CHALMERS
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Future challenges in development and deployment of autonomous vehicles

Master's thesis in Automotive Engineering

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Gothenburg, Sweden 2019

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Abstract

The race towards autonomously driving vehicles has already, and will continue to, have large effect on the automotive industry. This Master's thesis is a study that aims to identify the challenges that the automotive industry faces in the transformation towards producing and deploying autonomous vehicles. It also aims to identify similarities and differences between the stakeholder in the industry. The insights gained can be used as input to stakeholders in the industry for strategic decision making regarding what focus areas to consider in this transition towards autonomous transport solutions.

Interviews were conducted with a wide range of stakeholder in the industry to get a larger scope on the result and possibility to compare relevant information. Literatures studies was conducted prior to the interviews to build a foundation of knowledge and identify research questions. Topics that were addressed during the interviews were: (1) General information and future thoughts, (2) testing methods, (3) data collection and storage, (4) safety, and (5) communication possibilities. The stakeholders that participated in the interviews were: one university research laboratory, one research organisation, one strategic innovation program, one consultancy company, two OEMs and two testing service providers.

From the interviews conducted, it can be argued that the challenges are many and it is uncertain what challenges will be the hardest to overcome. The two government organisations claim that the biggest hindrance will be the safety of the technology and the testing service organisations claim that the regulations and laws will be the biggest hindrance. Multiple interviewees brought up the problems of having different regulations and road infrastructure in different countries. All stakeholder agrees that more collaboration, increased transparency and new mythologies for testing and verification will be needed in the future for the technology of autonomous vehicles to be successfully developed and deployed. The OEMs will have a hard task in finding the balance between; sharing information and technology to increase the speed and reduce the cost of the development; and finding unique solutions that creates great customer value in their products compared to competitors.

Another challenge for autonomous vehicles is the one related to responsibility. This will in the end be a problem that the government or international regulators will have to address, just as the one with data ownership. It can be argued governments will play a major role in the future that will shape the way the development of autonomous vehicles will continue.

Key words: Autonomous, Automotive, Self-driving

Acknowledgement

This thesis has given me experience from one an industry in fast development and possibly on the way to change its foundation completely. Several persons that have been involved in the process deserves gratitude.

First, I would like to thank my advisor Christian Berger and examiner Ola Bederius for their continuous support and guidance. I also wish to show appreciation for the industry partner that supported the scoping of the thesis and gave valuable insights to forming the interview questions.

Finally, all companies and persons that were willing to participate in the interviews deserves many thanks and have my greatest gratitude.

Gothenburg, Sweden, December 2019
Emil Rylén

Thesis advisor: Christian Berger
Thesis examiner: Ola Benderius

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1 Introduction

In this chapter the background of the study is presented. Also aim, limitations, possible stakeholder, and research questions are presented for the reader.

1.1 Background

Autonomous vehicles might currently be the fastest growing trend in the automotive industry. An increasing number of companies and universities are competing in the race towards the first fully automated vehicle (Payne, 2017). If they succeed, the first level 5 autonomous vehicle will be driving on the road, according to the SAE J3016 classification (SAE, 2016). Today's vehicles only reach level 2 on this ranking. Chalmers University of Technology, as one actor in this race, is operating its vehicle laboratory Revere at Lindholmen, Gothenburg.

The automotive industry is already a highly competitive industry with relatively low profitability (Parkin, 2017). Adding that other big corporations like Alphabet (project Waymo) and Apple (project Titan) are entering the field of transportation, the competitive climate in the industry increases as the industry moves towards producing autonomous transportation solutions (Payne, 2017).

Sweden, as number four (KPMG, 2018) on a global list of countries readiness for autonomous vehicles, plays a leading role in the future for autonomous vehicles. This high ranking is merely due to the high rating of innovation, substantially located in Gothenburg. However, the conversion from manually controlled vehicles to autonomous vehicles is not only about what type of technology the OEMs and subcontractors can produce. For autonomous vehicles to take a larger role in the society it will be important with a well-functioning interplay between OEMs, testing companies, municipalities, insurance companies, and customers in the future (KPMG, 2018).

For a company to be able to sell vehicles, the customers must trust that the autonomous characteristics of the vehicle are safe. The importance of safety verification was proven in an American study in 2016 that showed that the most important catalyst for people to buy autonomous vehicles of level 4 and 5 is "proven to be safe" (COX Automotive, 2016). Another study done by MIT showed that between the years 2016 and 2017 the interest in owning a level 5 autonomous car decreased (Hillary, Abraham 2017). People shifted towards preferring level 3 automation where the driver is always in control and only assisted by the autonomous systems. These insights lead to questions like: what will it take for people to give up the steering wheel and trust the new technology to keep them safe on the roads? Who should be responsible for verifying this safety for the customers? The MIT study also stresses the importance of customer and driver education on self-driving technology systems to increase consumer interest and trust towards higher level of automation in the future (Hillary, Abraham 2017).

1.2 Aim

The study aims to identify the challenges that the automotive industry faces in the transformation towards producing and deploying autonomous vehicles. By doing this key success factors can be found. Similarities and difference between OEMs, testing companies, and municipalities view on autonomous vehicles will be crucial for the future of the industry.

As the author is a member of the Chalmers Formula Student Driverless 2018 team, this study will in addition include insights from the Formula Student Germany competition.

1.3 Limitations

Since new technologies constantly arise in this fast-moving industry, it is impossible to make any estimations of which specific technologies that will play major roles in the future. Therefore, this study will focus on the product and not on technical components. This implies that the study will not set target requirements on sensors, software and other components in an autonomous system that must be fulfilled for the system to correspond to the stakeholder or customer expectation.

1.4 Specification of issue under investigation

The automotive industry is highly competitive with many actors racing towards deployment of autonomous vehicles on the roads. How well the OEMs handle their future challenges will determine who is successful in launching fully autonomous vehicles to the customers and thereby, who will outperform the competitors in the industry. Therefore, this study will be of importance for strategic decisions made in the future by the OEMs participating.

Furthermore, the study can help legislators and other government organisations in their research regarding autonomous vehicles and how to both control the development to make it safe, and to help the industry companies to be successful.

By answering the following research question, which will form the framework for the results of this study, a base for conclusions in line with the purposes mentioned above can be created.

RQ1: How could stakeholders influence the development and deployment of autonomous vehicles in the automotive industry? What similarities and differences does OEMs and other stakeholders have in their view on the industry's transition towards fully autonomous vehicles?

The Chalmers Formula Student driverless project aims to compete in a global competition between universities where each university builds a driverless race car. By completing this project in one year, it is very much related to the highly competitive automotive industry, racing towards autonomous vehicles on the

roads. By answering the following research question future Chalmers Formula Student Driverless teams can develop and reach higher results in the future.

RQ2: What challenges did the formula student driverless teams have at the Formula Student Germany competition?

1.5 Stakeholders

The automotive industry companies such as OEMs and testing companies that accepts to be a part of this study and gives relevant input data could make use of the results in their future improvements to be a successful autonomous vehicle provider. Furthermore, the government organisations involved in this study will have a chance to affect the future direction of the industry with their insights.

2 Methodology

This chapter focus on the methods used to carry out the study. The three main phases can be described as Pre-study, Data collection and Data processing

2.1 Study strategy

Different kinds of methods were used throughout the three main phases of this master thesis. An overview can be seen in Figure 2.1 below, where blue indicates the Pre-study where the question framework was established, the yellow boxes includes the second phase of Data Collection in interviews and finally the green box is the last phase of Data processing where conclusions drawn from the collected data.

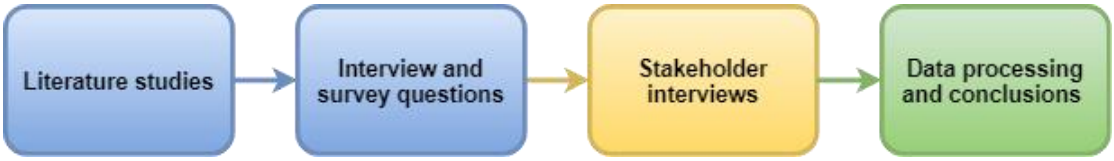

Figure 2.1 Methodology overview

2.2 Pre-study

First, literature studies on previous papers regarding the future for autonomous vehicles was conducted to build a foundation of knowledge and find the framework in terms of aim and research questions, which is established in the Chapter 1 Introduction, Sections 1.2 and 1.4. Together with experts from both the university and industry the interview questions were created in such a way that they cover the research questions and ensures that the study will result in valuable conclusions for the industry.

2.3 Data collection

In-depth structured interviews with stakeholders (OEMs, municipalities, and testing companies) were conducted to give answers to the questions from different stakeholder. The questions were organised under subtopics to make the interview structured in a good way and comparison of answers easier. These subtopics were; (1) General information and future thoughts, (2) testing methods, (3) data collection and storage, (4) safety, and (5) communication possibilities. Furthermore, the questions were formulated both open-ended to cover the future expectations, and more specific to discover similarities and differences in thoughts regarding the future of autonomous vehicles. These interviews involved cross checking questions to ensure scientifically valid data (Ridder 2016).

The first interview was done with a representative from Chalmers University of Technology to get feedback on how well the questions corresponded to the study purpose, to find new questions of interest, and to give the interviewer a chance to

practice. This helped to reform some questions and organise the interviews in a way that gave better flow and depth.

2.3.1 Interviewees

As the complexity of the vehicle system increases when autonomous functions are introduced, the areas of knowledge will increase. Therefore, the stakeholders asked to participate in interviews for this study was not only OEMs. The interview questions were designed in a way that all stakeholder got the same question, even if they were not working in the specific area. The interviewees can be seen in Table 2.1 below.

Table 2.1 Showing the stakeholders, their field of work, geographical area of work and area of expertise of the interviewees

Stakeholder	**Geographical area**	**Area of expertise of the interviewee**
Revere vehicle laboratory	Sweden	Research
Government research organisation	Sweden	Research
Strategic innovation program	Sweden	Research and collaboration projects
Consultant company	World-wide	Research and development
OEM #1	World-wide	Testing
OEM #2	World-wide	Development and testing
Testing service provider #1	Sweden	Testing
Testing service provider #2	World-wide	Testing

All stakeholders were found via personal connections of the author or via the advisor and examiner to the thesis. The stakeholders received an email that briefly described the thesis topic and what the interview was for. No questions were given to the interviewees before the interview and no preparations were made from their part. The interviewees decided a time and place for the interview to make it more convenient for them and more likely that they accept the request to participate. Only one stakeholder that was asked to participate in the study declined the request. This was a large world-wide acting OEM.

