The past, the present and the potential future of autonomous vehicles in the EU and in the USA

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Abstract

This thesis discusses the rapidly developing autonomous driving technology by comparing the technology, the legislative environment and consumer attitude in the EU and in the USA. The research focuses on Tesla as it is the company with the most advanced vehicles regarding self-driving functionalities, with often unique development approaches. The thesis answers the following research question:

"Which disconnects can be observed in the EU and the USA between legislators, industry, and society regarding the attitude towards the emerging autonomous driving technology and how can these disconnects influence the immediate roll-out of AVs in the studied region as the technology becomes available?"

In order to answer the research question, I have identified 8 unique scenarios based on possible disconnects among the studied three actors (regulators, society and technology). I argue that disconnect between any of the three actors will hinder the roll-out of AVs at a different degree. Placing the scenarios into an alignment cube model allowed me to rank the scenarios based on the likelihood to facilitate the quickest possible adoption of the AV technology, once it becomes available. The thesis discussed the most relevant risks and perceived benefits of the technology, the past, the present and predicted future societal acceptance of AVs, the legislative actions, and the different industry actors in the EU and in the USA to conclude that once fully autonomous vehicles will be perfected, they are most likely to hit the road first in the USA. A perfect alignment was observed among all three actors in the USA. In the EU, some degree of disconnect was observed among regulation and technology, and possible disconnects were discovered among regulation and society and technology and society. The thesis aims to contribute to understanding how complex regulating emerging technologies can be by building upon the theories on regulatory disconnect and discussing the possible disconnects not only among regulators and technology but among society and the other two actors as well.

Keywords: *Autonomous vehicles (AVs), Self-driving, Tesla, Regulating smart technology, Disconnect, Societal acceptance, Comparative analysis, EU, USA*

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List of Abbreviations

ADS	Automated driving system
AVs	Autonomous Vehicles
CAVs	Connected and Autonomous Vehicles
CEN	European Committee for Standardization
C-ITS	Cooperative Intelligent Transport Systems
CVs	Connected Vehicles
DARPA	Defense Advanced Research Projects Agency
DDT	Dynamic driving task
DOI	Diffusion of Innovation Theory
DOT	Department of Transportation
ETSI	European Telecommunications Institute
EU	European Union
FHWA	Federal Highway Administration
GM	General Motors
HAVs	Highly Autonomous Vehicles
ISA	Intelligent Speed Assistance
LIDAR	Light Detection and Ranging
MS	Member State
NAV	Networking for Autonomous Vehicles
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transport Safety Board
ODD	Operational design domain
OEDR	Object and event detection and response
OEMs	Original Equipment Manufacturers
PAVE	Partners for Automated Vehicle Education
RDW	Rijksdienst voor het Wegverkeer
RWS	Rijkswaterstaat
SEA	Society of Automotive Engineers International
UN	United Nations
USA	United States of America
VW	Volkswagen

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1. Introduction

Driverless cars have inspired many fictional products in the past. As early as in the 50's, The Science Fiction Theatre featured an episode in which a driverless car remotely controlled by a radar caused panic when its controls got jammed, and it injured a woman seriously. While the episode had a happy ending, it portrayed an experiment gone wrong involving a driverless vehicle. Nearly 60 years later fiction became reality when the first driverless car prototypes were shown on TV in the news rather than in science fiction programs. What was once an idea for the distant future is now our reality. Car robotization is a major trend in which the entire society is invested (Fortunati, Lugano, & Manganelli, 2019). Driverless cars are debated in the mass media and in social media as well. Policy reports are produced focusing on the topic and manufacturers issue press releases about the newest developments rapidly.

Autonomous vehicles -which are capable of sensing their environment and operating without any involvement form a dedicated human driver- were expected to be ready to hit the roads by the end of 2020, according to Elon Musk, CEO and product architect of Tesla, Inc (ARK Investment Management LLC, 2019). While this was considered to be a bold prediction according to industry experts (Gessner, 2019), it is not necessarily due to the technology not being available. Bryan Reamer argues that while driverless cars are indeed the future, the timeline we are looking at might be longer than car manufacturers are suggesting. There are several factors influencing when driverless cars can hit the public roads once they are fully developed. Improvement or changes in the current road infrastructure or communication systems are just as crucial as additional traffic laws to regulate driverless cars according to Reamer (2019).

In order to understand how fast the automotive industry arrived at the point where discussion of deploying self-driving vehicles became reality, part 1.1 and 1.2 offers a brief presentation of the main achievements during the past century. The focus is on highlighting how smart technologies rapidly transformed the industry, creating uncertain, dynamic, and evolving transport problems (Shunxi, Pang-Chieh, Jinsheng, & Chahine, 2019).

1.1. Milestones in a rapidly developing industry

The beginning of the automobile industry dates back to the late 1800s, when Ransom E. Olds opened an automobile manufacturing factory in Detroit (Automotive Hall of Fame, 2019). Olds had built several prototype cars. Among others, at least one of steam, one of electric and one gasoline-powered vehicle. Before a definitive choice could have been made on which of the prototypes should be put into large-scale production, a factory fire destroyed all but the gasoline-powered prototype. Based on this model, 425 cars have been manufactured in 1901 and the groundwork for the American automotive industry had been laid (Automotive Hall of Fame, 2019).

The next milestone in the industry was the debut of Ford's Model T on October 1, 1908. Between 1908 and 1927 Ford built 15 million Model T automobiles. This volume of production was made possible by the development of an assembly line in 1913 by the Ford Motor Company (QAD CEBOS, 2019). Since the mass production of automobiles had started, the industry has been shaped by a never-ending chain of development. The technology used to produce the vehicles improved tremendously over the past 100 years to keep up with the increasing demand of consumers. In 2020, 77.9 million motor vehicles were produced around the world (ACEA, 2021).

In the meantime, the technology used in the vehicles has also been developing rapidly. Some of the most important safety and quality of life improvements, including automatic transmission, air conditioning, seat belts and airbags were introduced between 1940 and 1980. Besides those features, that have become baseline over the past decades, the research and development of vehicle automation was initiated by General Motors and Radio Corporation of America Sarnoff Laboratory in the 1950s (Faisal, Kamruzzaman, Yigitcanlar, & Currie, 2019). Since then, a number of other programs focusing on the development of self-driving vehicles in the transportation industry have been operational mainly in Japan, in the USA and in the EU. Some of these programs were initiated by government agencies and academia, others were driven by leading manufacturers (Faisal, Kamruzzaman, Yigitcanlar, & Currie, 2019).

The development of automated vehicles has been fast paced. The breakthrough was in the 90's, when hybrid cars became increasingly interesting for car manufacturers. The focus of the automotive industry began to shift from gasoline to alternative fuel options to make cars less dependent on the environmentally unfriendly fuels (QAD CEBOS, 2019). To be able to develop environmentally friendly cars the technology used in vehicles began to evolve rapidly. One of the biggest milestones in the history of the automobile manufacturing was the incorporation of state-of-the-art AI technologies enabling the development of autonomous features (FutureBridge, 2020).

