesn't become popular, the industry will need extensive biofuel usage for heavy-duty and long-haul transport in order to reach the emission goals by 2030, according to a freight forwarder. The interviewee also stated that rapid biofuel adoption will increase prices and lower profitability in the industry, since the demand of biofuels will increase considerably. That some heavy-duty truck models will become fitted with a hybrid electric powertrain was confirmed by an OEM, due to local emission restrictions in urban areas. However, adoption of hybrid powertrains for heavy-duty trucks that are not operating in urban areas will be dependent on whether the technology is sufficiently cost-efficient.

Impact on component suppliers
Component suppliers are not expected to be largely affected by the transition to alternative fuels, such as biofuels, since the ICE will continue to be the dominant powertrain. The component suppliers are expected to focus on improving their products to increase the efficiency of the vehicle, but not try to integrate further forward in the value chain, according to an OEM.

Impact on OEMs
OEMs are expected to be able to sustain their current business, since the transition into biofuels and other alternative energy sources to the ICE will reduce the need to change products, according to an OEM. Furthermore, the revenue stream from spare parts relating to the ICE will remain. If the OEMs are not pressured to innovate in terms of fuel and powertrain, more resources will be available for innovating in the digital sphere, according to the interviewee. At the same time, the interviewee reflects that low adoption of electric powertrains could mean that OEMs have to continue experimenting with other alternative fuels, and might have to adjust to different fuel sources becoming dominant in different markets. It is costly and difficult to

certify an ICE, considering the demands in terms of emissions, and therefore the interviewee expects that the current incumbent OEMs will not be challenged by many new entrants.

Impact on haulers
Haulers are not especially concerned with how the truck is powered, according to one interviewed hauler. Basically, haulers see the truck only as a business tool, and are not concerned whether it is powered by electricity or biofuels, as long as it is cheap and reliable.

Challenges related to the adoption of biofuels
One challenge identified by a freight forwarder, is that the move towards sustainable fuels is simultaneously happening in the shipping and flight industries, and these industries are unlikely to adopt battery technology on a large scale. Thus, the interviewee stated that the road transport industry will have to compete with other transport industries for biofuels, which could lead to increased costs of these fuels. Furthermore, political decisions will likely favor the use of biofuels in the shipping and the flight industries. This would be the case since it will be more difficult to electrify in these transports, according to the interviewee. On the contrary, another freight forwarder stated that the same phenomenon might happen, but on a smaller scale in the road transport industry. Since light and urban trucks are easier to electrify, biofuels might be favored towards the heavy regional and long-haul truck industry, since these trucks are more difficult to electrify. Conclusively, some political regulations are likely to hamper biofuel usage in the road transport industry as a whole, while other regulations might promote biofuel usage by heavy regional and long-haul trucks.

7.4 Electricity considered the dominant fuel in the industry

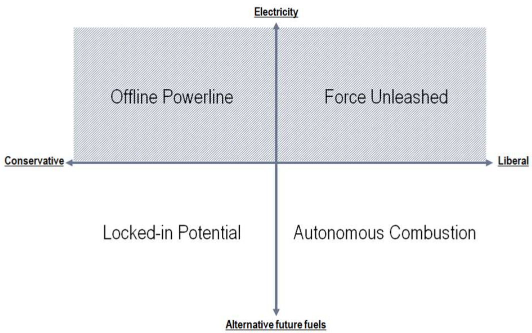

Figure 14. Illustration of concerned scenarios: Offline Powerline and Force Unleashed

General impacts on the industry
Electrification of the transport industry would lead to considerable cost reductions and environmental benefits, regardless if static or dynamic charging becomes dominant, according to one freight forwarder argued.

One interviewed OEM believed that the industry would not have changed considerably by 2030 if RPEVs become the dominant application of electricity as a fuel, since it would take longer than to 2030 to build the network of electric roads big enough to be impactful. The interviewee also stated that the range extenders of RPEVs would likely be batteries, since this enables a production of trucks with a single electric powertrain. However, this opinion was not shared by another interviewed OEM, who believed that the range extender for RPEVs would be based on the ICE. The reason for this belief was the high energy density of fuels to the ICE, which would be preferable if used as a range extender and that the fueling network for the ICE is already built out. The interviewee argued, that if batteries would be the preferred range extender, then two new charging infrastructures, static and dynamic, would have to be build out simultaneously. Then, there would be a risk that the static infrastructure eventually becomes irrelevant once the electric road system was extended enough.

Impact on component suppliers

Most interviewees commented that component suppliers will be greatly affected by an electrification. One OEM stated that a large part of their suppliers is delivering parts to the ICE-based powertrain, with stated examples being pistons and gearboxes. Other components, such as the fuel tank, cooling system, generator and compressors may disappear or be changed, according to an interviewed component supplier. In addition, electric trucks might integrate separate electric engines with each wheel, which in turn will impact current wheel suppliers, according to an OEM.

Another problem is that If incumbent suppliers want to transition into EV components, they will have to compete with new suppliers that are already emerging, according to a component supplier. There are new actors who focus solely on building competence and products for the electric powertrain, which will have gained a competitive advantage. In addition, a component supplier saw a trend among new suppliers of selling system solutions to OEMs, where they provide for example the whole powertrain together with the wheels. Thus, there is a risk that many smaller component suppliers might be outcompeted.

Impact on OEMs

With an electric powertrain, the complexity of a truck decreases and thereby also its value, according to an interviewed component supplier. Furthermore, one hauler stated that due to the decreased complexity of the electric powertrain, current OEMs will be faced with new competition from manufacturers that are focusing on electric trucks. One OEM stated that large electric powertrain suppliers might try to forwardly integrate in the value chain and become an OEM of trucks. This phenomenon has already been seen in the car industry.

Even if OEMs currently are specialists on the ICE, and not the electric engine, one OEM did not consider these new entrants at real threats. The underlying reasoning of this statement was that new entrants would not be able to compete with the current large OEMs regarding efficiency in production.