2.4 Data processing

All interviews were recorded and later transcribed in detail. This made sure that all answers were analysed and used as empirical data in the study. Bryman & Bell (2014) argues that by recording the interviews the interviewers can focus at the interviewee rather than focusing on taking notes. Furthermore, the recording makes it

possible to listen to the actual interview instead of having to rely on the notes taken. These two important aspects make the analysis of the data easier and improves the results.

The interviews lasted for approximately one hour and all interviews except one was held in person. The exception was with the testing service provider #2 and was held via online meeting system. This interview was however also recorded as the others. All interviews were with a single representative except the one with OEM #2 where three experts from the company participated. This made this interview cover a broader perspective from the company. The answers are however not separated between the individuals in the transcription and they are used in the results as answers from one OEM rather than from multiple individuals.

Later, the transcription was sent back to the stakeholder for them to cross-check all their answers and add or remove information. Since most stakeholders are anonymous in this study the approval of transcriptions was essential. This also gave the stakeholders the opportunity to reflect on their answer which was found useful since some valuable information was added in this process. During the transcription process the answers were moved to the corresponding subtopic. The subtopics can be found in Section 2.3.1. This made the analysis easier, since the comparison of answers become more accurate and efficient when answers on the same topic from different interviewees are visualized together. This visualization was done by summarizing the results from the approved transcriptions in a table with stakeholder on one axis and subtopics on the other. The subtopic *general information and future thoughts* was reworked since the conclusion was drawn that this topic covered more answers than the others and could be separated into *the future* and *organisation for autonomous vehicle development*.

3 Stakeholder Findings

In the following chapter the stakeholder's answers are presented in a summarized way. All information stated is directly taken from the transcription and sometimes direct quotes are used. Table 2.1 shows all stakeholders, but the subsections below will start with a brief description on the stakeholder and the interviewees.

3.1 Stakeholder #1: Revere vehicle laboratory

The Resource for Vehicle Research at Chalmers, Revere, is a facility in Lindholmen, Gothenburg, focusing on automotive related research. The focus areas are self-driving vehicles, active safety, and vehicle dynamics.

3.1.1 The future

The interviewee claims that the technology is not yet safe enough for deployment. This have been shown in resent event and it will take more research and development before we see self-driving vehicles on the market. The first implementation will be in very controlled operational design domains, meaning that the risk of uncontrolled scenarios is somehow limited. City traffic is still too complex since the possible scenarios are close to unlimited.

Customer trust and knowledge is also a problem according to the interviewee. This is related to the safety, which hopefully will be the most important improvement that comes with autonomous vehicles. The interviewee hopes that we will soon see a paradigm shift in the way we look at transportation and that both the number and severity of accident will be reduced in the future. For the interviewee an autonomous vehicle must be safer than a human driver before it should be deployed. How much safer is however hard to say. A problem will be to avoid not only the accident caused by human, but also to avoid the accidents than humans are able to avoid.

The interviewee hopes that the number of vehicles will be reduced in the future with implementation of car sharing services but says that we might see the opposite because of the increased availability when autonomous vehicles are introduced. People still like to own a car and to have their personal space.

A challenge that was highlighted by the interviewee was problems with different weather conditions. Snow, fog, heavy rain, and so on will challenge the sensors and systems of an autonomous vehicles. Revere is currently involved in a project that aims to handle urban weather conditions.

3.1.2 Organisation for autonomous vehicle development

Revere works to boost the industry research towards future sustainable transport systems, both considering the personal safety and environmental impact. They act as a link between the academy and the industry and students can use the lab as a platform for research. Revere currently has three full-time employees and two part-time employees.

Most of the projects are related autonomous drive and currently all testing done by Revere is conducted on test tracks. However, Revere is working on an application for real traffic testing of autonomous functions and hope that test will be conducted in the near future.

All the in-house research is open, and the software used is open source, meaning that the software can be found, downloaded, and reviewed by anyone.

Besides research, Revere is also doing work to spread knowledge and trust for autonomous vehicles. This is done by inviting people to the lab to see the research being done and participating in public seminars and presentations.

3.1.3 Testing

Many actors are trying to come up with new test and validation methods for autonomous vehicles, but the interviewee believes it will take more research on this before we will see any standards on how to verify safety. It will be more important to assess the safety aspect of testing in the future and the systems will need redundancy. Also, the aspect of cyber security will be related to testing.

3.1.4 Data

Revere is currently in the process of building their own dataset. A dataset of scenarios provided by Revere could be open source in the future and available to download. The interviewee believes in more shared data between stakeholder because everyone needs more data. Revere could be open for collaborations in sharing data with industry actors.

Today all data at Revere that can be considered personal data is handled according to GDPR. This includes outlooking camera data from the vehicle. Data is stored on a secure server with only personal access.

3.1.5 Safety

The interviewee thinks that the OEM should be held responsible of the safety for an autonomous vehicle. However, the OEM can hold suppliers responsible of failures in their systems. This is how it works already today, but it will need more clarification and adoption for autonomous vehicles before it is clear who is responsible and to what degree.

Revere is a research organisation and part of a university and will therefore not need to take any responsibility for safety of sold autonomous vehicles. However, safety of tests is of course of great importance.

The interviewee believes that the technology needs to be mature more before legislations hinder the development. Still, legislations are needed, and they must adopt to this new trend of autonomous vehicles fast.

3.1.6 Communication possibilities

Revere is not currently involved in any project regarding infrastructural changes for autonomous vehicles, but this does not mean they will not be involved in this type of projects in the future. However, projects regarding vehicle to X (X standing for things like other vehicles, road units etc) are conducted and a big part of the work at Revere.

3.2 Stakeholder #2: Government research organisation

This stakeholder is a research institute for the Swedish government. This means they work between the academy, the industry, and the government. They bring stakeholder in the automotive industry together in collaboration projects and conduct in-house research related to the future of sustainable mobility. Half of the employees have doctor degrees and there are approximately twenty employees in this department.

3.2.1 The future

It is common, says the interviewee, that that laws and regulations is brought up as a hindrance. Therefore, the institute have a field of research that is called regulatory innovation. This research is both for regulations of technology, but also on regulations for business, since new business models will come with autonomous vehicles. By helping the industry stakeholders to interpret already existing laws and helping the regulators set new regulations and laws the industry can growth faster in a safe way. These new laws should be to ensure safe development but must not hinder the technological development in any way. Another possible limiting factor in the future for autonomous vehicles will be the trust and understanding among customers and users.

The government will have to rework the tax system according to the interviewee. Today we have high taxes on cars but subsidize public transport. In the future the difference might not be as clear and there is no easy way forward here.

The interviewee hopes that the biggest advantage for autonomous vehicles will be the increased productivity. We already see deployment of autonomous trucks in mining and other confined areas. Later we will hopefully see new public transportation implementations. The safety improvements will come, but they might also be a hindrance since we will put higher demands on safety and verification of safety. In the long run the interviewee believes we will see vehicle fleets with autonomous vehicles and that fewer people will own their own car.

According to the interviewee, we are today overconfident in the human capability of driving since we see speeding and accidents everywhere. For the interviewee an autonomous vehicle that is as safe as a normal human driver and follow the regulations is enough to justify deployment.

3.2.2 Organisation for autonomous vehicle development

The institute works with all aspects of technology, business models and regulations related to autonomous vehicles. Also, research is being done on future city planning with focus on usage of autonomous vehicles. In the future the interviewee believes in a growth of the organisation, especially related to testing, verification, and certification.

In the future the interviewee believes that more collaboration in needed. To create a business model for autonomous vehicles stakeholder like city and road network builders, landowners, operators, suppliers, network provider, OEMs, and so on must be involved. This is a completely new way, but also the only way of working in the future if we, according to the interviewee, want to be successful. All these new features on transportation was initiated by the technology of autonomous vehicles, but now we need to find ways of making use of the technology in a smart way. "Our work is top down. We want to change mobility into a safer, more sustainable, and better future." It is hard to say how the future cities will look like, but we must assume that we will have some level of autonomous vehicles very soon. The question is not if we will see electrification, automation, and shared economies, but when, how and where it will happen first? According to the interviewee the society will reach a tipping point where the way we look at transportation changes completely.

The interviewee believes we might see more start-ups related to autonomous vehicles, but they will need help from bigger actors in the industry to build trust. A more open approach from the OEMs to help start-ups would be good, since successful start-ups will encourage even more of them to pop up. The industry should grow an ecosystem around development of autonomous vehicles.

The projects conducted by the institute varies in transparency. Some projects with industry stakeholder are secret and some are more open. In as large extent as possible the institute tries to tell the public what the projects aims for and what the results might be, but the process in detail might still be kept away from public knowledge.

3.2.3 Testing

The interviewee believes that the most difficult thing with testing of autonomous vehicles will be to cover all possible scenarios. This will force the industry to use a more model-based development and verification methodology. It will be hard to prove that what is tested in simulation also corresponds to reality. The methods for testing and verification still requires more research, which is party of what the institute is doing. This research must involve all stakeholders in the value chain of autonomous vehicles and will be related to regulations and laws.

According to the interviewee there is a clear difference between Europe and US on regulations regarding testing and safety. In the US they use self-certifications and have high fines its case of failures. In Europe we are using more approvals to limit

the possibility or errors beforehand. The system for liability and responsibility, including the government role, will have to be reconstructed to keep up with the technology. The interviewee highlights the problem with European countries having different road regulations, which makes it hard to sell vehicles in all Europe already today, and it will make it even harder for autonomous vehicles.

We might see some standardized tests for autonomous vehicles in the future says the interviewee. However, the interviewee believes we will see more standards on development and testing processes to reach self-certification of the vehicle in the end. Well documented and proven correct development process will lead to safe vehicles. It also enables the technology development to be more open for new solutions.

The institute is involved in project with real traffic testing of autonomous vehicles. In these kinds of projects, the responsibility for safety lands on the industry stakeholders, since this is something we must learn and increase the knowledge about. However, the institute pushes the stakeholder to do meticulous documentation and implement scientific methods. Furthermore, factory and site acceptance test are being done before real life testing.

Another interesting aspect of testing that was mentioned by the interviewee was the problem of verification of deep learning software. How will we verify and test safety of software we have not developed ourselves?

3.2.4 Data

The institute is currently not collecting any sensor data. According to the interviewee, they could possibly be involved in projects regarding creation of frameworks for collecting and storing data to make it easier to share data between stakeholder in the future. The interviewee believes we will see increasing problems with data quality as we move further into usage of deep learning.

Both in-inhouse research and collaboration project on cyber security is being done by the institute. The interviewee stresses the importance of technology understanding and process of keeping order and remedy. The problem is complex and will according to the interviewee also be a key factor related to customer trust for autonomous vehicles.