1.2. Smart technology in the automobile industry

The use of smart technology in the automobile industry dates back to the early 2000s. The motivation was to build safer and environmentally friendly cars. Major car manufacturers began developing their own technology for automated vehicles. In 2006 Ford started developing autonomous driving technology and in 2017 the first test vehicle was ready for road testing. Google set out the goal to produce fully autonomous vehicles in 2009 and by 2017 the test fleet had completed three million miles within four US states (Faisal, Kamruzzaman, Yigitcanlar, & Currie, 2019). Audi, BMW, Mercedes-Benz, and Nissan are also planning to introduce their AVs within a few years (Fagella, 2017).

While the speed at which these companies have produced initial results is impressive, if one mentions autonomous driving in 2021, it is likely that people will associate it with Tesla. In 2014 Tesla introduced a semi-autonomous driving technology, first of its kind. Their cars were capable to automatically take safety actions, park themselves and had advanced cruise control. This was the first step towards creating fully autonomous vehicles which can handle all aspects of driving in certain conditions (Geonovum, 2017). By 2016, Tesla developed the hardware needed for self-driving which became available on all their vehicles sold since. Although full autonomous self-driving is not yet available for the public, Elon Musk claimed in 2019, that the hardware part of the technology is ready, and it is a software update away from being available for the public on all Tesla vehicles (ARK Investment Management LLC, 2019).

This marks the beginning of the transformation of both the automotive and the transport industry. The introduction of fully automated vehicles onto the roads would bring positive changes among others on traffic efficiency, traffic safety, environmental or accessibility issues. However, it would also pose for example safety, liability, privacy, cybersecurity, and industry risks (Shunxi, Pang-Chieh, Jinsheng, & Chahine, 2019). As with all rapidly developing technologies, the role of the governments is crucial to maximise the potential benefits and minimise the risks associated with autonomous vehicles in a timely fashion (Taeihagh & Si Min Lim, 2019).While fully autonomous vehicles are still in development, semi-autonomous vehicles are already on the roads.

There are six generally agreed levels of automation going from no driving automation (Level 0) to vehicles with full driving autonomation (Level 5) (SAE International, 2021). Level 1, 2, 3 and 4 automations refer to vehicles which are equipped with gradually more capable automated assistance systems that can take over certain tasks from the driver (see Table 1 for more explanation on the levels of automation). In 2018, 29% of all motor vehicles were produced in China, 23% in the EU and 18% in the USA. Most of the level 1 and 2 AVs currently in traffic are in the USA and in the EU (Geonovum, 2017). With the growing number of Level 2 and some level 3 vehicles on the road and the quick development of the technology that can eventually allow self-driving cars to be ready for roll-out within years, legislators in the EU and the USA have a long way to go if they want to keep up with the speed dictated by the autonomous driving technology (Ramsey, 2015).

1.3. Methodology and theory

The focus of this paper is to describe the political, legal, and social environment in which driverless cars are being developed. Specifically comparing the European Union and the USA to see if differences among the two can be observed. I chose to focus on Tesla and their road to create autonomous vehicles. As explained in chapter 2.2.1, Tesla is considered to be ahead of the industry in the development process. They set the pace at which society as well as legislators are forced to react on the emergence of this new technology. In order to understand why Tesla is ahead of other manufacturers, and whether the technology they developed is to be fully utilized as soon as it is available, I will compare the different stakeholders' presence, the different regulatory environment and societal acceptance to identify possible disconnects among them. I compare the EU and the US on the status of all three variables. The goal is to determine whether AVs will more likely to be deployed on the European or US market first based on the observed differences.

In order to be able to draw conclusions, I have been collecting data on the studied topics through studying scientific articles, non-scientific media coverage, interviews as well as video recordings. Additionally, legal documents from the EU and US regulatory bodies have been studied to provide guidance on the regulatory strategy and environment in the studied regions, while statements, blog posts or similar proceedings from manufacturers contributed to widening my knowledge about the current and predicted future state of the AV technology. Finally, the main source of information on consumer attitude have been collected by studying several survey results on the topic over time in both the EU and the USA. The main topics guiding my search for literature included autonomous vehicles, regulatory disconnect, regulating emerging technologies and consumer acceptance. The aim of this thesis is to answer the following research question:

Which disconnects can be observed in the EU and the USA between legislators, industry, and society regarding the attitude towards the emerging autonomous driving technology and how can these disconnects influence the immediate roll-out of AVs in the studied region as the technology becomes available?

I have formulated four sub-questions to help structure the thesis and to help answer the main research question. These are the following:

Sub-question 1 (SQ1): What have been the main technological advancements allowing the development of autonomous vehicles and what are the expected societal, economical, or environmental impacts of the rapidly developing AV technology?

Sub-question 2.1(SQ2.1): Who are the key industry, legislative, and societal actors on the autonomous driving landscape, and what impact do they have on the AV ecosystem? Sub-question 2.2 (SQ2.2): Are there differences between the EU and the USA regarding the attitude of the studied actors towards the AV technology?

Sub-question 3 (SQ 3): How has the development of the AV legislation in the EU and the USA been evolving and what are the main similarities and differences that can have an impact on the tempo of the rollout of autonomous vehicles in these two regions?

Each sub-question is addressed in a separate chapter from chapter 2 to 4, while chapter 5, the conclusion presents the answer for the main research question. To strengthen the structure of the thesis, I have decided to work with a guiding hypothesis which reads as follows:

Disconnect between any of the three studied actors (regulators, technology, and society) will hinder the roll-out of AVs but at a different degree.

The hypothesis is guiding in nature, since the moment of writing the thesis, it is impossible to fully test this hypothesis (Punch, 2006). Autonomous vehicles are yet to be available for roll-out so the true impact of my chosen independent variables (regulation, technology, societal acceptance) on the dependent variable (roll-out of AVs) is only observable in limited capacity and on a theoretical level. However, I see an added value of structuring the thesis with the hypothesis in mind, since the model created (see Figure 1) will help answer the main research question and its validity will be testable once AVs hit the road in one of the studied regions.

The main thought process behind creating this hypothesis started from three very simple assumptions how an emerging technology could fail:

- If people are not open to purchase a self-driving vehicle, the technology will eventually fail, and manufacturers will look at other fields for innovation.
- If regulation prohibits the use of self-driving vehicles, the technology will eventually fail, and manufacturers will look at other fields for innovation.
- If self-driving vehicles are never to be perfected due to lack of sufficient technological innovation, the technology will eventually fail, and manufacturers will look at other fields for innovation.

These three simple assumptions are the result of extensive literature review on challenges of regulating and lack of/slow regulation of emerging technologies in the EU and in the USA. Most scientific literature on the topic studies the potential impact of a disconnect between regulation and technology and what can be improved in the process of creating fitting regulation. Fosch-Villaronga and Heldeweg (2018, p. 1259) argues that "regulation does not move as quickly as innovation happens". Even though both are in a continuous state of changing, this does not imply that they are moving to the same direction or with the same speed. This potential disconnect can cause uncertainties for the developers of the technology and for the regulators as well (Fosch-Villaronga & Heldeweg, 2018). It can become unclear for the technology actors which, if any of the existing legal framework is applicable for development or roll-out of the new product, while it can be unclear for the regulators when an emerging technology warrants for normative change (Fosch-Villaronga & Heldeweg, 2018). The proposed solution to minimize disconnect between those two actors was the creation of a hybrid top-down/bottom-up approach when it comes to developing the regulatory framework on robot governance.