Since it is uncertain if static or dynamic charging will become dominant, and which technology within both categories that will become the market standard, developing electric trucks is currently associated with high risks, according to a freight forwarder. Furthermore, the OEMs are unwilling to develop trucks that would only be suitable for the Swedish market, which means that they actively will need to keep track of the electrification process in other markets.

One way to reduce the risk of developing electric trucks, is to also be part of developing the charging infrastructure, according to the interviewee.

All actors that are attempting to sell electric trucks will have to adjust to new customer demands, according to an OEM. It is likely that customers will not only want to buy the truck itself, but a whole transport solution. The reason for this is that customers want to make sure that the related charging infrastructure is sufficiently developed. Since customers will place more responsibility on the OEM to guarantee the uptime of the vehicles, OEMs will have to improve their understanding of the customers' operations. As an example, in order to optimize the battery usage and the maintenance of the vehicle, the OEMs must understand the logistics pattern of the customer. Furthermore, OEMs must ensure that workshops have the competence to properly service these new types of vehicles, according to another OEM.

The aftermarket business for ICE-based trucks is currently a big profit source which will be affected by electrification, according to an interviewed OEM. One component supplier stated that with electrification, OEMs will lose spare parts as a primary revenue source. The electric powertrain, except for the battery, is less subject to wear and is in less need for frequent maintenance, according to a hauler. In order to manage the loss of income, OEMs will have to collaborate with energy distributors and component suppliers to create new value combinations.

Impact on haulers

Haulers are an industry actor typically operating with low profit margins, according to a hauler. This is because the hauler industry segment is characterized by small actors with little bargaining power. Furthermore, they are the industry actor directly affected by increasing fuel prices, that has occurred due to the environmental legislation. In addition, according to the interviewee, the hauler industry is traditional and thereby skeptical to new technologies. Thus, drivers are afraid that electric trucks would lead to unforeseen problems, and the haulage companies are afraid that electric trucks would be too expensive. However, if the technology would prove to be both trustworthy and cost competitive, it is likely that the technology would be more widely adopted.

The adoption of electric trucks will further depend on the location and the owner. The haulage industry is likely to experience a specialization based on what infrastructure for fuel, including electricity, that is locally available. Generally, one hauler believed that the distribution transports will be more subject to electrification than construction-related transports, since the latter is often located in remote or inaccessible areas where electric charging infrastructure is likely to be undeveloped. Regarding different owners, one freight forwarder argued that larger organizations will be able to stimulate an adoption of electric trucks in their in-house hauling business, and that it is likely that these haulers will be first to adopt electric trucks. On the contrary, family owned haulers are more likely to be conservative in their approach.

A risk connected to electrification, is that the second-hand market could be reduced for an electric truck. This is the case since the operation of electric trucks is dependent on a sufficient charging infrastructure. Most of the time, the second-hand market is located in developing countries, which are likely not to have invested in such an infrastructure. This could lead to haulers being even more skeptical towards buying electric trucks, and to instead prefer leasing.

Also, the second-hand value of a truck could be reduced due to the fact that the most valuable component would be the battery, according to an interviewed hauler. Therefore, once the battery does not perform optimally, there might not be much value in the truck itself. Another issue that was raised during the interviews is that an investment in electric trucks implies an increased business risk. For haulers that have already invested in RPEVs, they suffer the risk that a specific contract with a freight forwarder for a certain electric road will be lost. If this would be the case, the RPEVs that the hauler bought might become unusable.

Impact on freight forwarders
According to an interviewed freight forwarder, successful electrification would lead to lower costs of transports, and therefore be a significant benefit for them. Another freight forwarder stated that they see the electrification as such an important development, that they have started to develop their own electric truck to suit their needs and to speed up the transition process. The same interviewee stated that due to the reduced complexity of electric trucks, compared to ICE-based trucks, they see a possible future where big freight forwarders develop their own vehicles for their specific needs. In addition, these trucks can be sold to haulers.

Potential new actors
When discussing potential new actors for a highly electrified future of the industry, the most frequently mentioned actor was the increased role of the Swedish government. The reason for this is that the government is likely to play a significant role when deciding which charging infrastructure to favor. A freight forwarder added that infrastructure-related issues tend to be decided on a political level, and it is not always the best solution that wins, but the solution that gains political popularity. Both interviewed haulers stated that haulers will be skeptical towards investing in electric trucks, as long as the government does not clearly communicate that they will give their long-term support for electrification and a specific infrastructure.

In the case of a wide-spread electric road infrastructure, there will be a need for an additional new type of road maintenance function, according to an interviewed OEM. The owner of this function will be in contact with haulers, and haulers will have to pay a fee to access the electric road functionality. The interviewee sees that this function will either be performed by the government, or possibly by the companies that have developed the electric road technology. Another interviewed OEM added that if the electric roads are to be developed due to a political push, it is extra likely that the government will assume the responsibility for maintaining the electrified roads. The interviewee at Vattenfall stated that it is possible that the electricity supplier also could assume this role.

Challenges to electrification
One freight forwarder suggested that on an European level, politicians are skeptical towards electricity as the dominant fuel for the industry. The main reason for this is that few countries have as sustainable energy as Sweden. Therefore, the interviewee believed that other European countries will be slower to develop electric roads than Sweden. This could lead to a situation where all goods have to be transshipped at the Swedish borders, which would be a logistical challenge. Transshipments could also be increasingly important inside the country, if the electric road network is not sufficiently spread, according to a component supplier.

Another identified challenge, but relating to BEVs, is range anxiety of haulers. A component supplier stated that it might be difficult to achieve the behavioral changes that are necessary in order for trucks to diffuse.