3.2.5 Safety

The latest published report from the Swedish government states that the owner should be responsible of the vehicle. The interviewee believes this a good way to approach the problem regarding safety responsibility. The owner can then go back to the OEM, which can go back to the suppliers, in case of failures. However, the interviewee says that this is related to the future of autonomous vehicles where the interviewee hopes for mobility services where individuals does not own vehicles and therefore the service provider would be responsible and not the service subscriber.

The interviewee believes that software updates on already deployed autonomous vehicles will be safe if the architecture and development processes are approved in a safe way. This relate to what was mentioned before regarding regulations on processes rather than on technology.

The institute has a public and free of charge digital newsletter that includes updates regarding the industry of autonomous vehicles. Individuals from the institute also participates in public seminars and can be seen in media, spreading knowledge about the development of autonomous vehicles.

3.2.6 Communication possibilities

The interviewee does not see the government taking on a role as service provider of digital maps or central control operation for autonomous vehicles. The industry must create what they need themselves.

Regarding communication possibilities for autonomous vehicles the interviewee believes in a cellular technology where no or very little infrastructure-based communication is used.

3.3 Stakeholder #3: Strategic innovation program

This stakeholder is an innovation program created by the Swedish government to work with projects for sustainable future transportation. The program helps to establish and finance projects with different stakeholders that helps both the industry and the society. All project involves more than one stakeholder and are therefore collaboration projects.

3.3.1 The future

The interviewee hopes that the autonomous vehicles will help make the future of transportation more sustainable. The biggest hindrances according to the interviewee will be the lack in safety of the technology, which also makes the lack in trust a problem. We will not have autonomous vehicles with zero accident from a start, as has been seen in the recently occurring event in the US with an accident of an autonomous vehicles with deadly outcome.

Many others might see the increased comfortability in riding an autonomous vehicle compared to driving a manual one as only positive. However, the interviewee believes that this might lead to problems if we see an increase in distance driven by vehicles in the future due to this increased convenience. Instead the interviewee hopes to see implementations of autonomous vehicles as last-mile transportation to bigger public transport hubs. To fit everyone in the future cities we cannot all ride our own cars.

According to the interviewee the advantages of increased availability, safety and more environmentally friendly transportation will be the biggest. Moreover, with shared vehicles services we will see a release in capital and cheaper

transportation. The interviewee also stresses the fact that there is a gap between the large and expensive SUVs and the city busses. Different and new ways for transportation of people together would be very useful and we must find new way of balancing public transport and personal vehicles.

The big question everyone is asking is how do we prove that the vehicle is safe enough? The interviewee believes that this problem will be solved by doing stepwise deployment of functionality on the autonomous vehicles.

3.3.2 Organisation for autonomous vehicle development

The innovation program has 79-member organisations, where some are more active than others. The interviewee is the only full-time employee of the program and works with setting up the collaboration projects between stakeholder.
The interviewee sees two parallel developments. One is the autonomous vehicles, where the first step is small shuttles for low speed usage in limited areas. The other one is the creation of mobility as a service. This development will need more research before we can build a "Spotify for mobility" instead of having cars owned by individuals and standing still for most of the product lifetime.

Many on the projects for of the innovation program are pilot projects where concepts on mobility services are implemented and evaluated in smaller scales. Since the projects are partly founded by the Swedish government there is high transparency in the projects. Some part might however be kept secret due to the industry stakeholder's innovation rights.

According to the interviewee we need to implement these new trends in large scales to see how it truly effects the society and cities. Compared to countries like China and Singapore, Sweden is not yet as committed to these changes. Larger scale project would involve even more stakeholder like insurance companies, telecom operators and other government departments. In the future the interviewee claims that the innovation program could make use of more mandate from the Swedish government to implement large scale and lasting projects in the society.

In this new era on autonomous vehicles and mobility services the interviewee believes we need more collaborations between all different stakeholder to be successful. The OEMs will not be able to handle the future challenges on their own.

3.3.3 Testing

The interviewee thinks it would be good to see some global validation organisation doing tests on autonomous vehicles in the future before deployment. Hopefully both in real life and simulations with a set of standard tests. However, according to the interviewee many stakeholders would see this as a hindrance since it would slow down the process even more than today.

One project of the innovation program is doing real traffic testing of autonomous vehicles, and hopefully more will follow in the near future. The interviewee believes that first projects will be in low speeds and limited areas to ensure safety.

According to the interviewee a big challenge will be to ensure quality of autonomous vehicles without having to drive the vehicles for hundreds of years. Also, the interviewee stresses the fact that when introducing deep learning in the software development the systems will be even harder to control and verify for safety.

3.3.4 Data

The data that might be collected in the projects are up to the industry stakeholders to handle according to the interviewee. The innovation program does not collect any data for internal purposes.

To ensure safety from hacking of autonomous vehicles the interviewee believes we will see more research. The data should however follow the legislations like GDPR on personal data and therefore be secure enough.

The interviewee thinks that we will see more shared data between stakeholder in the future. It might not be possible for everyone do share data, but in some collaborations, it might work and be very useful.

3.3.5 Safety

The innovation program is decoupled from the projects when they have started and therefore does not take any responsibility of the safety. The interviewee believes that the government publication on how to handle responsibly for autonomous vehicles is correct and that the product owner should have the most responsibility. This will lead back to the OEM in case of failures. The interviewee also believes that the regulations should not stop the innovation process, but some regulations of testing and verification will be needed to reduce the ensure safety of the testing and deployed products.

In the projects the innovation program is spreading knowledge about the development by showing and implementing the technology in practice with the future users. The interviewee hopes that this work will increase the trust and understanding of future mobility systems. Some projects provide services that are open for everyone to use, which is a good way to spread the interest and knowledge about the future technology.

3.3.6 Communication possibilities

The innovation program has projects regarding infrastructural changes that will help the future of mobility and autonomous vehicles. This is mostly on city planning and the city is a big stakeholder in this development.

The interviewee says that a couple of year ago it was a big hope for vehicle to vehicle communication and a common protocol for this technology. However, no pressure was put from the EU or US and now we see a shift towards use of 5G network and communication via the cloud instead.

A dynamic map would be of great help for autonomous vehicles according to the interviewee. However, the problem with who should be responsible for this map is highlighted and it is hard to find a good business model to make it happen. The interviewee believes that the government cannot take on this role and that the industry must create their own map in some way.

3.4 Stakeholder #4: Consultant company

As a big consultant company in Sweden, with many international offices, and with many projects related to the automotive industry this consultant company is of interest for the study. The interviewee can be described as a senior consultant expert in active safety and autonomous vehicles development and strategy. The person has years of experience working for a big OEM, a supplier and now the consultant company in these fields.

3.4.1 The future

The interviewee stresses the fact that we today do not have a test and verification method, or a "sign off method" as the interviewee adds, for autonomous vehicles. To come up with these new methods, the interviewee believes will be a big topic and that it will involve many different stakeholders such as OEMs, governments, regulators, and insurance companies. The problem is also a world-wide one, since most actors in the industry are international. Differences in regulations between countries will according to the interviewee lead to big problem for the industry, both regarding increased cost and control of difference models for specific countries.

The future of autonomous vehicles will according to the interviewee be a stepwise deployment of more complex technologies. This would increase the possibility to learn on the way and reduce the risks. The interviewee claims that it is a long way to go before we can see level 4 vehicles in most areas. To further back this claim the interviewee speaks about the problem regarding infrastructure and cloud communication. Compared to active safety systems, the autonomous vehicles will have to handle all possible scenarios, and this will be hard without information from other sources than the vehicle itself.

To express the possible advantage of autonomous vehicles the interviewee brings up things like ending up in a traffic jams due to accidents when you could have taken another route. Furthermore, the interviewee mentions the cost of transportation, both for goods and people, which the interviewee hopes will decrease in the future when autonomous vehicles can replace the driver cost. However, the interviewee expresses concerns that the autonomous vehicles might not avoid accidents that humans can handle today even if autonomous vehicles avoids other type of accidents that are caused by humans. To make the technology

safe, the interviewee believes we need a fall-back mechanism that handled hardware failures and unexpected weather conditions before we can deploy level 4 autonomous vehicles.

The interviewee states that it is not yet clear how the business models of autonomous vehicles and the related services will look like. The increased profitability will drive the technology forward, but who gains or saves the most is not always clear. According to the interviewee the EU will become a more competitive market with autonomous vehicle and better transportation. The countries will hopefully reduce their environmental footprint and decrease cost of accidents. Finally, the last mile transportation solutions might solve many problems for public transport according to the interviewee.

Another interesting future scenario that the interviewee discussed was who will buy autonomous vehicle? According to the interviewee it depends very much on the functionality and what roads the user regularly drives on if the user finds in worth the extra cost to buy an autonomous vehicle. Say that the user never drives on highways more than on occasional long trips, then there is no point of paying 60 000 SEK just to get a highway pilot.

3.4.2 Organisation for autonomous vehicle development

At the consultant company there are approximately 100 people working closely with automotive development. If heavy transportation is included the number increases with 50 – 100 people according to the interviewee.

The company has a relatively new CEO and the strategy that he sets will influence how the company works with development related to autonomous vehicle in the future according to the interviewee. However, the company is continuously hiring new engineers in the field of automotive and other areas like safety, sensors fusion, cyber security etc. The in-house research at the company is increasing, but no research is yet related to autonomous vehicles directly. According to the interviewee the company could likely be part of a cluster collaboration between stakeholder in the future development of autonomous vehicle to support the industry. The interviewee stresses the fact that the OEMs will need more support from other stakeholders and that we need more collaboration if the Swedish autonomous vehicle industry should be successful. Stakeholders should be government, suppliers, research industry, universities, OEMs, and others.

3.4.3 Testing

The interviewee stresses the fact that since the industry of autonomous vehicle is not yet mature enough to know how the future will look like, we will see stepwise improvements on both technology and testing methods. Problems like *how to test software* and *how to make sure hardware implementations works as wanted* must be answered, according to the interviewee. This seemingly small problems could end up in many accidents if the complete system in not controlled before large scale deployment.

To make the testing of autonomous vehicle safe, the interviewee believes that the government will have do initial assessment on development and testing methods before issuing certificates to industry projects. The interviewee does not believe that the safety driver can handle sudden driving scenarios when kept out of the loop. The safety driver will be more to handle vehicle failures like a flat tire.

A future scenario is described by the interviewee where a simulation environment is provided to the industry. In this simulation the vehicles can run in a virtual world and be tested on a wide range of unexpected driving scenarios and changing environment like, weather, road quality etc. This would be a very useful tool to reduce the need for real traffic testing according to the interviewee.