Similarly to robot governance, when regulating the AV technology, taking only the top-down approach into consideration comes with risks. This approach relies on the existence of regulation that applies to the specific technological area that is developing rapidly. However, in case of the autonomous technology, European standards lack to provide regulatory coverage (Fosch-Villaronga & Heldeweg, 2018). Therefore, relying on top-down approach solely is creating a risk of regulatory disconnect. According to Fosch-Villaronga and Heldeweg (2018) the bottom-up approach to regulating emerging technologies can offer a more realistic picture on the risks and benefits of an emerging technology. It can also offer specific views on complex systems that potentially could be regulated by the same set of rules even though the application of the technology is different, as risks they pose on the user might be very different. An example Fosch-Villaronga and Heldeweg gave was regulating care robots and drones. While the care robots can't fly, they might pose similar privacy risks to the society as flying drones. The bottom-up approach is generally considered time demanding and is rarely explored as a viable option to regulating emerging technologies (Fosch-Villaronga & Heldeweg, 2018).

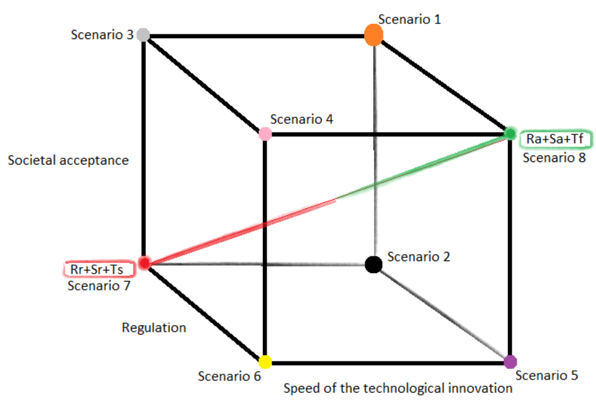
A mixed approach is suggested by Fosch-Villaronga and Heldeweg (2018) where part of the process comes from the traditional top-down, parts from the bottom-up approach in order to narrow the gap of the potential disconnect between regulators and technology developers while safeguarding ethical, legal and societal consequences in all stages of the product development cycle. Fosch-Villaronga and Heldeweg (2018) also suggests that "the closer the connection between developers, manufacturers, users and regulators the greater the chance of avoiding a regulatory disconnect." Besides the closeness, an iterative nature to the regulatory process is key to avoid such disconnect. While this paper's focus was mainly on the biliteral relationship of regulator and technology developer, it does mention a third prominent actor, the user. The closeness of all three actors is relevant when creating effective and efficient governance of an emerging technology (Fosch-Villaronga & Heldeweg, 2018). Therefore, I have decided to broaden my focus, and study how each of these three actors influence the success of the emerging technology in question, the autonomous vehicles. This explains why I identified regulation, technology, and societal acceptance as my main independent variables, and roll-out of AVs as the dependent variable. I will observe the differences of the state of these variables in the EU and in the USA and I will compare my findings between these two regions.

In order to operationalize my variables, I have assigned binary values to each of them: Regulation can be either restrictive (Rr) or allowing (Ra), technology can be either fast (Tf) or slow (Ts) and society can either be accepting (Sa) or rejecting (Sr). While using binary values is limiting me from measuring my dependent variables to the fullest, the scope of this thesis would not allow me to work with a more precise measurement system due to time and space restrictions. I will compare the observed values on each variable among the two studied regions in chapter 2, 3 and 4. Further thinking about these assumptions -after the clarification of the values I assigned to the variables- allowed me to map out all possible scenarios between my selected three actors. There are 8 possible unique scenarios created from the set of variables:

Scenario 1: Rr+Sa+Tf
Scenario 2: Rr+Sr+Tf
Scenario 3: Rr+Sa+Ts
Scenario 4: Ra+Sa+Ts
Scenario 5: Ra+Sr+Tf
Scenario 6: Ra+Sr+Ts
Scenario 7: Rr+Sr+Ts
Scenario 8: Ra+Sa+Tf

Each of these scenarios have possible disconnects or alignment situations among the three actors. Scenarios 7 and 8 do not have a disconnect to be observed. In case of scenario 8, the regulation is allowing, the society is accepting, and the technology is fast to keep up with the offered regulatory space and demand for AVs. If in either of my regions I would observe this situation, the region would likely to be among the earliest adaptors of the AV technology. In Figure 1, this scenario is represented by the green dot. Contrary to this, scenario 7 presents a different type of alignment among my three studied actors. Regulation is restrictive, society is rejecting the technology and the technology itself is too slow to be available in the foreseeable future. In Figure 1, this scenario is represented by the red dot. In case I observe this situation in either of my studied region, it is most likely the technology will not be rolled-out at all there.

Figure 1 Alignment cube: model of the alignment/disconnect scenarios among the studied actors



The remaining six scenarios all have a disconnect among two of my studied three actors. According to my hypothesis, the presence of a disconnect will likely impact the roll-out of the AV technology negatively, however there are scenarios where the impact is less severe while in case of some disconnect, the impact is higher. To determine how to rank the impact of the disconnect between different actors, I have used the findings of the article: A multicriteria decision making approach to study barriers to the adoption of autonomous vehicles (Raj, Kumar, & Bansal, 2020).

Raj et al. (2020) identified ten barriers to AV-adoption, to assist policy makers and governments in focusing on the crucial areas that can lower the chance of the technology succeeding. They have identified these ten barriers based on literature review and expert interviews: Reduced security and privacy, social inequality, obscurity in accountability, lack of customer acceptance, potential loss of employment, inadequate infrastructure, lack of standards, absence of regulation and certification, manufacturing costs, induced travel. In order to rank these barriers based on relevance, the study conducted a multicriteria decision making technique (Grey-DEMATEL) to characterize how these barriers influence each other and are influenced by each other. Following a sensitivity analysis Raj et al. (2020) presents a casual loop diagram visualizing the cause-and effect relationships between these barriers. The findings of this study help me rank the three variables I chose to study as they (or very similar ones) are also studied by Raj et al. (2020).

They identified based on the Grey-DEMATEL analysis that Lack of consumer acceptance is the main barrier to AV-adaption. It can be considered a cause if you study it in relation to other barriers. Both the lack of appropriate regulation and the lack of proper technological standards have a strong impact on how open society is to self-driving vehicles. Following lack of societal acceptance, the lack of standards has the second highest impact on the success of the AV technology long-term. Lack of standards are considered to be a cause when it comes to its relationship to other barriers. While Raj et al. (2020) uses the terminology: lack of standards, it refers to a broader set of influence, the industry that is developing the technology has on the success of it. It includes cooperation among industry actors to speed up development, to create a product that is desirable by the customers and one that is fulfilling regulatory requirements in different regions. I have labelled this potential barrier as "technology" and I intend to study the industry actors, their way to cooperate or the lack thereof in chapter 3.1, taking into account the findings of Raj et al. (2020).