7.5 Interplay between high data utilization and electricity as dominant fuel

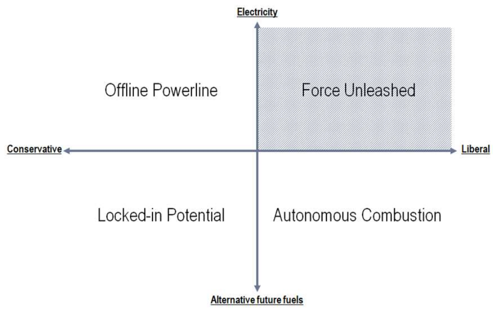

Figure 15. Illustration of concerned scenario: Force Unleashed

Several interviewees stressed that they see a synergy between the prospect of high data utilization and electricity becoming the dominant fuel in the industry. This synergy might result in new types of actors in the industry, and significantly change how road transport is consumed and how vehicles are designed.

In terms of new actors, one component supplier mentioned that many new actors are investing in businesses that includes trucks that are both electric and are utilizing data to a high degree. This is because electric autonomous trucks do not exist on the market today, which implies that new actors could potentially become successful in this new segment. One such actor is Einride, whose business model is radically different than incumbent OEMs and haulers according to the interviewee at AEOLIX. They will be able to provide transport incredible cheap, since they mostly eliminate driver costs, cut fuel cost in half, and cut capital investments in half, according to the interviewee. Another reason for an increased number of new actors in this case is, according to an interviewed OEM, that the competence required to construct a good cabin and to develop an engine that can pass emission tests will become irrelevant. Therefore, it will be much easier to construct an electric and autonomous truck. Furthermore, the interviewee believed that a standardization of trucks will be seen, in order to allow for a large-scale production of the new types of vehicles. However, the interviewee was not concerned that the new entrants would outcompete incumbents with new types of vehicles, since the new entrants would not possess production related expertise.

How road transports are consumed might change radically if electrification and fully autonomous trucks would be available on the market by 2030, according to a freight forwarder. In Sweden, where electricity is cheap and mostly sustainable, the result might be an overconsumption of transports. In the case of an unforeseen increase in transports, the importance of optimizing logistics will grow, according to an interviewed OEM. If the operational cost of trucks will become significantly lower, the optimization criteria of the industry will instead become to deliver the goods as fast as possible.

In terms of vehicle design, simultaneous electrification and high data utilization might start a trend of trucks becoming smaller, according to several interviewees. Currently the industry attempts to create as big trucks as possible to fit a maximum amount of goods, signified by the current popularity of High Capacity Transports, according to an interviewed OEM. However, the interviewee adds, when fully autonomous electric trucks enter the market, the industry could reach a breaking point, where these vehicles become seen as optimal.

Another argument for trucks becoming smaller, is that e-commerce is an industry under strong growth. This puts much emphasis on quick deliveries, and in the future, it is possible that the delivery times for aggregated goods in big trucks might be considered too long, according to an interviewed OEM. Smaller trucks could increase the flexibility of road transports, as they could be sent directly to their final destination. However, not all interviewees agreed with this development, that trucks would become smaller in general. Many interviewees instead believed in a dominance of a hub-and-spoke system, where the long-haul trucks only would get larger and larger, and small distribution vehicles would carry out the last-mile delivery.

7.6 Visualization of impacts on the industry value chain

This subchapter presents a summary of how the future value chain of the industry might look like. However, it is possible that the proposed value chain could become relevant in only certain segments of the industry, and that it only is one of many new value chains that will develop. Segments could refer to different locations in the country, or to different business segments, such as construction transports or agricultural transports.

Each proposed value chain will focus on what is new, and highlight the proposed value chain differs from the current value chain, in terms of position of and activities performed by incumbents, as well as new actors. Hence, the new actors that have been added in these visualizations of the value chain should be regarded as complements to the traditional actors, and not as substitutions.

Locked-in Potential

Interviewees assumed that if this scenario were to come true, the value chain would not change much. Instead of focusing on technological advancements, some interviewees speculated that focus of value chain actors might lie in market-driven innovation. One example of this could be to become more customer-oriented, such as selling traditional products as services instead. Due to the scenario implying no significant changes for the industry actors, the value chain presented remains the same as the current industry value chain, and can be seen in figure 16.

Figure 16. Visualization of value chain for Locked-in Potential

Offline Powerline

The value chain will operate with a structure similar to the current value chain. Component suppliers that traditionally supplied parts for the ICE powertrain are most likely to be the actors that will struggle the most in this scenario. Instead, new suppliers delivering batteries and parts for the electric engine will gain a larger market share. Because of the simplicity of the electric powertrain, compared to the ICE, these new component suppliers, that are delivering parts to the electric engine, might integrate forward in the value chain by either challenging OEMs or providing complete solutions instead of parts.

OEMs will experience a decrease in current aftermarket revenue streams, due to the electric engine leading to less spare parts having to be replaced. OEMs are likely to seek new value combinations by cooperating with energy distributors. Haulers will likely experience a shrinking secondary market for their vehicles, since few countries are likely to have developed electric roads by 2030. Freight forwarders could potentially integrate backwards in the value chain, by developing trucks for their specific needs.

The proposed value chain reflects that, as previously mentioned, many interviewees saw that the government will get an increasingly important role in this scenario, as financier and possible operator of the electric road. The role as an electric road operator could also be taken by electric power supply companies, or construction companies. The activities of the electric road operator will primarily be to guarantee uptime and continuous development of the electric road network. The electric road operator will be collaborating closely with OEMs and electric powertrain suppliers, since haulers will demand that the trucks they purchase will function without any flaws, and that the solution will be viable in the future. The proposed value chain can be found in figure 17.

Figure 17. Visualization of value chain for Offline Powerline

Autonomous Combustion

Component suppliers will be able to gain more knowledge about the use of their products, by utilizing data generated from connected trucks. OEMs will have to develop truck models specifically designed for full AV, that will not have a driver's cabin. In addition, with fully autonomous vehicles allowed on public roads, OEMs will be able to forward integrate towards haulers, by providing transport solutions. This implies that OEMs could become owners of large vehicle fleets, since digitalization makes it easier to coordinate the vehicles and gain economies of scale. Haulers thus risk being challenged by OEMs, especially on long-haul transports. However, last-mile delivery, and non-standardized deliveries, are likely to still need traditional haulers.