3.4.4 Data

The difference between collecting data for active safety systems and for autonomous vehicle will according to the interviewee be the need for raw data. Then simulation models will have to simulate the raw data into sensor data in order for the system to use data related to the controlled movement of the autonomous vehicle. Data collection is important, but "we must have a clear view on what the data should be used for and how it should be used."

The interviewee however stresses the fact that to share data the industry must have better understanding of differences between sensors setups and the circumstances that the data is recorded. If errors are found during simulation, the data must be traceable to find the source.

The consultant company is not currently collecting and storing any data but would however be open to sharing data with other organisations in the future.

To handle the problem of data security the interviewee believes the automotive industry will need more support from both government and data technology companies. It is both a problem related to vehicle hacking and to safety of communication with the cloud. The consultant company has a department working with cyber security that could possible take on projects related to autonomous vehicle in the future.

3.4.5 Safety

According to the interviewee the responsibility of safety can be shared on different levels. The owner should handle the maintenance and software updates provided from the OEM. The product responsibility falls on the OEM, including software and hardware. As before, the interviewee brings up the need for testing and sign-off methods to make the autonomous vehicle safe. The interviewee can see the consultant company taking some responsibility for what they deliver to customers from the in-house research.

Regarding regulations on autonomous vehicle the interviewee believes that in the short-term the industry should be free to conduct research and find the best

solution. However, in the long-term the industry needs regulations on minimum performance and deployment plans.

3.4.6 Communication possibilities

The interviewee believes that infrastructure and cloud information need standards. Who should set the standards is however hard to say. Another question brought up by the interviewee is who should pay for the connection to the cloud of autonomous vehicle? According to the interviewee the government has an interest in this service since they would benefit if emergency vehicles could communicate their path. The government must find new financing models in many areas with relation to autonomous vehicle and without regulations on vehicle to vehicle communication protocols it will not be possible.

According to the interviewee the autonomous vehicle will generate new data for the industry that can be valuable for other areas like advertisement locations, traffic flow efficiency and road quality information for maintains work.

3.5 Stakeholder #5: OEM #1

This OEM is an international provider of vehicles. The interviewee has eleven years of experience in testing and verification of active safety systems. Since 2014 the role has been as technical expert for verification methods of active systems and autonomous vehicles.

3.5.1 The future

The interviewee starts by bringing up the fact that with the old verification methods we would have had to start hundreds of years ago verifying our autonomous vehicle for them to be tested enough for deployment today. According to the interviewee the technology is almost ready for first deployment, but the verification methods are not.

For the OEM safety is critical and the customers' demands high performances related to safety. A problem brought up by the interviewee related is also that the they know very little about how drivers will handle not being in control and how the autonomous vehicle will replace the driver. The OEM is conducting research on what can go wrong and how to make the vehicle safe. Questions like *what happens if an autonomous vehicle gets a flat tire* are yet to be answered and therefore needs research. The interviewee stresses the fact that there is no right way to go, because no one have ever done this before.

Many companies conduct testing on autonomous vehicle and people might think that they are ready, but according to the interviewee the vehicles are not. Before we will see deployment the autonomous vehicles must e proven safe in every possible scenario. Standards on traffic situations and scenario creation would be good according to the interviewee. However, the OEM still want a unique sellingpoint to make them successful. It is a tradeoff between the greater good and

the making the company vehicles the best. “A good thing would be to have a scenario database that everyone could access and test their systems on.”

The interviewee believes that the autonomous vehicle will bring customer benefits like comfortability and safety. Other benefits more related to the infrastructure and society will come when the autonomous vehicle fleet have grown big. According to the interviewee it is hard to compare the autonomous vehicle to a human driver in terms of safety. Even good drivers makes misstake, but they also aviod many accidents that autonomous vehicle might not be able to.

3.5.2 Organisation for autonomous vehicle development

The OEM have seen some recent reconstruction of the company regarding development of autonomous vehicle, but they are currently in the process of inceaseing the number of in-house personnel. The interviewee says “it takes a lot of resources to develop an autonomous vehicle and we are still relatively small actor.”

The interviewee says that the OEM is working on developing new strategies for test and verification and it will take more time. It is however already clear that it will be very different to the methods they have used before. To test an autonomous vehicle only in real traffic would take too much time.

The future customer for autonomous vehicles might be different in some ways compared to today's customers. According to the interviewee, the autonomous vehicles will be more expensive and might attract very technology interested individuals at start.

The OEM have collaborations with suppliers regarding sensors, verification, deep learning etc. They also use consultants in their in-house projects, but no projects are completely outsourced today.

In the future the interviewee believes the OEM will introduce new business models for autonomous vehicle, but many people will still buy a personal vehicle. The OEM will try to adopt the busniess models to suit the customer needs and preferences.

3.5.3 Testing

The OEM is currently in the process of applying for permission to do real traffic testing with level 4 autonomous vehicles. However, the interviewee believes that more testing will have to be done in simulations in the future, but it will not be easy to verify that the simulation methods are good enough to say that the vehicle will work in real traffic if it works in simulations. The hardware will still need real life testing to answer questions like: how does the sensor act when the sun is low or there is a thin layer of snow on the road?

The interviewee hopes that certification and rating organisations will include autonomous vehicles in the future and that it will be both simulation and real lif testing.

3.5.4 Data

Today the OEM is collecting data while driving vehicles and the data is stored on secured servers. To prove that an autonomous vehicle is safe all data used for testing and verification must be stored. There is a department working with cyber security problems and vehicle hacking. The interviewee believes there will be more problem related to this and that more work will be needed.

It will be a problem with data storage in the future according to the interviewee. Mostly since the data will require a lot of disk space and be expensive to store. Already now the OEM is trying to store only valuable data for scenario reconstruction and not everything, since the storage will be expensive in the long run.

The interviewee is positive towards sharing data with other organisations but does not see how this will be possible since data is very sensors dependent. Different sensors setups will perceive the surrounding differently and therefore the system would also act differently. For the OEM the data that will be available from the already sold vehicles would be very useful and the government would benefit it data from possible accident could be easy to obtain.

3.5.5 Safety

According to the interviewee the safety responsibility should be on the OEM. The owner has some responsibility to maintain and not to tamper with the systems. This could possibly be controlled by having a black box in the vehicle monitoring any changes.

For software updates the interviewee believes the industry needs more research before it is safe to use. With badly updated software the worst outcome could be deadly accidents.

The interviewee believes that it is very hard for a government organisation to anticipate how the technology will look like in the future and therefore also hard to regulate. The regulations should according to the interviewee come after the technology to ensure safety of deployment but also not to hinder the development on new and smart solutions.

The OEM have PR departments working with advertising. Part of this will in the future be related to autonomous vehicles and will then help increase the customer trust. Furthermore, the test project with real traffic testing is done together with customers and will hopefully increase the trust if successful. A way that the OEM have been studying driver behaviour in autonomous vehicles is by having a vehicle being driven from the backseat and a driver in the front only observing as it would be in a level 4 autonomous vehicle.

3.5.6 Communication possibilities

In the future the interviewee hopes for communication of for example emergency vehicles and traffic lights, together with information from a digital map to help the autonomous vehicles become safe.

In the real traffic testing project waiting for permission to start the OEM have been working with city planners to see how the new technology could change transportation in cities. Both the road authorities and the city are stakeholders in the project.

For vehicle to vehicle communication to be possible in the future the interviewee believes we need standards. Smaller companies are generally more open to standards on such things than bigger actors. The interviewee addresses the problem with differences in road signs between countries and that the EU will have to solve this problem very soon.

3.6 Stakeholder 6: OEM #2

This stakeholder is an international provider of vehicles. The interviewees are three persons with expert areas in testing and verification methods and involved in strategy regarding development of autonomous vehicles at the company.

3.6.1 The future

The interviewees see future hindrance in customer acceptance, understanding, and trust. Another thing mentioned is the problem to validate that an autonomous vehicle is safe enough for deployment. Furthermore, legislations might also hinder the deployment of autonomous vehicle according to the interviewees. They see a gap between the technology development and legislations.

The problem of sensor performance and perhaps an over-trust in the sensor capability is another thing discussed during the interview. The software functionality relies on good perception data from the sensors. The interviewees believe that this will result in speed limitations of autonomous vehicle to make sure they have time to process the environment and act accordingly. The importance of having redundancies in the system is also brought up during the discussion.

When asked about advantages of autonomous vehicle the interviewees bring up customer comfort, fuel consumption, usage for disabled people etc. They do however not believe that the number of vehicles will decrease, as politicians are hoping for. The interviewees things the biggest advantage will be increased traffic safety, but a big drive behind the development is the industry growth and profitability. The possibility of new business models is discussed, and the interviewees believes we will see more collaboration between companies, start-ups and other actors in the industry in the future regarding development of autonomous vehicles.

When asked how safe an autonomous vehicle should be the interviewees talked about different perspectives dependent if one look at the OEM, customer, government, or others. For the interviewees themselves it would be enough with an autonomous vehicle being as safe as a human driver and they brought up the possibility to just limit the speed of an autonomous vehicle to make it safer and possible accidents less sever. Also, the possibility to limit the usage of autonomous vehicles only to specific geographical areas were discussed. The question itself was also discussed regarding how we measure how good a normal driver is, and how do we compare a driver that might brake laws to avoid accidents with an autonomous vehicle that might not brake laws and crash?

3.6.2 Organisation for autonomous vehicle development

The OEM currently has approximately 25 people working with strategies on development and verification of autonomous vehicles. However, they will employ many more people in this area in the future. The project with autonomous vehicles has been ongoing for less than a year.

In terms of features the OEM aims to produce a highway pilot with traffic jam functionality and a valley parking function to start with. The interviewees believe that the way demands are set on functionality will change completely compared to active safety systems. Furthermore, the interviewee believes that the complexity will increase when deep learning is implemented in the development since machine learning makes it problematic to trace the development process.

Investigations are being conducted on new business opportunities and models by the OEM, but it is too early to tell how the future will look like. The interviewees are however very clear that they want to move more of the development in-house and be less reliant on one supplier. Furthermore, the transparency and understanding of what suppliers provide in both software and hardware must increase for the OEM to create unique and safe autonomous vehicles. The downside brought up by the interviewees will be that with more common and shared modules in the system the development becomes faster and easier. A good balance between in-house development and outsourced development must be found in the future.

3.6.3 Testing

The interviewees agree that the focus in testing will shift towards simulation compared to testing of today's vehicles. This is the only way, since to test all possible scenarios in real traffic is impossible in terms of time and cost. The autonomous vehicles will not only be tested on hazard events, but all other possible driving scenarios must be tested as well.

According to the interviewees the challenge for virtual verification methods will be to prove that what is proven safe in simulation also works in real life. The fact that to do good simulations, good data is needed, and the OEM will need to collaborate with another company regarding the simulation testing is discussed.