Following technology, the third most prominent potential barrier was the absence of regulation. This barrier is on the edge between being a cause or an effect in relation to the other barriers. It can have impact on other barriers (for example by lowering trust in the technology due to inadequate regulation or setting different requirements in different regions making it more difficult to industry actors to set standards) but both other barriers can have impact on the absence of regulation as well. Lack of customer acceptance might encourage regulators to prohibit the development of an emerging technology early on and remain unresponsive when the technology changes (Raj, Kumar, & Bansal, 2020).

To summarize it, Raj et al. (2020) concluded that while there are ten main barriers to the adaption of the AV technology, the three most prominent ones in order of relevance are the followings: societal acceptance, technology, and regulation. (The rest of the ten barriers are covered in a later part of the thesis where I discuss more risks and benefits of the AV technology) This finding allows me to rank the remaining six scenarios from most likely to adapt the AV technology as soon as it becomes available to least likely to adapt the AV technology once it is available. The ranking is the following: Scenario 1 > Scenario 4 > Scenario 3 = Scenario 5 > Scenario 2 > Scenario 6. Based on this classification I will be able to draw conclusions on where (EU vs USA) self-driving cars are more likely to be allowed on the road once the technology is available.

The limitation of this model comes from two main decisions. For relative simplicity, I have decided to assign only two values to each of my variables, and due to the limited scope of this thesis I have decided to focus only on the three most influential variables that are defined to be a potential barrier to the adaption of AVs according to Raj et al. (2020). If the model were to be expanded upon, there would be endless number of scenarios within the 3D cube. Assigning numerical values for example on a scale from 0 to 1 would allow a more detailed description of the actual values attached to each variable, and by then, a very precise prediction could be made on which studied region is more likely to allow the roll-out of AVs the soonest. Similarly, by adding more dependent variables to the model, a more precise prediction could be made, however it would increase the number of scenarios to study excessively. Therefore, I have decided to make these two restrictions when it comes to how I measure my variables, and how many variables I study. I expect my findings to be of value to anyone that is interested in a comparison on regulatory, societal and industry influence on the development of self-driving cars in the EU and in the USA.

In order to establish the relevance of this study, Chapter 1 describes the nature of the automotive industry dating back to the time before smart technologies. A short description of the history of the automotive industry demonstrates a relevant characteristic of the industry, namely the speed at which it innovates. Several big milestones occurred the past 100 years before the revolutionary change of the self-driving vehicles became reality. Dealing with change can be challenging. Not only for the industry but other relevant stakeholders. In part 1.3 a theoretical background is established that serves as the base for answering the main research question and sub-questions.

Chapter 2 describes the technology that is the focus of this research: autonomous vehicles. In order to determine the complexity of dealing with the emergence of this new technology, it is important to fully understand how it works. The focus in Chapter 2 is on the technology itself. I compare Tesla's technology to the main competitors to understand what the differences are and why Tesla is argued to be years ahead in the race to create fully autonomous vehicles. I have selected Tesla to study, as it the most advanced actor on the market. According to industry actors, the likelihood of Tesla being the first to launch a fully autonomous vehicle is high but years away. According to Elon Musk, it can happen any moment by a software update. Chapter 2 will look at the validity of both claims in order to establish a realistic timeline for the development of AVs. Chapter 2.3 describes the risks and the benefits of AVs. The introduction of driverless cars has potential influence on several policy areas, a wide range of social, financial as well as safety concerns will be explained. This completes the first part of the thesis that is focusing on the technology, the history, and the potential impact of AVs on society. This part presents the answer to SQ 1.

Chapter 3 consists of three sub-chapters, each of which deals with a different major stakeholder. First, the most relevant industries are discussed, that are new, or already for years active in the self-driving vehicle ecosystem. When it comes to partnerships or patenting, Tesla operates based on different approaches compared to other manufacturers. Differences between actors on the EU and US market will be revealed as well. The second major stakeholders are legislators. Chapter 3.2 focuses on the role the legislators are playing, the most relevant principles they have and the differences between the European and the US regulatory environment. Chapter 3.3 addresses societal acceptance. This concludes the three main stakeholders which are the focus of this thesis. This chapter offers an answer to SQ 2.1 and SQ 2.2.

Chapter 4 describes the regulatory efforts in the USA and in the EU. I have selected two member states and two states who are on the forefront of enabling innovation to compare with each other. Establishing the pace at which regulation is willing or able to react to the advances in the autonomous technology allows me to draw conclusions regarding potential regulatory disconnect among the three observed actors. This chapter presents the answer to the final sub-question, SQ 3.

Chapter 5 includes the conclusion, where observed disconnects and their impact on the likelihood of autonomous vehicles being able to hit the road as soon as the technology is available are analysed. The EU and the USA will be placed in the model presented in Figure 1, and the answer to the main research question will be given based on the theory and hypothesis I have presented in chapter 1.

2. The technology

Chapter 2 focuses on the technology under the microscope in this thesis: the autonomous driving technology. The chapter intends to answer the first sub-question: *What have been the main technological advancements allowing the development of autonomous vehicles and what are the expected societal, economical, or environmental impacts of the rapidly developing AV technology?* The first part (Chapter 2.1) allows the reader to develop a deeper understanding of the different levels of automation, while the second part (Chapter 2.2) describes in detail what the technological break-through's are which allow the creation of self-driving vehicles. The chapter's main focus is on Tesla, but it also touches upon some differences in the approach they take developing their iteration of self-driving vehicles, and the differences in the technology used compared to manufacturers in Europe. This comparison enables me to assign, based on the development speed of the AV technology in the EU and in the USA, a fast or slow label to the technology and place it in the 3D model presented in chapter 1. The chapter ends with a risks and benefits analysis that presents other barriers to succession determined by Raj et al. (2020) among many relevant risk factors that are to be taken into account by all three major actors my thesis focuses on.

2.1. Autonomous vehicles

Autonomous vehicles are also often referred to as self-driving vehicles or driverless cars. In cars on the roads right now, there are several automated systems (for example: cruise control). If the vehicle's automated system can perform all dynamic driving tasks in all driving environment, the vehicle is considered autonomous (Faisal, Kamruzzaman, Yigitcanlar, & Currie, 2019). Autonomous vehicles can drive themselves without any human supervision. No human input is needed to control the steering, acceleration and breaking (Geonovum, 2017).

At this point in time, there are no vehicles in traffic that fulfil this requirement. There are however cars with different levels of autonomy. To classify the level of autonomy of a vehicle, a 6-level scale is used. This scale was introduced by the Society of Automotive Engineers International in 2014 (Faisal, Kamruzzaman, Yigitcanlar, & Currie, 2019). The scale was later updated in 2016 and 2018, before achieving its current form in 2021. Table 1 shows the SAE's taxonomy that has become the industry standard for classifying vehicles.