Freight forwarders might lose their current role of being the interface towards transport customers, as the transport market becomes increasingly digital, and will instead have to specialize on optimizing goods flows. For market segments where an open market model is not suitable, freight forwarders might still be challenged by OEMs who have ventured into the hauling business. For this to happen, OEMs need to establish better contacts with end customers, and also enable more data gathering from the goods itself.

New entrants attempting to replace OEMs will struggle in establishing themselves on the market, due to the dominance of the ICE rather than the relatively simpler electric powertrain.

The proposed value chain reflects that several industry segments are likely to see the emergence of haulers focusing on fully autonomous trucks. With an increasingly digital and automated logistics industry, the role of a control tower that optimizes logistics flows will become increasingly important. The proposed value chain can be found in figure 18.

Figure 18. Visualization of value chain for Autonomous Combustion

Force Unleashed

Component suppliers will experience many radical changes to their businesses. The reason for this is that the electric powertrain starts to replace the ICE, components become connected, and the cabin of the truck is increasingly disappearing.

OEMs will experience that electric and autonomous trucks are gaining market share, and will need to adapt their offerings. As stated in the scenario "autonomous combustion", it is likely that in this case, OEMs will produce trucks that will be part of a connected and autonomous vehicle fleet. This is expected to be a challenge for current haulers, which eventually will lead to a reduced need of traditional hauler. The role of connecting transport buyers and transport providers, which is currently performed by freight forwarders, will in many industry sectors be seen as an unnecessary middle-man. Therefore, when the transport market becomes increasingly open, this role will successively be automated. However, as long as freight forwarders can maintain control of goods data, they will be able to stay relevant.

The proposed value chain emphasizes the increased significance of electric powertrain and battery suppliers. As for Autonomous Combustion, the role of the control tower will assume a significant role in optimizing logistics flows. The proposed value chain can be found in figure 19.

Figure 19. Visualization of value chain for Force Unleashed

8. Discussion and proposal for future studies

This chapter contains findings of interest that are not directly related to the research questions, and proposals for future studies. The findings and the proposal for future studies relate to the performed scenario planning, the industry as a whole, specific industry actor groups and the three technology areas.

8.1 Findings of interest not directly related to the research questions

Concerning the adoption of the three technology areas of autonomy, connectivity and electrification, the industry at large displayed a great optimism for the future, with two exceptions. The first exception was haulers, which indicated that they would probably face challenges in case of high-AV scenarios. They stated, however, that only certain parts of the hauler industry segment would be challenged by automation. As an example, transports to construction sites will be harder to automate in the near future, because of the lack of necessary AV-infrastructure in these remote areas. The second exception was component suppliers, which identified future challenges in certain product segments that could lose relevance with high automation or electrification. In general, the majority of the interviewed industry actors believed themselves to be able to adjust to all proposed scenarios. Furthermore, many interviewees stressed that they would not idly wait for the future to happen, but be part of shaping it. OEMs and component suppliers expressed their potential to affect the connectivity and autonomy development, while haulers and freight forwarders expressed their potential to drive the development of electrification through their demands to OEMs. In this study, the industry actors' ability to actively contribute and reshape the development of the technology areas has not been paid any considerable attention. Thus, if this more active contribution from industry actors would have been considered, it is possible that the findings would have been different.

Even when considering potential competence destruction and the threat of new entrants, the industry actors shared an optimistic attitude towards the future. Instead of being concerned of these matters, the industry actors considered a situation of competence destruction as an opportunity to extend their current knowledge, and that the threat from new entrants generally should be low. More specifically, the OEMs saw it as unlikely that new entrants could compete with them in their industry segment due to economies of scale and their many years of experience of assembling trucks. Freight forwarders did consider new open market models in their industry segment as a threat, but also as an opportunity to extend their network. It is possible that the ability of the current industry actors to resist the threats of competence destruction and new entrants will influence the industry development in favor of any of the developed scenarios. As an example, it is reasonable to think that the scenario of Locked-in Potential would be favored in case of a successful resistance of these threats, while the scenario of Force Unleashed would be favored by more unsuccessful attempts to resist the threats of competence destruction and new entrants.

Data gathering, utilization and ownership have been emphasized as important for all industry actor groups throughout the study. Data gathering is already extensive, but cost and knowledge-related limitations still hold back the extent to which parts and goods are digitized. Furthermore, there are uncertainties regarding how the data can be utilized effectively. Another data-related challenge relates to cooperation, as it was identified that the efficiency of logistics could be improved if OEMs and freight forwarders were better at sharing vehicle and goods-related data with each other. Cooperation is currently limited, due to freight forwarders being afraid of OEMs building competence in logistics, and thus being able to challenge freight forwarders in the future. With regards to the four scenarios developed, it is possible that this general strive for valuable data in conjunction with different degrees of collaboration could influence the development in favor of any of these scenarios. Concerning the key uncertainty of the political approach to data utilization, it is possible for this political approach to vary depending on the degree of collaboration, if any societal benefits could be demonstrated by such a collaboration.

The benefits and drawbacks of static versus dynamic charging of electric trucks have been discussed in the report. The developed scenarios reflected that a conservative approach to data utilization is more connected to a dynamic charging infrastructure, while a liberal approach to data utilization is more connected to a static charging infrastructure. However, this is not a certain connection. The main argument for why static charging should be most relevant in combination with autonomous trucks has been that the trucks can be charged without generating any extra costs for a driver awaiting fully charged batteries. However, a counterargument is that the drivers nevertheless need to rest regularly, which could then be combined with recharging the batteries. In addition, it was identified that fully autonomous trucks could drive almost without downtime with dynamic charging, since the need for driver breaks is removed. Hence, the reasoning regarding the relationship between different types of charging techniques and the political approach to data utilization, and thereby autonomy, is not obvious, and would have needed more attention to be verified.