"We need to find good tools for verification. These competences that we don't have today would take too long time to grow in-house for us."

The testing of active safety systems for the OEM is outsourced today. The interviewees believe that this can continue in the future for also autonomous vehicles, but the transparency needs to increase, and they need better insight and understanding of the software that is being tested. This is important for the OEM to be able to trace possible errors in the system. To summarise, the OEM should work more closely with all actors in the value chain according to the interviewees.

Before moving into real traffic testing the interviewees believe that besides simulations, testing of basic scenarios on test tracks will be of importance. Furthermore, they believe that rating and certification organisation should create some guidelines for how to test autonomous vehicles and how to make the real traffic testing safe.

3.6.4 Data

During the testing of active safety systems, the OEM collects data that could be used for development of autonomous vehicles. The most useful data will according to the interviewees be the reference data that is collected.

The interviewees believe that they must share data with other stakeholders in the future to get enough data. However, they address the problem of collecting data in different ways and that it might be hard to share data without any standards on how to collect. The data must be traceable in case of failures found in simulations.

If data should be collected from already sold vehicles the interviewees are clear that some sort of agreement must be signed by the customer. However, this would be very useful for the OEM and save time and money on data collection.

A department of the OEM is already working with cyber security and they are adopting towards autonomous vehicles. The interviewees believe this problem will influence the software architecture and how connection to the cloud is handled. This is something that the OEM might have to collaborate on with other companies that are more related to cyber security and the interviewees brought up the fact that if the government were to set standards and legislations on cyber security, it might backfire and make it easier to hack autonomous vehicles.

3.6.5 Safety

The problem of updating autonomous vehicles was brought up by the interviewees. They stated questions like: *when to update*, *is it acceptable not to update*, *would it be acceptable to charge the user for the update*, *and when is an autonomous vehicle to old from a safety perspective*?

The interviewees believe that the OEM should be responsible when an autonomous vehicle is in autonomous driving mode and that the driver should be responsible when they are driving. To know this, the autonomous vehicles must

have some sort of closed data logger that can only be accessed by the government organisation or insurance companies.

Currently, the OEM is not working with spreading any knowledge about autonomous vehicle, but the interviewees see this changing as they come closer to deployment.

3.6.6 Communication possibilities

All three interviewees agree that the cloud communication will be the way all autonomous vehicle communicate in the future. However, they stress that this will put demands on safety classification of information being sent and received.

3.7 Stakeholder #7: Testing service provider #1

As a provider of services and test track for active safety and autonomous vehicle testing this stakeholder has an important role in the automotive industry. The facility is one of very few dedicated for active safety and autonomous vehicle in the world and the test tracks are situated in Sweden. Most customers are also therefore based in Sweden. The interviewee is the CEO of the organisation and has long knowledge in the field of automotive with focus on development of active safety systems, powertrain, and test equipment.

3.7.1 The future

The interviewee believe that the biggest hindrance will be laws and regulations. Future transport system is an area where more research is needed before good regulations can be implemented. According to the interviewee this is a process that takes long time and will therefore be a hindrance if it is not solved soon. Regardless of regulations, the interviewee claims that the technology will push through and with cheaper hardware and more money being spend this will go fast. Therefore, the regulations must adopt very soon. The interviewee believe that other problems will be solved by the industry and thereby not be a hindrance in the long run.

When asked about future advantages of autonomous vehicles the interviewee believe that the biggest advantage will be the increased efficiency in transportation, both regarding energy, cost, and time. Other benefits like safety and customer comfort are somewhat included in this. “We need to think of autonomous vehicles as something completely new compared to today's vehicles.”

The interviewee thinks that autonomous vehicle must be safer than a human driver before deployment. However, it is hard to say how much better and this will require more research.

3.7.2 Organisation for autonomous vehicle development

In the organisation, two persons are working with development of the testing possibilities for autonomous vehicles. The interviewee sees the organisation as the world leader in testing possibilities for the automated transport system.

According to the interviewee the testing possibilities is continuously improved on the facility to follow the market needs. As the technology is changing rapidly, so does the testing organisation. Examples of new important improvements are increased testing efficiency. The interviewee believes a lot of testing will be done in simulation but testing on test facilities will still be important and the efficiency of these test must increase to handle the industry's needs. Another thing mentioned by the interviewee is the possibility for customers to test sensor availability in repeatable weather conditions. Also, the importance of good data is mentioned to stress the fact that all simulations need real life collected data as an input.

The services provided by the organisation is applicable to all stakeholders in the industry of autonomous vehicles. The services include the spectrum from conducting the complete test to renting the test track. However, the interviewee sees the possibility to increase the usage of the facility for policy making organisations and other governmental project for the future of transportation.

The organisation works closely with an industrial tech and production company that develops unique testing equipment for the facility. According to the interviewee they cannot have all the expert competence in all areas and therefore they must work closely in collaborations like this to provide the best possible service to their customers.

The interviewee sees an increase in need for the testing facility and believes that they can meet this need by increasing the capacity of the facility. Currently new test tracks and equipment are added to the service portfolio of the organisation.

3.7.3 Testing

According to the interviewee many organisations and companies are trying to create standard sets with test scenarios. However, the interviewee believes that there will always be a need for specific test scenarios and new technologies will demand new tests. The fact that tier one suppliers and OEMs might want different type of tests is also mentioned.

When asked about standards for testing the interviewee expressed that it would be good to see some standard set of test scenarios for autonomous vehicles. However, the interviewee does not believe that this will come in the near future. “We can provide a service where we can implement testing of standard scenarios. However, our role is not to establish what should be tested. This is up to the customer.” The organisation can help to make sure that the tests are safe and carried out to get the best possible results.

The organisation provides services with real traffic testing today. The interviewee could not say if this service will increase or not and brought up the fact that the balance between real traffic and facility testing is yet unknown. However, the resent accidents with testing of autonomous vehicle was discussed and the interviewee believe that this might shift the testing to be more on facilities in the future.

The interviewee believes that that we will see more real traffic testing in the future. This could however be reduced by the improvement of good simulation methods where obstacles and scenarios can be custom made in the virtual environment. This would decrease the need for collecting real traffic data.

Many new problems and trends will appear for autonomous vehicle as the technology matures according to the interviewee. This could be problems like how to transport an autonomous vehicle without steering wheel to testing track, and how to perform random testing with a predefined scenario. Today testing start with ideal testing and moves on to more complex but still controlled scenarios. Perhaps random testing at facility will be the last step before real traffic testing.

3.7.4 Data

Currently the organisation only collects and stores data for the customers and not for internal usage. The interviewee does not believe that the organisation will change in this aspect but brought up that they could be part of projects where other organisations collects sensor data for research in the future.

The interviewee claims that the organisation follows state of the art regarding data security and that data is handled with high security. However, the best would be if the customers could handle the data directly, but this is not always the case.

3.7.5 Safety

According to the interviewee the responsibility of the safety of an autonomous vehicle should be on the OEM. Then then OEM can have agreements with suppliers on their responsibility for subparts of the system. This is how it works already today with normal vehicles. “It might change in detail in the future for autonomous vehicles, but he the framework I believe will stay the same.”

The organisation will not take any responsibility of any products since this is out of their control. However, they take some responsibility to make the tests that are conducted safe. The results of the tests are up to the customer to handle.

The interviewee believe that the facility could be used for future certification of autonomous vehicles and that the organisation would be open to work with certification testing. However, the rules and framework for the test scenarios needed is up to some certification organisation to come up with.

The organisation does work with spreading knowledge about the development of automated transportation by publishing articles in media and other public

statements. The interviewee sees their role to be technological realistic, where other companies like OEMs might be too optimistic. “We need people to have an opinion on what they want for the future and not just accepting what the industry produces. This will be important to form the future of mobility.”

The interviewee would prefer regulations on safety performance rather than on technology details to not hinder the development of smart solutions. Examples was brought up like train, naval, and aircrafts where according to the interviewee regulations have limited the technological development in some ways.

3.7.6 Communication possibilities

The organisation has been deploying both their one 4G network and 5G network before most others. “We try to stay in front regarding digital communication since this is a big are for our customers.” Related to this the organisation is investigating how to build a digital dynamic map of the facility, but it still too early to say what the customers need and therefore the map is still in the future.

The interviewee sees some possible problems with vehicle to vehicle communication, one being the problem of standard protocol and securing information from all vehicles. On the facility one can today find connected infrastructure like traffic lights.

3.8 Stakeholder #8: Testing service provider #2

This stakeholder is a company providing all kind of testing services for the automotive industry, including services related to active safety systems and autonomous vehicles. The company is international and not based in Sweden.

3.8.1 The future

The interviewee believes that that more effort must be put on vehicle validation on component level and that this is an area where more research is needed. The OEMs and suppliers focus on the technology development but might find it harder with the validation in the future. Using the current methodology of testing would result in difficulties in terms of cost and time. “We need to validate not only the function but assess the performance of the vehicle also during no hazard events.” There are no clear scenarios and if we try to test everything the scenarios would become to many and to complex. According to the interviewee this means the industry currently lack the necessary tools and methods for autonomous vehicle validation.

Another barrier mentioned by the interviewee is regulations. Today type approval is based on physical testing, which will be impossible in the future as explained before. According to the interviewee this will be a big hindrance. It is also related to the risk of fragmentation between countries since regulations, road signs etc might be different in different geographical areas. The interviewee explains how the US market uses code of practice and high fines, while in the EU there is more assessments and certification done before deployment. It is not clear which way

is the best, the US way might make it easier for testing and deployment, while the EU way might be more protective of the road users. Governments sees great possibilities with the autonomous vehicles, but also great risks.

The interviewee expects the cost of sensors and other hardware to go down in the future when production increases, which will make the cost of autonomous vehicles to go down. The benefit with decreased cost of transportation when a driver no longer is needed is also brought up. However, the interviewee believe that more research must be done on business models before we see successful implementation.

When asked about the problem of customer trust the interviewee claims that we need to promote both the possibility, but also the limitations of the automated vehicles more. Already today there is a misuse of active safety features and this problem will increase with autonomous vehicles according to the interviewee.

3.8.2 Organisation for autonomous vehicle development

The company works already today with type approval for some European governments. The interviewee would however not share any information regarding how many employees that are working related to autonomous vehicles.

The interviewee believe that the company must continue to adopt to the industry fast since the technology is changing so rapidly. This is done by putting resources in research and development. New customers will possibly come from emerging geographical industry segments like US and China, and this will be a good way for the company to grow. The interviewee also sees opportunity in growth of work with governments regarding certification, regulations, and type approval.