Table 1 Summary of levels of driving automation

	Level	Name	Narrative Definition	*DDT*: Sustained Lateral and Longitudinal *Vehicle* Motion Control	*DDT*: *OEDR*	*DDT Fallback*	*ODD*
Driver Performs Part or All of the *DDT*							
	0	No Driving Automation	The performance by the *driver* of the entire *DDT*, even when enhanced by *active safety systems*.	*Driver*	*Driver*	*Driver*	n/a
Driver Support	**1**	*Driver* Assistance	The *sustained* and *ODD*-specific execution by a *driving automation system* of either the lateral or the longitudinal *vehicle* motion control subtask of the *DDT* (but not both simultaneously) with the expectation that the *driver* performs the remainder of the *DDT*.	*Driver* and System	*Driver*	*Driver*	Limited
Driver Support	**2**	Partial Driving Automation	The *sustained* and *ODD*-specific execution by a *driving automation system* of both the lateral and longitudinal *vehicle* motion control subtasks of the *DDT* with the expectation that the *driver* completes the *OEDR* subtask and supervises the *driving automation system*.	System	*Driver*	*Driver*	Limited
Automated Driving	**3**	Conditional Driving Automation	The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* with the expectation that the *DDT fallback-ready user* is receptive to *ADS*-issued requests to intervene, as well as to *DDT* performance-relevant *system failures* in other *vehicle* systems, and will respond appropriately.	System	System	*Fallback-ready user* (becomes the *driver* during *fallback*)	Limited
Automated Driving	**4**	High Driving Automation	The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will need to intervene.	System	System	System	Limited
Automated Driving	**5**	Full Driving Automation	The *sustained* and unconditional (i.e., not *ODD*-specific) performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will need to intervene.	System	System	System	Unlimited

(SAE International, 2021)

If a vehicle has no automation, it is considered level 0. Level 0 automation means that the driver is fully responsible for all tasks while driving. These tasks include braking, steering, navigating and motive power. It is possible that the vehicle provides warnings or can intervene while diving, however in case of a Level 0 automation, the human driver is full-time controlling all dynamic driving tasks.

Level 1 autonomy is referred to as “Driver Assistance” by the European Commission. (Digital Transformation Monitor, 2017) Level 1 automation provides assistance to the driver at one or two specific control functions. An example for such a function is electronic stability control or pre-charged breaks (Geonovum, 2017). The automation only exists in some driving modes, and it is only assisting the human driver in executing a task while the human driver is regaining control. This system uses information about the driving environment to assist the driver in executing a specific dynamic driving task, while the human driver is responsible to perform all other dynamic driving tasks.

Level 2 autonomy refers to “Partial Driving Automation” (Digital Transformation Monitor, 2017). This system involves the automation of two primary control functions designed to work together. The system is able to use information about the driving environment to both steer and accelerate or decelerate while the human driver remains responsible to monitor the driving environment and perform the remaining dynamic driving tasks. An example for such a system is the enabling of the adaptive cruise control in combination with lane assist.

A vehicle with level 3 autonomy is considered an autonomous vehicle as of writing this paper. It is not a fully autonomous vehicle, but it allows the human driver to shift safety-critical functions to the vehicle. Level 3 is referred to as Conditional Driving Automation by the European Commission. The main difference compared to level 0, 1 or 2 autonomy is that the automated driving system takes over the responsibility to monitor the driving environment form the human driver. The automated driving system can perform all dynamic driving tasks. However the human driver is expected to respond appropriately if the driving system requests them to intervene. While on the lower automation levels the human driver was responsible for the localisation, the perception, the planning and the management operational functions, the Level 3 automation only requires the human driver to perform the management function however the environments in which the automation function is operational are restricted.

Level 4 autonomy is referred to by the European Commission as: High Driving Automation”. The driving system is fully autonomous, but not in every driving scenario. The vehicle is taking control of all safety-critical functions. It monitors the environment and performs all operational functions (localisation, perception, planning, management). The human driver is required to take occasional control, but with sufficient comfortable transition time (Geonovum, 2017). The system capability is still restricted, meaning that the automated system is not operational in all driving environment.

Level 5 autonomy is considered full driving automation. It is a full self-driving automation, where the vehicle is performing all dynamic driving tasks without the need for human intervention in any driving environment. This is the final and highest level of automation. Level 5 autonomous vehicles can perform all safety—critical driving functions while monitoring the roadway conditions for the entire trip. The human passenger of the car will only be required to input the destination (Geonovum, 2017).

According to the Federal Automated Vehicles Policy of the US Department of Transportation, a vehicle is denoted as AV if it has levels 3-5 automated systems. Vehicles of these levels of automation are also often referred to as highly autonomous vehicles (HAVs). The previously described four operational functions together with information acquisition completes the full set of responsibilities that can be either taken up by the human driver or the automated system of the vehicle. A self-driving car is able to determine its location by using Light Detection and Ranging (Lidar), GPS and digital maps (De Bruyne & Dr. Vanleenhove, 2018). To gather information about its surroundings, the AV uses various types of sensors, radars, and cameras. Lidar is placed on the top of the vehicle, to provide a 360-degree view around the vehicle for the detection of the movement and position of surrounding objects. Cameras and radars are also used to determine objects and their movements around the vehicle, while the cameras also provide the necessary information for example in case of traffic lights or signs. A set of these technologies, together with an appropriate software system is able to take over all dynamic driving tasks from a human driver.

If “the vehicle needs to communicate with other infrastructures to collect information or negotiate its manoeuvres”, it is considered to be a connected autonomous vehicle (CAV) (Faisal, Kamruzzaman, Yigitcanlar, & Currie, 2019). If a manually driven vehicle requires other infrastructures to collect information, it is a connected vehicle (CV). According to Faisal, Kamruzzaman, Yigitcanlar, & Currie (2019), CV technology is complimentary to the AV technology, but it is not mandatory. The CV system develops hand in hand with the AV system which introduces additional stakeholders that have to be taken into account to understand the challenges legislators are facing regulating AVs.

2.2. The development of AVs – the breakthrough by Tesla

According to Engelking (2017) the first driverless car was introduced in 1925 by the Houdina Radio Control Company. The vehicle was radio controlled by the signals sent to it from another car following the 1926 Chandler close after it. In 1926, Achen Motor also showcased their iteration of remote-controlled car, named the Phantom Auto. While the public showed interest and large crowds gathered to witness a driverless car during its tour in the 20's and 30's, the setup did not offer the possibility of an easier form of travel, since it required someone to control the car from another vehicle right behind it. The Phantom Auto was considered a spectacle, but it did not create actual demand for production.

It wasn't until 1939, when Norman Bel Geddes introduced his vision for an automated highway system, where cars would transport their passengers driverless. It was the first vision of an autonomous vehicle, providing enhanced safety and faster transportation for its passengers. Bel Geddes envisioned a system, where autonomous vehicles drive on automated highways with the help of certain devices eliminating human error from the traffic. RCA and General Motors picked up this concept, to work a 400-foot automated highway based on electronic circuits built into them. This piece of highway was unveiled in 1958. The project seemed to be a success, and GM expected to commercialize the technology within 15 years. The downfall of this initiative was the lack of funding, which resulted in the death of this project. Around the same time, the United Kingdom's Transport and Road Research Laboratory presented a similar driverless car, automated highway combination using a Citroen DS and a magnetic trail system. Similarly to the American government, the British one decided to cease funding as well resulting in the permanent halting of this initiative (Engelking, 2017).