8.2 Proposal for future studies

With regards to the considered industry actor groups, some future research areas are proposed. Common for all industry actors in the study, is the adopted perspective that the actors will mostly respond to industry changes as they happen, and not themselves being part of shaping the future industry. This is not necessarily the case, and it could be further investigated how individual actors can impact the industry value chain and the development of the three technology areas. Specifically for component suppliers, it would be of interest to investigate to what extent the industry segment would be affected by automation and electrification of the truck industry, both in number of companies and product categories. As for OEMs, it would be of interest to evaluate the significance of threats from new entrants in the OEM segment. For haulers, it would be of interest to evaluate how suitable different industry segments are for automation. For freight forwarders, it would be of interest to investigate how they can favorably utilize emerging open transport markets.

On the topic of data, the industry as a whole would benefit from a mapping of current and preferred future data generation in different parts of the value chain. For each industry actor group, it would be beneficial to evaluate how vehicle- and transport-related data can best be gathered and utilized. It would also be of interest to investigate which data could be accessed through cooperation with other value chain actors. Furthermore, an assessment of the risk of sharing data with potential competitors would be of interest for each value chain actor.

Relating specifically to the developed scenarios, two further research areas are proposed. Firstly, scenario planning studies typically conclude with the development of indicators. However, this has not been within the scope of this study. Thus, future research could include a development of relevant indicators for each of the already existing scenarios. The purpose of such indicators would be to continuously follow up on the development of the industry as the time progresses, and to conclude which scenario is about to become the most appropriate reflection of the reality. Secondly, the performed scenario planning showed possible future developments from an industrial perspective. As a complement to this industrial perspective, it should be valuable for the different industry actors to get a better understanding of how to commercially adapt to the development. As an example, future research projects could evaluate which business models would be successful for different industry actors, depending on scenario.

9. Conclusions

The purpose of this study has been to increase the understanding of how the technological areas of autonomy, connectivity and electrification may develop until the year of 2030, and how this development is expected to influence the industry dynamics as well as the value chain structure of the Swedish heavy-duty truck industry.

In order to fulfill this purpose, the study has been conducted according to two subsequent research questions. The first of these two questions addressed the uncertainty regarding the technological development of the areas of autonomy, connectivity and electrification. To increase the understanding of plausible future developments of these areas, scenarios were created through the use of the managerial tool referred to as scenario planning. The second of these two questions regarded how the industry dynamics would change for each developed scenario. In addition, simplified visualizations of potential new value chain structures were created for each scenario, based on the expected future changes of the industry dynamics.

The chosen research method implied that the main analytical effort has been directed to the development of plausible scenarios, in order to provide a useful basis for discussions regarding what implications that the industry actors expect to face in the future. The analysis of plausible scenarios, as well as the expected implications for the industry, will be concluded in the following subchapters.

9.1 Scenarios for the Swedish heavy-duty truck industry by 2030

The developed scenarios have been based on four basic trends, which have been regarded as common for all different scenarios, and two key uncertainties that constitute the reason for differences between the developed scenarios. The four basic trends have been analyzed to consist of transports becoming more digital, green technologies becoming more mature, increasing political sustainability efforts and continued relevance of the internal combustion engine. The two key uncertainties have regarded the political approach to data utilization and the industry perspective on dominant future fuel.

These different building blocks, referred to as basic trends and key uncertainties, have resulted in four different scenarios that have been named “Locked-in Potential”, “Offline Powerline”, “Autonomous Combustion” and “Force Unleashed”. These scenarios represent varying combinations of different development paths for the key uncertainties. Thus, for the scenarios of Locked-in Potential and Offline Powerline, the political approach to data utilization has been stated as conservative. In contrast, for the scenarios of Autonomous Combustion and Force Unleashed, the political approach to data utilization has been stated as liberal. In addition, the two scenarios of Locked-in Potential and Autonomous Combustion, have been seen as congruent with a situation where alternative sustainable fuels for the internal combustion engine have become dominant. The scenarios of Offline Powerline and Force Unleashed have, on the other hand, been combined with a situation where electricity and the electric engine is about to become the dominant propulsion for heavy-duty trucks.

Considering the development of connectivity, autonomy and electrification in the Swedish heavy-duty truck industry by 2030, these scenarios indicate a relatively high degree of variation of how these technologies could be applied. The application of autonomous as well as connected trucks is highly dependent on the political approach to data utilization, while the electrification process depends on the relative competitiveness of electricity and alternative fuels. With regards to autonomy, it is possible that a high level of automation has been developed, but is not allowed to be utilized due to regulations. However, it is also possible that the most advanced level of automated vehicles, level 5, is applied in heavy-duty trucks on public roads. Similarly, it is possible that the current discussion regarding electrification have become less relevant, due to the adoption of alternative sustainable fuels. On the contrary, it is also possible that the society have started to heavily invest in infrastructures for electric trucks, both considering electric roads and static charging stations. Concerning connectivity, the development is considered to be progressive regardless of scenario, which is due to the basic trend of digitalization in the transport industry and society at large. However, depending on the political approach to data utilization, the use of connectivity in trucks can become more or less restricted.

9.2 Changed industry dynamics

The industry dynamics and the value chain structure of the Swedish heavy-duty truck industry is likely to be influenced by the different development paths of autonomy, connectivity and electrification. The implications for the industry dynamics and changes of the industry value chain is expected to be the most significant for the scenarios where the political approach to data utilization is stated as liberal, or where electricity is considered to be the dominant fuel. Hence, the industry dynamics, and the value chain structure, are likely to significantly change for all scenarios except for Locked-in Potential. How the industry is expected to change for these extremes of the key uncertainties will be concluded in the following paragraphs.