By working in research collaboration projects with customers, governments, and universities the company gets a better understanding of the technology and the current industry challenges. The interviewee believe that the importance of collaborations will increase for the company as the system becomes more complex. Areas like deep learning are emerging and the company cannot have experts working in all areas. Therefore, collaborations are necessary to be able to adopt fast.

The company provides the customer with a private cellular 5G network, which was created in a collaboration project. They are also constructing a digital map of the facility to get ground truth both for internal usage and for customers. However, the interviewee spoke about a problem related to this. There are today many different ways to build digital maps and it is impossible to know what the standard way in the future will be.

Other new services that the company offers includes a driving simulator intended for testing of both manual and autonomous vehicles. “As a service provider for the automotive industry we cannot choose one technology over the other because the industry will demand all the possibilities.”

3.8.3 Testing

The interview brought up different approached of verifying safety. Some companies are trying to drive large number of kilometres in real traffic to prove statistically that the autonomous vehicle is safe. Other are trying to verify safety of modules. An association of car manufacturers have come up with the following four steps to verify safety: (1) Proving ground testing (according to the interviewee this will still be important but might change how it is used), (2) safety audit of the developer where it is checked that the development follows ISO standards, (3) real life driving to statistically prove safety (this is according to the interviewee easy but expensive), and (4) a new concept of driving license for the autonomous vehicle. The interviewee believe that the company will work with all these types of testing in the future and with virtual validation. However, the fact that virtual validation is hard to do for a 3rd party without all the information of the system is brought up.

The differences in testing of autonomous vehicles will according to the interviewee be that we need to test that the system is always safe and not only works in hazard events.

As mentioned before, the company works closely with governments already today. One of the areas includes legislation on testing. The legislation that the company helped develop for testing permissions of autonomous vehicles includes information from the OEM including *where*, *when*, *how*, *under what conditions*, and *in which operational design domain* the test will be conducted. Furthermore, the safety function should be tested and proven safe on test tracks and an override function should be verified. The safety drivers that conducts the tests should have the right knowledge about the systems and have the right education on test driving. Finally, documentation on development process must be submitted that shows that the applicant follows ISO standards.

The interviewee believe that how much testing will be necessary depends mostly on what operational design domain the functions are intended to be used for.

3.8.4 Data

The company works with collecting data in real traffic for OEMs during active safety testing and the interviewee believe that this business will increase in the future when autonomous vehicle comes. “The real traffic driving will be used to trigger false positives, which will be very important for the calibration of autonomous driving functions.” The company also collects data for internal use in research. If data could be compatible with the company usage, they would be open to share data with other organisation to get more data.

To secure the data, the company has internal procedures and when working with client data the clients often have their own demands on cyber security that always are implemented.

The interviewee spoke about the future with a common database for critical scenarios that can be used to test autonomous vehicles in simulation and on testing facilities. Problems was brought up like: *who would own this dataset*, *who should create it*, *how many scenarios*, and *will the policy makers agree*? The interviewee believes that the scenarios will have to continuously change over time since the traffic also changes. Moreover, even if autonomous vehicles can avoid many accidents, we cannot yet know what type of accidents autonomous vehicles might cause and it is therefore hard to decide on scenarios to test.

The interviewee believes that the company could be part of collaborations to create a database with critical scenarios, but it is not yet a strategy decided on. It will be a challenge since it must be clear what the data should be used for. According to the interviewee the data should be open if it is used for certification, but the company might have a dataset for internal and customer usage only. A problem brought up by the interviewee is that it is expensive to manage and store data. To handle this new way of working with data, perhaps different business models are needed. One solution could be that companies pay to access the data, or they must contribute to get access.

3.8.5 Safety

According to the interviewee the responsibility should be shared between the driver and the autonomous vehicle, depending on who is in control of the vehicle. In manual mode we will still have the classical solution with insurance companies, and in autonomous mode the insurance company can hold the OEM responsible. The OEM can then hold their suppliers responsible if a subsystem is found to be the source of the failure that led to an accident

The interviewee says that the company cannot take any responsibility of safety for a deployed vehicle since they are not in control of the development. However, the company is open to do certification of autonomous vehicles for governments as mentioned before.

The company is involved in testing done by a rating organisation today. This rating organisation spreads knowledge about the vehicles they test and explains the functionality to increase knowledge among possible customers. The interviewee believe that this kind of work will help to increase the trust and understanding of autonomous vehicles in the future.

3.8.6 Communication possibilities

For good features on connectivity to be possible the interviewee believes that the industry needs standards. This will help different vehicles to communicate regardless of brand. The interviewee hopes that the rework of ISO26262 that is being done will include more on these kinds of topics related to autonomous vehicles.

The interviewee brought up problems with both vehicle to vehicle communication and the usage of 5G network. The first solution will need standard protocols to work and the second solution will need investments on infrastructure to make 5G available everywhere. Regarding dynamic maps, the interviewee believe that it will be hard to ensure that the information quality is good enough. Especially in poor countries this will be a problem.

4 Analysis

In this chapter the authors compare and analysis the answers from the stakeholders. The comparison is done within the same subtopics as used before and in many cases the comparison is focused on stakeholder in similar businesses.

4.1.1 The future

From the stakeholder interviews many different challenges and hindrances are present for the development and deployment of autonomous vehicles. The stakeholders cannot agree on what hindrance is the most important or hardest to overcome. Most of the problems are discussed in all interviews. This shows how unclear the future for autonomous vehicles is and that many problems still do not have a clear solution. The industry knows that there will be hindrances for the development and deployment, but not yet what they will look like and how to solve them.

Some similarities can be seen from the interviews with the Chalmers and the two government organisations. They all claim that the biggest hindrance will be the safety of the technology. In the same way, similarities can be seen from the answers from testing service organisations where they claim that the regulations and laws will be the biggest hindrance. In the interviewee with government organisations in was mentioned that collaborations are done with regulators. Both the government research organisation and the testing service provider #2 brought up the problems of different regulations in the US and the European Union. Also, the risk of fragmentation between countries regarding road regulations and road infrastructure was mentioned. This could possibly be very costly for the industry in the future.

Moreover, all stakeholder seems to agree that more collaboration and increased transparency between organisations in all areas of autonomous vehicles will be needed in the future for the technology to be successfully developed and deployed. However, Chalmers is the only stakeholder in these interviews that have an open source code already today.

Most of the stakeholder brought up the problem of lack of methodologies for test and verification. They all believe that the methods used today will not work for autonomous vehicles and that it will take more research, and trial and error, before good methods are found.

Several of the stakeholders mentioned the problem of increased number of vehicles. Even if they all hope for a reduces number, they express concern that the increased availability and reduced cost of transportation that might come with autonomous vehicles will make people travel more in cars. This is a problem that will have to be handle both by the industry, but also by government and the society itself.

4.1.2 Organisation for autonomous vehicle development

Since the stakeholders play different roles for the industry, the organisation is also different. By comparing the stakeholder with other stakeholder in the same area, some analysis can be made.

The two testing service providers spoke about having to be fast in adoption to keep up with the industry demands. An example of this how both organisations have implemented 5G networks on their facilities and are soon to have digital maps. Both organisations also conduct research on new equipment for testing and have collaboration projects with partners to improve the services. The importance of this is expressed by both interviewees as they brought up the fact that they cannot have in-house expert knowledge in all areas. However only the testing service provider #2 have a simulator and is working with virtual validation. Both interviewees believe that the usage of test tracks will continue to be important in the future. Testing service provider #2 already today works with approval for governments, while the testing provider #1 would be open to this kind of assignments in the future.

The two OEMs are in the process of increasing their workforce related to development and verification of autonomous vehicles. However, the OEM #1 is further ahead in this and already have project that will start testing soon. Both interviewees spoke about increasing the in-house development and believes that test and verification will be a big thing that must be rework in the future for autonomous vehicles. They both also believe that new business models will come, but that it is yet to early to say what they will look like. The conclusion can be made that both companies will continue to sell vehicles to private users, and this will be the bigger part of the business also in the future with autonomous vehicles.

The two governmental organisations and Revere are different actors compared to the rest of the stakeholders in this study since part of their purposes is to help create useful collaborations in the development of autonomous vehicles. Revere links the industry and the university together in research projects that pushes the limits of the technology forward. The government research organisation links research on future technology and the government organisations for regulations on the topic, sometimes with the industry involved in the projects. This work helps both the industry to work according to the regulations and the regulators to find new ways to regulate that is both safe and helps the industry to be successful. Finally, the government strategic innovation program works to link industry companies and organisations together to help push the technology forward. Often the projects are focused on what is beneficial for the society. The conclusion can be made that these organisations is a big part of the reason why Gothenburg have become a hub for the development of autonomous vehicles, not only for Sweden but also for Europe.

4.1.3 Testing

Both the interviewees from OEMs believes that more testing will be done in simulation in the future. The challenge to prove that what is tested in simulations

also works in real life is stressed by both interviewees. The OEM # 2 already today work with outsourcing of testing and both OEMs works with partners in hardware and software development. The conclusion can be made that the development of autonomous vehicle is very reliant on suppliers and their products and knowledge. Both interviewees also hope that rating organisations will soon include autonomous vehicles and that some guidelines on how to test will be presented. This shows how much the OEMs are dependent on ratings and that they need the rating organisation to form the path for how to conduct testing. The testing service provider #1 agree that simulation will be important, but still believed that the real-life testing will increase in parallel. Another possible solution for approval was discussed in the interview with the testing service provider #2, where the interviewee mentioned the possibility to have a driving licence for autonomous vehicles.

A topic that was discussed in most interviews was also how regulations should look for real-traffic testing permissions. The testing service provider #2 brought up multiple ways of securing safety of such tests like override functions, proper education for drivers and to prove safety of function on test tracks before going into real traffic. The regulations will continue to vary across the world for now, but most interviewees seem to agree that it would save the industry both money and time if an international regulation on how to get testing permissions was established.

Across most interviews the possibility of set of standard test scenarios for autonomous vehicles was discussed. Some problems related to this was also brought up. The interviewee from the testing service provider #1 spoke about the constant change in demands of scenarios and that specific tests always will be demanded from the industry. The testing service provider #2 mentioned that we cannot today know what accidents autonomous might cause, and therefore we cannot set any standards on what scenarios should be tested. Because of these reasons and others related to business models, it becomes hard to create standards on test scenarios.

Furthermore, there seem to be a strong trust in future implementation of deep learning from most interviewees. However, the problem with validation of autonomous vehicles that have software developed with deep learning implementations is brought up multiple times across the interviews. The interviewees see the technology as promising, but there is still many uncertainties and problems to be solved. It is also important to mention that none of the interviewees are an expert in deep learning.