It required a shift in the perspective to produce a viable alternative to these failed initiatives. In order to reduce costs, focusing on developing a smart vehicle instead of a combination of highway with a fitting vehicle had to be the centre of attention. In 1960, James Adams set out to create a lunar-controlled rover. This vehicle had a video camera assisting and improving navigation. While this initiative was promising, it took long years of development before the vehicle was even able to navigate outside of a closed and controlled environment.

It wasn't until 1977 that a Japanese engineering laboratory created the first vehicle that is considered to be a stand-alone, autonomous vehicle. Machine vision assisted in the navigation with the help of built-in cameras to monitor its environment. A prototype had been built and it was able to drive with a maximum of 20 miles per hour. The car was programmed to follow the road by analysing where the white street markers are located.

The next remarkable step toward AVs as we know them today was in the 80's, when Ernst Dickmanns, a German aerospace engineer set out to combine artificial intelligence with transportation. It was Mercedes-Benz that provided the necessary infrastructure to create a concept version of the vehicle. It was capable of driving autonomously at a speed of 39 miles per hour. Cameras, sensors, and a computer program's cooperation provided the necessary information for the vehicle, to be able to drive without human involvement. The prototype was called VAMORS and after successful tests, it debuted publicly on the autobahn in 1987 in Germany.

The success of this project resulted in a European research organization, the EUREKA launching a project, called PROMETHEUS between 1987 and 1995. A large (749.000.000 euros) investment allowed Dickmanns to develop the VaMP and VITA-2 robot vehicles. They were able to drive up to 130 km/h and drove on the highway at Paris throughout 1000 km's. In the meantime, in the USA, the Autonomous Land Vehicle project created the first off-road map and a sensor based autonomous navigation system. They tested it at a 1.9mph on terrain, going more than 2000 feet.

It was in 1989, when the biggest development towards laying the groundwork for today's AV took place. The Carnegie Mellon University incorporated the use of natural networks into the steering and control of an autonomous vehicle. This vehicle combined a Chevrolet panel, a GPS and a supercomputer creating an autonomous car that was capable of traveling off road. It completed a 3100 miles journey. The prototype was semi-autonomous, as the throttle and the breaks were controlled by a human driver.

The U.S. military began showing interest in autonomous vehicles in the 80's. Following that interest, they announced a challenge, DARPA. It was a long-distance competition awarding 1 million dollars for the creator of the vehicle that can complete a 150 miles long obstacle course. Even though there was no vehicle that could complete the course, this competition sparked the interest of innovation on the field of autonomous vehicles. In the following years similar competitions were organized to keep the newly sparked interest alive and further encourage engineers to keep developing technologies that can help create a fully autonomous vehicle in the future.

The beginning of the 2000's provided the big breakthrough in the development of the autonomous vehicles. Manufacturers like Ford or companies like Google started working on driverless cars. By 2015, Google's self-driving cars had travelled over 1.000.000 miles on the roads without causing accidents even though they were involved in 13 collisions. Google lobbied and achieved to make self-driving cars legal on the streets in four states in the USA. Among others, this achievement opened up the door for traditional car manufacturers like Nissan, Toyota, Mercedes, VW, Honda, GM, and Audi to start developing their own self-driving cars, and the majority of the manufacturers assumed, that by 2020, driverless cars would be commercialized (Geonovum, 2017).

Besides these traditional car manufacturers, companies in other industries began to show interest in the development of autonomous vehicles as well. Uber, Microsoft, Nvidia, Intel, and, last but not least, Tesla also began to work on self-driving cars or parts/technologies that enable the development of such vehicles. Nvidia is focusing on creating a computing device strong enough to allow the vehicle to do autonomous driving without the need to be connecting to a network continuously (Geonovum, 2017). Intel helps automakers to deal with gathering, processing, and analysing data from autonomous vehicles. "Intel is incorporating the endpoint, connectivity and the data centre to offer end-to-end solutions (Geonovum, 2017)". Microsoft is contributing with storing huge volumes of sensor and user data which can be used by manufacturers in the process of perfecting their iteration of AVs (Geonovum, 2017).

While all the traditional car manufacturers mentioned above are working on developing the perfect self-driving vehicle, it is the company named Tesla, Inc., founded in 2003 that will serve as the focus when describing where the current state of development of autonomous vehicles stand. The decision was based on the fact that Tesla has the most advanced technology as of now when it comes to highly autonomous vehicles. It was explained previously that Tesla has the technology fully developed for level 5 autonomous driving. All their recently sold cars are equipped with this technology even though it is only utilized for level 3 autonomous driving currently. It is interesting to take a closer look at the technology, its development process, and the reasons why it is currently not yet fully utilized in the everyday traffic.

According to the information on the website of Tesla, Inc., the company (called Tesla Motors between 2003 and 2017) was founded in 2003 by a group of engineers (2019). Their goal was to create an electric car that can be just as fun to drive as a gasoline car while being quicker and being better for the environment. The vision of Tesla is that "the faster the world stops relying on fossil fuels and moves towards a zero-emission future, the better" (Tesla, 2019). The CEO of Tesla in 2003 was Martin Eberhard who was supported by Marc Tarpenning in the CFO role. They began to work on an all-electric vehicle inspired by the work of General Motors described earlier on in this chapter. Elon Musk, the entrepreneur who was made famous by creating PayPal invested 6.35 million dollars of his own funds into Tesla in 2004. He also became chairman of the board that year (CNN, 2019). In 2005 Tesla created its first electric car, the Roadster. It was a collaboration with Lotus, a British company who provided the body and the chassis for Tesla. The Roadster entered into production in 2008.

The first Roadster was delivered on the 1st of February in 2008 to Elon Musk. Creating the Roadster, Tesla had created an all-electric car that was to be similar enough to regular cars to create demand on the market by meeting consumer needs. The key difference between the Roadster and other manufacturer's models was that the Roadster had a battery powerful enough to last 250 miles on a single charge (The Street, 2019). The car had a cost-effective motor small enough to fit into a consumer vehicle. It came at a high cost however, starting above 100.000 dollar. Due to the high price, it has not become a widely viable product.

In 2008 both founders of the original Tesla Motors left the company. Elon Musk took over the CEO position in October 2008 and fired 25% of the staff. This is when the focus of creating electric cars paired up with the aim to do that at an affordable cost. In 2008 Tesla announced their first sedan, the Model S. At the price point of 76.000 dollar, it was considerably cheaper than the previous model. The Model S entered into production in 2012. In the following years Tesla introduced several non-automobile industry related products all based on self-developed cutting-edge technologies aiming to create an option for more sustainable way of living for the everyday people.

It was in October 2014, when Elon Musk introduced Tesla's semi-autonomous driving technology, called autopilot. As explained by Musk (2014) their autopilot consists of 4 different systems:

- A long ranged, forward-looking radar scanning the cars in front of the vehicle
- A camera with an image recognition to recognise obstacles, traffic lights, pedestrians and serves as a back-up system for the radar
- A 360-degree long range ultrasonic sonar serving as a protective layer around the car to observe the surroundings
- GPS system with real time traffic information

Based on the functionalities Musk described, the car was able to perform lane control while accelerating or decelerating, perform emergency breaking or self-parking on private property. The technology at its form in 2014 equalled to a Level 2 autonomous driving technology. It launched in cars in October 2015. While it could perform parts of the dynamic driving tasks, it was required from the human driver to stay vigilant at all times and monitor the environment while driving. The partial self-driving feature was enabled on the cars by a software update. The 7.0 version of the software allowed the cars to perform Level 2 autonomous driving.