Liberal political approach to data utilization

In the case of a liberal political approach to data utilization, it is likely that the transport industry will become more efficient in general, as well as more open towards new transport solutions. For instance, the increased data available will make it easier to guarantee uptime, which can be used by OEMs to successfully sell transports-as-a-service.

More specifically, the current industry actors will be affected in different ways. It is expected that the products delivered by the component suppliers will become increasingly connected, which will enable a collection of data from the connected components. The revenue streams for the OEMs are expected to change, due to the reduced need of drivers as the trucks become more automated. Furthermore, this implies a disruptive threat to the function of haulers, which could ultimately lead to a situation where OEMs are forwardly integrating in the value chain. Concerning freight forwarders, it is likely that these companies would benefit, as the adoption of automated trucks is expected to reduce the purchasing cost of transports. However, freight forwarders are expected to face new competition as the transport industry becomes more open for alternative logistic solutions.

Moreover, it is expected that new actors will try to penetrate the heavy-duty truck industry. Some of the most important new actors are developers of technology for automated and connected trucks, neutral brokers that would ensure a safe and trustworthy open data market and control towers that are supposed to monitor and manage the automated trucks.

Electricity considered to be the dominant fuel

For the scenarios where electricity is increasingly becoming the dominant fuel, it is likely that the heavy-duty truck industry would be considerably more sustainable. At the same time, it is expected that the overall costs to transport goods would be reduced, due to the relatively low electricity prices. In addition, the industry will be dependent on a new charging infrastructure, which could be a combination of electric roads and static charging stations.

The industry actors are expected to be affected by an extended electrification of the road transports. Many of the current component suppliers are expected to be negatively impacted, since a considerable share of the components that are currently being delivered are used in internal combustion engines. The incumbent OEMs are expected to face competition from new manufacturers of all-electric trucks, which are likely to be fully or partly autonomous. In addition, it is likely that the current aftermarket related to the internal combustion engine will be reduced. Similarly, the haulers would suffer from a reduced second-hand value of purchased trucks, as electric trucks will be dependent on local charging infrastructures. Finally, freight forwarders are expected to benefit from lower prices for transports, as electricity could become cost-effective as fuel. Furthermore, freight forwarders could possibly extend their operations through backward integration, by developing customized electric trucks.

New players that are expected to be a part of an electrified heavy-duty truck industry include new component suppliers for the electric powertrain and new actors that are involved in the extension and maintenance of charging infrastructures. For the extension and maintenance of these infrastructures, it is expected that the Swedish government will play a significant role.

9.3 Implications on the industry value chain

The structure of the industry value chain is expected to change for all developed scenarios, except for the scenario named Locked-in Potential. The main changes for each remaining scenario is presented below.

In the case of Offline Powerline, it is expected that new component suppliers related to the electric powertrain will start to emerge and that an electric road operator will assume a significant role in the value chain. For the scenario of Autonomous Combustion, it is expected that the hauler function will be increasingly disrupted and that autonomous trucks will be operated by OEMs. In addition, the function of control towers is seen as necessary. When considering the scenario of Force Unleashed, it is expected that a combination of the two previous scenarios will prevail. Hence, the value chain related to this scenario is expected to include new component suppliers to the electric engine as well as an establishment of control towers. However, in this scenario, there is no obvious need for an electric road operator, since the development of this kind of roads will be limited. In addition, it is expected that the hauling function will be challenged by new entrants, as well as OEMs.

Reference list

ACEA (2016) *Connected and Automated Driving*. http://www.acea.be/industry-topics/tag/category/connected-and-automated-driving (2017-11-25).

ATA (2017) *Truck driver shortage analysis 2017.* Report published by: American Trucking Associations.

Björkdahl, J. (2009) *Technology cross-fertilization and the business model: The case of integrating ICTs in mechanical engineering products.* Research policy, 38(9), 1468-1477.

Bombardier (2017) *Continuous energy transfer from road to heavy vehicles.* http://primove.bombardier.com/projects/europe/germany-mannheim-primove-e-truck.html (2017-12-11).

Bryman, A., Bell, E. (2003) *Business research methods.* New York: Oxford University Press.

Börjesson, P. et al. (2016) *Dagens och framtidens hållbara biodrivmedel - i sammandrag.* The Swedish knowledge center for renewable transportation fuels.

Capgemini (2016) *AutomotiveConnect.* https://www.capgemini.com/wp-content/uploads/2017/07/automotiveconnect_commercial_vehicles_pov.pdf (2017-10-21).

Daimler (2017) *Daimler Trucks launches E-FUSO and all-electric heavy-duty truck Vision One.* Daimler Global Media Site. http://media.daimler.com/marsMediaSite/en/instance/ko/Daimler-Trucks-launches-E-FUSO-and-all-electric-heavy-duty-truck-Vision-One.xhtml?oid=30010405 (2017-12-30).

Easterby-Smith, M., Thorpe, R., & Jackson, P. R. (2015) *Management and business research*. Los Angeles: Sage Publications LTD. (5th edition)

Edmondson, A. and McManus, S.E. (2007) *Methodological fit in management research.* Academy of Management Review, vol. 32, nr 4, pp. 1155-1179.

Einride (2017) Framtidens transport. *T-pod: Elektrisk och självkörande*. https://www.einride.eu/sv (2017-12-30).

Eisenhardt, K. M. and Graebner, M. E. (2007) *Theory building from cases: Opportunities and challenges.* Academy of management journal, vol. 50, nr 1, 25-32.

Electronic Design (2017) *Telematics Connect Your Car To The World*. http://www.electronicdesign.com/communications/telematics-connect-your-car-world (2017-12-02).

Energimyndigheten (2017) *Strategisk plan för omställning av transportsektorn till fossilfrihet.* Eskilstuna: Statens energimyndighet.

eRoadArlanda (2017a) *Elväg med konduktiv teknik.* eRoadArlanda. https://eroadarlanda.se/tekniken/ (2017-12-11).

eRoadArlanda (2017b) *Framtidens vägar - är elvägar.* eRoadArlanda. https://eroadarlanda.se/om-projektet/ (2017-12-11).