4.1.4 Data

The OEMs already today collects and stores data for future usage in the development of autonomous vehicles. The interviewees agree on challenges related to this. They both believe that it will be expensive to store data and therefore they store reference data and only data that is necessary for scenario reconstruction. Another problem that the interviewees from the two OEMs and

the consultant company brought up is that to share data with others could be hard if no standards are set on how to create and store data. Today the data recorded is very sensor setup depended. However, both the OEMs would be willing to share data with others to get more, if the data they got was ensured to be valuable. The conclusion can be made that there is great need for research on how to collect data, and as for methodologies for testing the OEMs are hoping for some other organisations to form a path on how to record data in a standard way. The interviewee from the government research organisation mentioned the possibility for them to involved in research projects regarding standards on how to record and store data in a way that would make it easier to share data between stakeholders. The conclusion can be made that this would be very valuable for the industry.

Both interviewees from the OEMs also agree that it would be valuable if data from sold vehicles could be obtained in the future. However, the problem of data ownership brought up by OEM #2 is still an unsolved problem in most countries. The problem was addressed by a government for the first time by the German government in their report on ethics for autonomous vehicle where they state: "It is the vehicle keepers and vehicle users who decide whether their vehicle data that are generated are to be forwarded and used" (Federal Minister of Transport and Digital Infrastructure, 2017). When interviews with both testing service provider was done both interviewees told that they collect data already today for customers. This emphasis the need for more data even more.

The two OEMs have departments working on cyber security already today, but the interviewees express a future need for more research. The interviewee from the consultant company spoke about the need for more collaborations on this problem between the automotive industry, the computer industry, and the government. This a good example of how more collaborations are need for the industry to be successful when the complexity of autonomous vehicles is addressed.

4.1.5 Safety

All stakeholders agree that the responsibility should be on the OEM if accidents happen in autonomous driving mode. Some on the interviewees discussed the need for a good data logger that can be used to verify if the vehicle or the driver was in control when the accident happened. This data logger could also be used to verify that the system has not been tampered with by any unauthorised persons. This way of reasoning has also been implemented by the German government in their report on ethics for autonomous vehicle where they state: "The distribution of responsibilities (and thus of accountability), for instance with regard to the time and access arrangements, should be documented and stored" (Federal Minister of Transport and Digital Infrastructure, 2017).

Both interviewees from the testing service providers told that they cannot take any responsibility for the deployed products, only on safety of the test conducted on their facilities. This is because they cannot control the development of the autonomous vehicle.

Furthermore, all stakeholder agree that the regulations should be designed in such a way that they do not hinder the technological development. All interviewees however believe that regulations are important to ensure safety of the system. The conclusion can be made that this will be a hard balance for the governments to handle, but also for the European Union. Regulations will be of great importance for the future development and the safety of road users.

Another safety problem was discussed in the interview with the OEM #2. The interviewee believed that many questions will arise related to updating of already deployed autonomous vehicles. Again, this is a problem that the German government brings up in the report on ethics for autonomous vehicles where they state: "From this, it follows that manufacturers or operators are obliged to continuously optimize their systems and also to observe systems they have already delivered and to improve them where this is technologically possible and reasonable" (Federal Minister of Transport and Digital Infrastructure, 2017).

The OEM #1 works closely with customers on their, soon to be deployed, autonomous vehicles in a project. By doing this and not only testing the vehicles with internal drivers, the OEM #1 hope to increase trust for autonomous vehicles. Other ways that stakeholders are trying to increase the trust are: Revere bringing people to the lab and participating in open seminars; the government strategic innovation program implementing the technology in small scale test in society; both the government organisations publishing two newsletters about future sustainable mobility solutions and new technology related to autonomous vehicles respectively.

4.1.6 Communication possibilities

Many of the interviewees believe in cloud communication rather than direct vehicle to vehicle communication. The arguments for this are mostly based on that it is hard to have cross brand standards and to get every OEM to implement this technology in sold vehicles. It will also take decades before most of all vehicles on the road would have such technology installed since manually driven vehicles will probably still be driven for a long time. However, some problems related to cloud communication was also brought up during the interviews. The interviewee from the OEM #2 spoke about that it will be necessary to put high demands on quality of the information being send and received from the cloud. To add to this, the interviewee from the testing service provider #2 brought up the need for more infrastructure if 5G network should be available everywhere and this might not be economically possible in all countries. The hope for 5G network and cloud communication was also indicated by that both testing service providers already have working 5G network on their facilities to meet the customers demand.

The general view of the interviewees is that digital maps will be of great importance in the future. Both the testing service providers are implementing this technology on their facilities and most other stakeholder are already conducting work related to this. However, it is still unclear how this will be implemented on a

broad scale in society and the interviewee from the government strategic innovation program brought up the problem of who should take responsibility. The interviewee did not believe it should be any government-controlled organisation and the business model for digital maps are yet not clear.

Some of the stakeholders like the OEM #1, both the testing service providers and the government research organisation are working in projects related to infrastructural changes for autonomous vehicles and they are often doing this in collaboration with city planners and road authorities. An interesting possible feature brought up by the OEM #1 was the possibility for emergency vehicles to communicate their route in advance via the cloud.

4.1.7 Formula Student Germany

As the author is a member of Chalmers Formula Student Driverless 2018 and visited the Formula Student Germany competition in Hockenheim some challenges that the formula student driverless teams are having can be discussed.

At the Formula Student Germany competition in 2018 only seven out of the seventeen teams in the driverless class were able to pass technical inspections to be allowed to drive their cars in the dynamic events. This is an increase compared to the year before where only four out of fifteen teams passed technical inspections, but still the numbers are low compared to the electrical car class where more than 62,5 percent (FSG, 2018) passes technical inspections. This reflects the complexity and many different knowledge areas that must be covered in order to create an autonomous race car. As the complexity increase, so does also the risk for errors and thereby need for personal with the right skills. It also emphasises the need for structured and documented design process in order to identify dependencies and possible faults in early stages of development and in case of errors. To identify the errors with limited time can be as hard as solving the problem once found.

5 Conclusion and Discussion

In this chapter the authors draw conclusions from the analysis and discuss important aspects of the future for autonomous vehicles. Finally, the author recommends future research that could be valuable in relation to this study.

This study aims to identify the future challenges for the automotive industry in the transition towards producing and deploying autonomous vehicles. From the interviews conducted with important stakeholders, it can be argued that the challenges are many and it is uncertain what challenges will be the hardest to overcome. Furthermore, the different type of stakeholders will have different challenges to handle. This will lead to combined effort for the industry to solve all challenges and be successful in developing and deploying autonomous vehicles. However, many of the challenges are shared between stakeholders, meaning that they cannot be solved without collaboration. To increase the transparency between stakeholder in order to reach a greater good could increase the speed and quality of the development but might also create problems for companies to differentiate themselves and in the end be more successful than competitors. The OEMs have a hard task in finding the balance between; sharing information and technology to increase the speed and reduce the cost of the development; and finding unique solutions that creates great customer value in their products compared to competitors.

From the analysis it can be argued that a lot of effort is being put into developing new methodologies for testing and verification. The stakeholders all agree that the methods used today will not work for autonomous vehicles. However, the methods are yet unknown. It can be argued that technology is not mature enough to create methods for testing and validation when it is too early to say what type of technologies will be used. This is related to the usage of new sensors; possible communication like 5G network and vehicle to X; standard test scenarios; implementation of deep learning and other such technological improvements being implemented in the development of autonomous vehicles.

The conclusion can be drawn that both simulation and real-life testing will be of great importance, but the balance between them will depend on how well the virtual validating can be proven to correspond to reality. Furthermore, the balance between real traffic and test track testing is still unknown. With more accidents happening in real traffic we might see a temporary shift towards test track testing for the technology to have time to mature even more. In the beginning there will be differences in regulations between countries and what type of real traffic testing they allow. This will influence both where we see future testing being done, but also where we might see customer mistrust if more accidents occur.

More data is constantly being recorded by different stakeholder in the industry and the hopes for sharing data to get more is common among the interviewees in this study. However, the differences in sensor setups and data recording makes it hard to share data today. It would be valuable with more research on how to record data in a good way that enables sharing and the need for standards related

to this is clear. To get more data some stakeholder hope that deployed vehicles will generate data back to the developer, but there are still unsolved problems related to this, one being data ownership. In the future it will be up to the governments or international regulators to regulate this possibility.

A big problem of autonomous vehicles is the one related to responsibility. This is something that will have to change with autonomous vehicles since the driver might not be in the control of the vehicle in the future, but accidents will still occur. A possible solution discussed in the interviews is to have a data logger, a black box, in the vehicles that monitors if the driver or the vehicle is in control. If an accident occurs when the vehicle is in control all stakeholders in this study agree that the OEM should be held responsible. However, the OEM can in turn hold the suppliers responsible, but this is will be dependent of their specific contracts. To conclude, this will be a problem that the government or international regulators will have to address, just as the one with data ownership. It can be argued that the regulations are slacking in comparison to the technology development and that many problems will have to be addressed in the future that will shape the way the development of autonomous vehicles will continue.

The German government have been pushing the regulations and guidelines for autonomous vehicles more than any other government or international organisation. Therefore, their reports from the Federal Minister of Transport and Digital Infrastructure will have great influence on other countries and organisation. It will also be a test to see how the industry reacts to the regulations and a chance for other countries to maybe improve the regulations. It is however very important to do this soon and the German industry will have a head start for testing and deployment possibilities because of their more matured regulations moving forward.

The low number of teams that passes technical inspections at the Formula Student Germany competition indicates that there is lack of mechanical and electrical knowledge in the teams in relation to the other classes. Furthermore, this fact emphasises the need for mechanical and electrical functionality in driverless cars. Without a reliable working car, the autonomous system will never be activated.

In the Formula Student Germany competition, all team in the driverless classes uses previously built vehicles, which mean that the car is not actually built for autonomous driving. This is for some vehicle manufactures not the case since they design autonomous vehicles in more detailed, but a lot of mechanical and electrical design is often kept from the manual cars. In order for autonomous vehicles to reaches the highest possible worth for the industry and the customers it might be necessary to rethink how we believe cars should look like. Some companies like Toyota (Dezeen, 2019) have already started looking at new concept vehicles for the future, but it is yet to early to say what will be put in production and what will only be a design.

5.1 Future research

The conclusion regarding customer trust from the interviews is that it will be an important part for the future of autonomous vehicles. To be able to make more detailed analysis it would be necessary to conduct a customer survey where diversified current and future car owners get to answers questions regarding autonomous vehicles. The results from this survey could then be compared with the results from the interviews conducted in this thesis. The comparing analysis would be interesting both for the industry and governmental organisations. As a part of this thesis, the author prepared question for such a customer survey. This could make a good starting point for future research on the topic of customer trust for autonomous vehicles and if the suggested questions are used the comparison between the results in this report would be easier to make. The survey question can be found in Appendix B.