Only 6 months later, the 7.1 update limited some of the functionalities of the autopilot, to reduce the unwanted, risky behaviour of Tesla drivers. In October 2016, Musk announced the 8.0 version of the Autopilot. It was an improved version of the previously used system that relied heavily on the camera. The 8.0 version of the software uses the radar signals to create a system similar to Lidar that can help improve navigating in low visibility situations. In this version of the software, it is thus the radar that is used as the primary source of information, not the camera.

In October 2016 the version 2 of the computing hardware launched. This hardware future proofed all Tesla's manufactured after that date to be able to perform advanced self-driving (thus level 3 or higher). This enhanced version of the autopilot included the ability of the vehicle to change lanes without requiring human input. It allowed Tesla's to switch from one freeway to another, exit freeways if the previously set destination was near. Tesla transitioned form using one, to using 4 cameras to improve accuracy. Additionally, 12 ultrasonic sonar sensors could now provide twice the range and resolution of the previous hardware. The processor could now process information 40 times faster than previously (Teslarati, 2016). While the hardware was powerful enough to be considered a Level 3 autonomous system, Tesla still treated it as a driver assistant system, where the human driver is still the one responsible for the dynamic driving process at all times.

In November 2016, an update launched to ensure more prominent warnings the human driver is receiving if the engagement level of the human driver isn't sufficient. It required the human driver to touch the steering wheel more often. While the first version of the software was live, Tesla's all around the word have made 1.3 billion miles in shadow mode on public roads. Autopilot for hardware 2 cars was introduces in February 2017. Among others it contained "adaptive cruise control, autosteer on divided highways, autosteer on local roads up to a speed of 35miles or a specified number of miles over the local speed limit to a maximum of 45miles (The Street, 2019)". Firmware version 8.1 for hardware 2 arrived in June 2017. It featured a new driving-assist algorithm, ability of the car to full-speed brake, updating the system to be able to perform parallel and perpendicular parking.

In order to further perfect its autonomous driving capabilities, Tesla released an update to its navigating system in April 2019. It allows the car to change lanes without the human driver's confirmation, while still requiring the driver to have his/her hands on the steering wheel. With this newest update, Tesla vehicles can navigate on the freeway on their own, with human driver supervision. While this technology is fully available, in May 2019, Tesla launched an updated autopilot in Europe. It was necessary to comply with the new UN/ECE R79 regulation. European Tesla owners are no longer allowed to switch lanes without confirmation from the human driver for safety reasons.

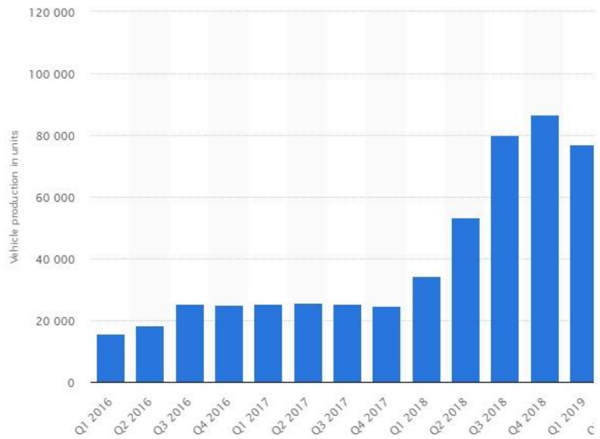
2.2.1. Tesla

With 145.850 units sold in 2018, the Tesla's Model 3 was the world's best-selling plug-in electric vehicle (Wagner, 2019). Model 3 sales account for nearly 40% of the total electric car sales in the USA. The demand for this model specifically is not only high in the USA but it is a popular choice in China and Europe as well. From 8% market share in 2018, by November 2019, 18% of the European electric vehicles on the road are Tesla's (BMW Group, 2019). It makes Tesla the leading manufacturer of electric vehicles both on the European and the USA market. This rapid growth can be partly explained by the Model 3's more affordable price point and the cutting-edge driving assistant offered by Tesla that is regularly discussed by the mainstream media as well.

While in the past the delivery time of Tesla cars were close to the 12 months, nowadays future Tesla owners are looking at a much shorter, 3-10 weeks. Tesla was able to increase its production capacity throughout the past 3 years. As shown in Figure 2, the quarterly delivery increased from 15.000 units in Q1 2016, to nearly 100.000 units in Q1 2019. While the predictions of Musk have been more optimistic about the volumes Tesla was going to be able to produce, the actual increase already cut waiting times down to an acceptable level for consumers (Tesla, 2019)

In order to try to understand what makes Tesla cars increasingly popular, looking at the Tesla Autopilot technology offered by the newest model of the manufacturer is a start. As Tesla produces the most popular electric vehicle on the two markets I intend to compare, I want to clearly understand the opportunities and risks that owning a Tesla would introduce into our society. It is the first step towards getting a clear image on the complexity the legislators are dealing with when having to make decisions about how to tackle regulating this rapidly developing technology.

Figure 2 Number of Tesla vehicles produced worldwide from 1st quarter 2016 to 3rd quarter 2019 (in units)

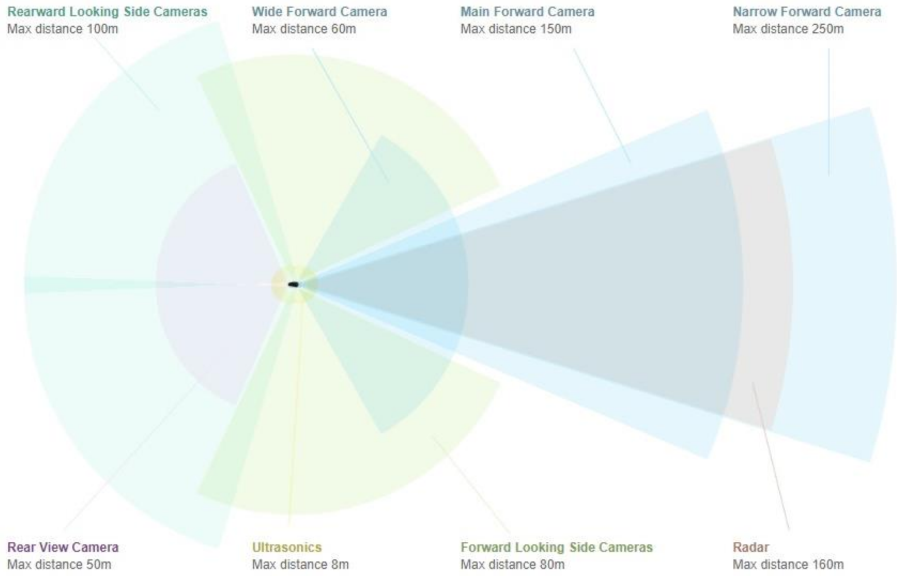


(Wagner, 2019)

All Tesla models sold currently are equipped with hardware that has full self-driving capability. The newest set of technology these vehicles are delivered with is called Hardware 3.0. It is available since April 2019 and it includes Tesla's self-designed processor (Tesla, 2019). According to the company's website, this new computer can process 2,300 frames per second and perform 144 trillion of operation per second. This allows the system to make better and faster decisions by for example being able to scan the area around the vehicle faster and more in depth. The processor together with the below explained tesla-developed neural net for vision, sonar, and radar processing software "provides a view of the world that a driver alone cannot access, seeing in every direction simultaneously, and on wavelengths that go far beyond the human senses (Tesla, 2019)".