ERTRAC (2011) *Hybridisation of Road* Transport. ERTRAC. (Version June 1, 2011).

ERTRAC (2016) *Future Light and Heavy-Duty ICE Powertrain Technologies*. ERTRAC Working

Group: Energy and Environment.

ERTRAC (2017) *European Roadmap: Electrification of Road Transport.* Belgium: ERTRAC, EPoSS and ETIP SNET.

EUCAR (2016) *Key challenges for the future mobility and transport.* http://www.eucar.be/wp-content/uploads/2016/08/Key-Challenges-for-Future-Mobility-and-Transport_final.pdf (2017-10-21).

European Commission (2012) *Indirect Land Use Change (ILUC).* http://europa.eu/rapid/press-release_MEMO-12-787_en.htm (2018-01-01).

European Commission (2017a) *Transport modes*. https://ec.europa.eu/research/transport/index.cfm?pg=transport&lib=road (2017-12-11).

European Commission (2017b) *Cooperative, connected and automated mobility (C-ITS)*. https://ec.europa.eu/transport/themes/its/c-its_hr (2017-11-20).

European Union (2014) *The EU explained: Transport.* Directorate-General for Communication. Luxembourg: Publications Office of the European Union.

Fenelon, K. (2017) *The economics of road transport*. London: Routledge.

Frost & Sullivan (2014) *Commercial Vehicles 2020 Vision Market Insight*. https://www.slideshare.net/FrostandSullivan/commercial-vehicles-2020-vision-market-insight (2017-12-12).

Gartner (2017) *Autonomous Vehicles.* Gartner IT Glossary. https://www.gartner.com/it-glossary/autonomous-vehicles/ (2017-11-28).

Gibbert, M., Ruigrok, W. and Wicki, B. (2008) *What passes as a rigorous case study?* Strategic Management Journal, vol. 29, nr 13, pp. 1465-1474.

International Energy Agency (2017) *The Future of Trucks: Implications for energy and the environment.* France: IEA Publications.

International Energy Agency and Electric Vehicles Initiative of the Clean Energy Ministerial (2013) *Global EV Outlook: Understanding the Electric Vehicle Landscape to 2020.* France: International Energy Agency.

ITF (2017) *Managing the Transition to Driverless Road Freight Transport*. https://www.itf-oecd.org/managing-transition-driverless-road-freight-transport (2017-11-23).

Naturvårdsverket (2017) *Fördjupad analys av svensk klimatstatistik 2017.* Bromma: Arkitektkopia AB.

NHTSA (2017) *Automated Vehicles for Safety*. https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety (2017-11-28).

Nikola Corporation (2017) *Nikola one.* Nikola. https://nikolamotor.com/one (2017-12-30).

Nordic Energy Research (2012) *Sweden: 96% CO2-free electricity*. http://www.nordicenergy.org/figure/two-thirds-renewable/96-co2-free-electricity/ (2017-12-15).

Panteia (2015) *Cost comparison and cost developments in the European road haulage sector*. Zoetermeer: Panteia.

Peterson, G. D., Cumming, G. S., & Carpenter, S. R. (2003) *Scenario planning: a tool for conservation in an uncertain world.* Conservation biology, vol. 17, nr 2, pp. 358-366.

Porter, M. E. (1985) *The Competitive Advantage: Creating and Sustaining Superior Performance*. New York: Free Press.

PowerCell (2016) *PowerCell har levererat bränslecellsstack när Coop i Schweiz lanserar landets första lastbil med bränslecellsteknik.* http://investor.powercell.se/nyheter/?file=powercell-har-levererat-branslecellsstack-nar-coop-i-schweiz-50430/PowerCell_Pressrelease_2016-11-04_Svenska.pdf (2016-11-04).

Regeringskansliet (2017a) *Regeringen banar väg för självkörande fordon.* http://www.regeringen.se/pressmeddelanden/2017/04/regeringen-banar-vag-for-sjalvkorande-fordon/ (2017-12-02).

Regeringskansliet (2017b) *Det klimatpolitiska ramverket.* http://www.regeringen.se/artiklar/2017/06/det-klimatpolitiska-ramverket/ (2018-01-01).

Regeringskansliet (2017c) *Riksdagen antar historiskt klimatpolitiskt ramverk.* http://www.regeringen.se/pressmeddelanden/2017/06/riksdagen-antar-historiskt-klimatpolitiskt-ramverk/ (2018-01-01).

Region Gävleborg (2016) *Världens första elväg på E16.* Region Gävleborg. http://www.regiongavleborg.se/regional-utveckling/samhallsplanering-och-infrastruktur/elvag/om-projektet/ (2017-12-11).

Ringland, G., & Schwartz, P. P. (1998) *Scenario planning: managing for the future*. New York: John Wiley & Sons.

SAE International (2016) *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles*. SAE International. (Report J3016™)

SAE International (2017) *Current SAE News Releases*. https://www.sae.org/news/3544/ (2017-11-28).

Scania Group (2017a) *Mine blowing - Scania Group*. https://www.scania.com/group/en/mine-blowing/ (2017-11-28).

Scania Group (2017b) *Press kit: Scania demonstrates autonomous transport system - Scania Group*. https://www.scania.com/group/en/scania-demonstrates-autonomous-transport-system/ (2017-11-28).

Scania Group (2017c) *Scania reaches milestone: 250,000 connected vehicles.* https://www.scania.com/group/en/scania-reaches-milestone-250000-connected-vehicles/ (2017-11-20).

Scania Sverige (2017) *Scania Hybrid.* Scania Sverige. https://www.scania.com/se/sv/home/products-and-services/trucks/our-range/scania-hybrid.html (2017-12-08).

Schoemaker, P. J. (1995) *Scenario planning: a tool for strategic thinking.* Sloan management review, vol. 36, nr 2, pp. 25.