Most of the interviewees in this study were acting in Sweden, even if some organisations were international. The one OEM that declined the request to participate likely did so because of the non-existing link to Gothenburg and Chalmers. In the future it would be valuable to expand the geographical area of the study and try to involve more organisations and companies in other countries than Sweden. This would make analysis possible on differences between countries and markets for the industry of autonomous vehicles.

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Appendix
A Stakeholder Interview Questions

First two open start up questions was asked.

What do you think will be the biggest hindrances to deploy autonomous vehicles on the market?

a. Vehicle technology not safe enough

b. Lack in infrastructure that supports autonomous vehicles

c. Lack in consumer trust and understanding regarding autonomous vehicles

d. Law and insurance disputes

e. Other:

What will be the biggest benefits with autonomous vehicles in the future?

a. Time for the driver to do other things while being transported from A to B

b. Reduced amount of accidents and reduced severity of accidents in traffic

c. The possibility for people without the possibility to get a driving licence (young, old or disabled people etc) to ride a car

d. Increased number of working and income possibilities for the industry

e. Other:

The following questions are divided under different topics and then mirrored to the different type of stakeholder to make it possible to identify similarities and differences.

General

OEMs	**TESTING**	**SOFTWARE**
In rough measures, how much of the company's resources goes into AD development? (People, Money)	In rough measures, how much of the company's resources goes into development of AD testing possibilities?	In rough measures, how much of the company's resources goes into AD development?
To what level of automation do you plan to reach? What will be the steps in between?	What levels of automation do you plan to be able to test? What	To what level of automation do you plan to reach? What will be the steps in between?

How do you work with development of AD vs assist system? Any differences`? If you would estimate, when will you launch a self-driving car to the market that can drive in Gothenburg city and near surrounding without a human driver having to be observant?	will be the steps in between? How do you work with testing of AD vs assist system? Any differences? If you would estimate, when will you launch a self-driving car to the market that can drive in Gothenburg city and near surrounding without a human driver having to be observant?	How do you work with development of AD vs assist system? Any differences? If you would estimate, when will you launch a self-driving car to the market that can drive in Gothenburg city and near surrounding without a human driver having to be observant?

Business

OEMs	**TESTING**	**SOFTWARE**
Who do you see as possible customer for the AD vehicle? Same as for your normal cars? How does the company work with outsourcing of different kind for AD development? (collaborations, start-ups etc?) How much of the AD development is outsourced or kept inhouse? Will this change? Drawbacks / Benefits with this? Will it change in the future? How much of the software would you be willing to share with other OEMs and how much do you want be brand specific? (Any standard "components"	Do you think you will have other types of customers moving into AD testing? How does the company business model look like in terms of testing yourself vs letting the developer test with the help of your resources? Will it change in the future for self-driving vehicles?	How does your customer base / business relations look like? How does the company work with outsourcing of different kind for AD development? (collaborations, start-ups etc?) How much of the AD development is outsourced or kept inhouse? Will this change? Drawbacks / Benefits with this? Will it change in the future? How much of the software would you be willing to share with other developers and how much do you want to be yours? (Any standard "components"

in the software you can see in the future?) Who would be responsible for verifying safety in case of outsourced development? Do you have any other business models in mind that one person buying one vehicle as it is today?		in the software you can see in the future?) Who would be responsible for verifying safety in case of outsourced development?

Testing

OEMs	**TESTING**	**SOFTWARE**
How do you believe the testing should be done on an AD vehicle? (Standards cases, runtime?) What kind of measures will you take to make the testing done in real environment safe? When do you think you have tested enough? Any general challenges regarding testing you see for AD vehicles?	How do you believe the testing being done on an AD vehicle? (Standards cases, runtime?) Will you be testing in real environment or only on test tracks? What kind of measures will you take to make the testing done in real environment safe? When do you think you have tested enough? Any general challenges regarding testing you see for AD vehicles?	How do you believe the testing should be done on an AD vehicle? (Standards cases, runtime?) What kind of measures will you take to make the testing done in real environment safe? When do you think you have tested enough? Any general challenges regarding testing you see for AD vehicles?

Data

OEMs	**TESTING**	**SOFTWARE**
Would you be open to share recorded data between companies to increase the data available for simulation and learning?	Would you be open to share recorded data between companies to increase the data available for simulation and learning?	Would you be open to share recorded data between companies to increase the data available for simulation and learning?

How do you collect and save data at the moment? How much data do you aim to store per second during running? How much runtime data do you aim to collect? Will you own the data collected in vehicles or does the car owner own the data? How do you plan to have safe and secured data?	How do you collect and save data at the moment? Any general challenges regarding safety and testing you see for AD vehicles? How do you plan to have safe and secured data?	How do you collect and save data at the moment? Any general challenges regarding safety and testing you see for AD vehicles? Will you own the data collected in vehicles or does the car owner own the data? How do you plan to have safe and secured data?

Safety

OEMs	**TESTING**	**SOFTWARE**
Who do you think should be responsible for the safety of the self-driving vehicle? (OEM, Testing, software?) Would you be willing to take any responsibility for safety of the finished car? To what extent? Who and how will safety be verified during software updates? Would you prefer strict laws to push safety or let the development improve continuously as for passive safety? Are you doing any work do increase the trust for	Who do you think should be responsible for the safety of the self-driving vehicle? (OEM, Testing, software?) Would you be willing to take any responsibility for safety of the finished car if you decided to test it? To what extent? Who and how will safety be verified during software updates? Would you prefer strict laws to push safety or let the development improve continuously as for passive safety? Are you doing any work do increase the trust for	Who do you think should be responsible for the safety of the self-driving vehicle? (OEM, Testing, software?) Would you be willing to take any responsibility for safety of the finished car? To what extent? Who and how will safety be verified during software updates? Would you prefer strict laws to push safety or let the development improve continuously as for passive safety? Are you doing any work do increase the trust for

AD among customers? How about increased knowledge?	AD among customers? How about increased knowledge?	AD among customers? How about increased knowledge?

Infrastructure

OEMs	**TESTING**	**SOFTWARE**
What kind of V2I would you like to see in the future that would help the AD vehicles? Other infrastructural features you can think of that would help self-driving vehicle deployment?	What kind of V2I would you like to see in the future that would help the AD vehicles? Other infrastructural features you can think of that would help self-driving vehicle deployment?	What kind of V2I would you like to see in the future that would help the AD vehicles? Other infrastructural features you can think of that would help self-driving vehicle deployment?

V2V

OEMs	**TESTING**	**SOFTWARE**
What kind of V2V would you like to see in the future that would help the AD vehicles? Any other information you would like to have from the cloud?	What kind of V2V would you like to see in the future that would help the AD vehicles?	What kind of V2V would you like to see in the future that would help the AD vehicles? Any other information you would like to have from the cloud?

B Customer Survey Questions

Info

All the answer will be handled anonymously.
To be able to categorize the answer we would like some background information about you as respondent:

Your age:
Under 20 years, 20-39 years, 40-60 years, Over 60 years

Are you regularly using a car?
Yes, I own
Yes, I rent a car
Yes, I have access to a car
No; I do not use a car on regularly basis

What is your current state of occupation?
I´m an elementary or high school student
I´m a college or university student
I´m working with technology development
I´m working with something non-technological related
I´m not working or I´m a senior citizen

Attitude and experience

Manny modern vehicles have systems that aids the driver to drive safely. Have you ever drove a car with the active safety systems?

Auto emergency brakes (AEB)
Adaptive cruise control ACC)
Lane keeping assistance (LKA/LDW)
Blind spot detection (BSD)

How would you say experienced these systems?

Good, they perform their task and I always keep them on
Mediocre, sometimes performs well, sometimes it does not feel secure
Not good, I feel unsecure and I tend to turn the systems off when I can
I have never drove a car with such systems

It is written and talked a lot about self-driving vehicles. How big would you say your insight in the development of autonomous vehicles is?

I know nothing or very little about autonomous vehicles
I know little and understand the basics about how autonomous vehicles works
I know a lot, understand how they work, and can imagine how autonomous vehicles could change the transportation in the future

I work with autonomous vehicles and therefore have deep understanding about the technology,

There are many different types of driving scenarios the developers hope that autonomous vehicles will handle in the future. Would you be willing drive or ride in a vehicle that can drive autonomously without your monitoring at:

Highway	Yes/No
Rural road	Yes/No
City traffic	Yes/No
Parking	Yes/No

The possibilities that autonomous vehicles bring with them could be many. Are there any further possibilities or features of autonomous vehicles you would like to see?

TEXTBOX, not mandatory.

A vision that might be even further into the future is new kinds of transportation vehicles that no longer looks like todays cars. Would you be willing to buy or to subscribe to a service with a vehicle that can drive fully autonomous and do not have any steer wheel or pedals?

Yes/No

If you answered No on the question before, why not?

TEXTBOX, not mandatory.

Testing

Many questions are raised regarding testing of autonomous vehicles. Would you as a road-user (pedestrian, bicyclist, driver etc.) feel save if there were self-driving vehicles conducting testing on the roads? For this question we can assume that there is a fallback person in the vehicle monitoring the testing.

Yes, I trust the governments regulations for permission of testing
Yes, if it is clearly visible which cars are self-driving so that I can adopt my action accordingly.
No, I would feel unsafe and I do not think that autonomous vehicles should be allowed to test in real traffic

Autonomous vehicles will come sooner or later to some extent. How safe do you think that an autonomous vehicle should be compared to a human driver before it is acceptable to sell and drive it in real traffic?

An autonomous vehicle should never cause an accident
An autonomous vehicle should be safer than a human driver

An autonomous vehicle should be as safe as a human driver
An autonomous vehicle can be less safe than a human driver, because they bring other benefits.

If you answered alternative 2 on the previous question, how many times safer do you think an autonomous vehicle should be compared to a human driver before it is acceptable to sell and to drive it in real traffic?

TEXTBOX for number insert, not mandatory.

It is important to feel safe before buying a car. If you were to buy an autonomous vehicle of any level, what would make you feel the most trust?

That I´m exempted from any responsibility for accidents caused by the vehicle itself
That the government have tested the model of the vehicle and declared it safe
That the manufacturer has tested the model of the vehicle and declared it safe
That the manufacturer has tested the specific vehicle I´m buying and declared if safe
That I can test drive the vehicle I´m buying and declare it safe myself

I hope that this survey has made you think about the future of mobility and all the possible solutions. Would you wish that there was more information about the development of autonomous vehicles?

Yes, I would like to see more available information
No, it is enough information already

I deeply thank you for your participation in this survey

(Perhaps share information about where to read more about the development of autonomous vehicles and links to the governmental newsletters)