Schwartz, P. (1996) *The Art of the Long View: Planning for the Future in an Uncertain World*. New York: Currency Doubleday.

Statens Offentliga Utredningar (2016) *Delbetänkande av Utredningen om självkörande fordon på väg*. SOU 2016:28. Stockholm: Elanders Sverige AB.

Sveriges Åkerier (2017) *Åkerinäringen med verksamhetsområden.* SANT, (September 2017).

Tatcham (2017) *Insurers set out criteria for what drivers should expect from vehicles described as "Automated"*. http://news.thatcham.org/pressreleases/insurers-set-out-criteria-for-what-drivers-should-expect-from-vehicles-described-as-automated-2251926 (2017-12-15).

Tesla (2017a) *Tesla pressinformation.* Tesla. https://www.tesla.com/sv_SE/presskit?redirect=no (2018-01-02).

Tesla (2017b) *Tesla Semi.* Tesla. https://www.tesla.com/semi (2017-12-30).

Trafikanalys (2017) *Prognoser för fordonsflottans utveckling i Sverige.* Stockholm: Trafikanalys.

Trafikkontoret (2017) *Regler för långa, tunga och breda fordon.* foretag.stockholm.se. http://foretag.stockholm.se/Tillstand/Trafik/Tung-trafik/Regler/ (2017-12-02).

Trafikverket (2016) *Demonstrationsanläggningar av elvägar.* Trafikverket. https://www.trafikverket.se/for-dig-i-branschen/upphandling/Leverantorsinformation/Elvagar/ (2017-12-11).

Trafikverket (2017a) *AutoFreight – Självkörande lastbilar för smartare logistik.* https://www.trafikverket.se/resa-och-trafik/forskning-och-innovation/aktuell-forskning/transport-pa-vag/autofreight--sjalvkorande-lastbilar-for-smartare-logistik/ (2017-11-28).

Trafikverket (2017b) *Tyskland och Sverige samarbetar om elvägar.* https://www.trafikverket.se/om-oss/nyheter/Nationellt/2017-09/tyskland-och-sverige-samarbetar-om-elvagar/ (2017-12-08).

Transportstyrelsen (2017) *Regler om kör- och vilotider*. https://transportstyrelsen.se/sv/vagtrafik/Yrkestrafik/Kor--och-vilotider/regler-om-kor--och-vilotider/ (2017-11-29).

Vin Basics (2017) *Infotainment vs. Telematics Systems: What is the Difference?* https://vin.dataonesoftware.com/vin_basics_blog/vehicle-infotainment-vs-telematics-systems-what-is-the-difference (2017-10-28).

Vinnova (2016) *Sweden 4 Platooning*. https://www.vinnova.se/p/sweden-4-platooning/ (2017-10-25).

Volvo Group (2017a) Automation. *Volvo Group*. http://www.volvogroup.com/en-en/about-us/r-d-and-innovations/automation.html (2017-11-28).

Volvo Group (2017b) *Volvo pioneers autonomous, self-driving refuse truck in the urban environment*. http://www.volvogroup.com/en-en/news/2017/may/news-2561936.html (2017-11-28).

Volvo Trucks (2013) *Hybridrevolutionen – resultatet av många års forskning och utveckling.* Volvo Lastvagnar SVERIGE. http://www.volvotrucks.se/sv-se/news/magazine-online/2013/jun/inside-volvo-the-hybrid-revolution.html (2017-12-08).

Volvo Trucks (2016a) *Volvo first in the world with self-driving truck in underground mine.* Volvo Group. http://www.volvogroup.com/en-en/news/2016/sep/news-2297091.html (2017-11-28).

Volvo Trucks (2017a) *The new gas-powered Volvo FH LNG.* Volvo Lastvagnar SVERIGE. http://www.volvotrucks.com/en-en/trucks/volvo-fh-series/volvo-fh-lng.html (2017-12-08).

Volvo Trucks (2017b) *Volvo Truck tests a hybrid vehicle for long haul.* Volvo Lastvagnar SVERIGE. http://www.volvogroup.com/en-en/news/2017/feb/news-2476234.html (2017-12-08).

Wallén, G. (1996) *Vetenskapsteori och forskningsmetodik.* Lund: Studentlitteratur.

WWF (2008) *Styr rätt med biodrivmedel.* Solna: Världsnaturfonden.

Appendices

Appendix 1 – Interview template, orientational interviews

In a semi-structured interview format, the interviewees were asked questions with the purpose to build knowledge regarding the three technology areas of autonomy, connectivity and electrification. The questions related to the following topics within each technology area:

Autonomy

- Benefits
- Drawbacks
- Driving forces
- Barriers
- Enablers

Connectivity

- Benefits
- Drawbacks
- Driving forces
- Barriers
- Enablers

Electrification

- Benefits
- Drawbacks
- Driving forces
- Barriers
- Enablers

The interviewees were then asked to present their vision for the year 2030, by answering the question: "How do you believe that the following three technology areas have developed until the year 2030?"

Appendix 2 – Interview template, value chain interviews

As a start, the four developed scenarios were presented, and the technology areas of autonomy, connectivity and electrification were described. Thereafter, each interviewee was asked the question: ”How will the industry dynamics and the value chain structure change, given each specific scenario?”. The interviewees were asked to especially comment regarding how the activities and positions of incumbents would change, and which new entrants might enter the industry.

1. Offline Powerline

1.1 Component suppliers

1.2 OEMs

1.3 Haulers

1.4 Freight forwarders

1.5 New entrants

2. Force Unleashed

1.1 Component suppliers

1.2 OEMs

1.3 Haulers

1.4 Freight forwarders

1.5 New entrants

3. Autonomous Combustion

1.1 Component suppliers

1.2 OEMs

1.3 Haulers

1.4 Freight forwarders

1.5 New entrants

4. Locked-in Potential

1.1 Component suppliers

1.2 OEMs

1.3 Haulers

1.4 Freight forwarders

1.5 New entrants