The forward radar has a range of 160m. It has enhanced processing power and its main function is to provide additional data about the car's surroundings on a redundant wavelength which is able to see through heavy rain, fog, dust and even the car ahead. There are three forward looking cameras. The narrow angled one has 250m range, the wide one has 60-meter range, and the main forward camera has 150m range. The wide camera has a 120-degree fisheye lens, and its function is to capture traffic lights, obstacles cutting into the path of travel and objects at close range. This camera is most useful when the vehicle is at a low speed, especially in urban areas. While the main camera covers a broad spectrum of use cases, the narrow one is specifically designed to offer a long-range view of distant objects in high-speed operation. Hardware 3 comes with a left and a right forward camera. Both have an 80m range. They have a 90 degree overlap with the forward-looking wide camera and their function is to monitor for cars entering the used lane. They also provide added safety in limited visibility situations, for example at intersections. The two rearward looking side cameras are monitoring blind spots. With their 100m range they are helpful when changing lanes or merging into traffic. The rear-view camera completes the set of 8 cameras, Tesla's are equipped with. This camera has a 50m range and it is one that can be used by the human driver as well in case of for example complex parking manoeuvres. The 12 surrounding ultrasonic sensors complete Tesla's hardware 3 package. They have an 8m range with improved sensitivity using unique coded signals. Their function is to detect nearby cars and provide additional guidance when parking. Figure 3 illustrates how the above-mentioned hardware functions in Tesla vehicles.

Figure 3 Tesla's Autopilot system



(Tesla, 2019)

The functioning of hardware 3 is supported by the newest software by Tesla. Version 10.0 was released out of beta access in September 2019. Tesla announced that this update contains convenience, entertainment, gaming, and music features to make their cars more capable and the time spent in the car more enjoyable (Tesla, 2019). Version 10.0 allows the driver of the car to use streaming services like Netflix or YouTube as long as the car is parked. It added a karaoke library that is to be used while driving as well. This version enabled the smart summon feature which will be discussed more in detail below. With version 10.0 the car can now connect to and control for example the garage door and the owner is able to remotely control several functions of the car including the heating system or the windows.

Tesla currently sells their cars with two options when it comes to driving assistance. The autopilot package includes adaptive cruise control and auto steering. The adaptive cruise control is able to match the speed of the surrounding traffic while the auto steering function keeps the car within the lane if it has clear markings. The autopilot can also break and accelerate the car. This option is designed to assist the driver by easing the most burdensome parts of driving according to Tesla. It is a safety and convenience feature that requires human driver supervision at all times. A vehicle equipped with autopilot package is therefore not classified as autonomous.

The second option buyers can purchase is the so called "full self-driving capability". This includes the beta version of the navigate on autopilot function which can suggest lane changes, steer automatically towards highway interchanges and exits and it can automatically engage the turn signal. Tesla suggests that this function allows full self-driving on highways. This package includes the auto lane change function which allows the vehicle to execute lane changes on highways without the need for the human driver to assist. The "autopark" function lets the vehicle perform parallel or perpendicular parking manoeuvres if the human driver enables it. The summon function allows the driver to move the car in or out of tide spaces without him/her sitting in the vehicle by using a mobile app or the keycard. The smart summon feature allows the car to navigate in more complex environments to find its owner. This function is suggested to be used for example to summon the car in a parking lot. Smart summon allows the car to drive without a human driver present inside of the car. This function is only intended to be used on private properties and as a disclaimer Tesla warns that the driver is responsible to monitor the car and its surroundings at all times while using this feature.

The above-mentioned features all require active driver supervision according to Tesla. While this disclaimer is mentioned consistently on their website, Elon Musk has repeatedly made the claim that the hardware Tesla's are equipped with are capable to execute full autonomous driving in almost all circumstances. Not all features are currently enabled in all jurisdictions where Tesla's are on the road due to lack of regulatory approval at this point in time. Some features have been in the vehicles are currently still not enabled by Tesla. Automatic driving in the city is one of these features together with traffic light and stop sign recognition. These were to be enabled by the end of 2019 by a software update. Tesla aims to enable the full autonomous driving option on their vehicles once regulation allows it and if the system is clearly proven to demonstrate reliability far in excess of human drivers (Tesla, 2019).

Figure 4 Tesla vs Nvidia processor development timeline

(ARK Investment Management LLC, 2019)

ARK Invest claims that Tesla is ahead of its competitors on three areas by at least three years. They explain this partially by the vertical integration strategy that sets Tesla apart from other manufacturers developing EV's and self-driving vehicles (Wang J. , 2019). An example for that is Tesla's launch of Full Self-Driving computer featuring their own processor. Figure 4 illustrates how developing their own hardware instead of waiting for Nvidia's new chipset grants a four year advantage for Tesla compared to other manufacturers in the race to create Level 5 autonomous vehicles (Wang J. , 2019).While Tesla's chipset doesn't claim to be better than Nvidia's, it is specifically designed for Tesla vehicles so it is performing the job more efficiently. While Nvidia's chipset had to support a number of different neural network architectures and sensor modalities, Tesla's own processor has to support only the sensor suite and the neural net. This reduces complexity and improves performance and efficiency (Wang J. , 2019). ARK Invest argues that the other two areas where Tesla is ahead of its competition are the following:

- "Battery production and efficiency: Both the chemistry of battery pack management system and its scale with GigaFactory. The Tesla Gigafactory was born out of necessity and will supply enough batteries to support Tesla's projected vehicle demand.
- Autonomous Data: Tesla has billions of miles of customer data, as compared to the second highest competitor with only tens of millions of customer data (an order of magnitude of more autonomous data with Tesla." (Wagner, 2019)

By taking a closer look at the technology behind Tesla's currently available driving assistant and the features it offers to their customers, it is clear that the possibility of Level 5 autonomous vehicles being available in the very near future is real. Selecting Tesla as the main focus gives a complete picture about the speed of development in this field. While other manufacturers are using technologies that differ from Tesla's, the results they achieved on efficiency and safety do not outperform Tesla's vehicles. Tesla has logged the most km's driven with their version of autopilot enabled in traffic and they claimed to be ready to launch fully autonomous driving assistant in 2020. In an interview by ARK Invest, Elon Musk discussed the possibility for Tesla to open its vehicle platform, Autopilot, and supercharger network to other automakers as long as the integration process wouldn't require Tesla to have to deal with engineering overhead (Keeney, 2019). While Tesla is argued to be far ahead in the race to release Level 5 autonomous vehicles, if the technology behind their cars will be available to other manufacturers, the development process would possibly accelerate. That could pose an increased amount of pressure on legislators to react on the rapidly emerging reality of driverless cars being ready to enter the roads.

2.3. Risks and benefits of AVs

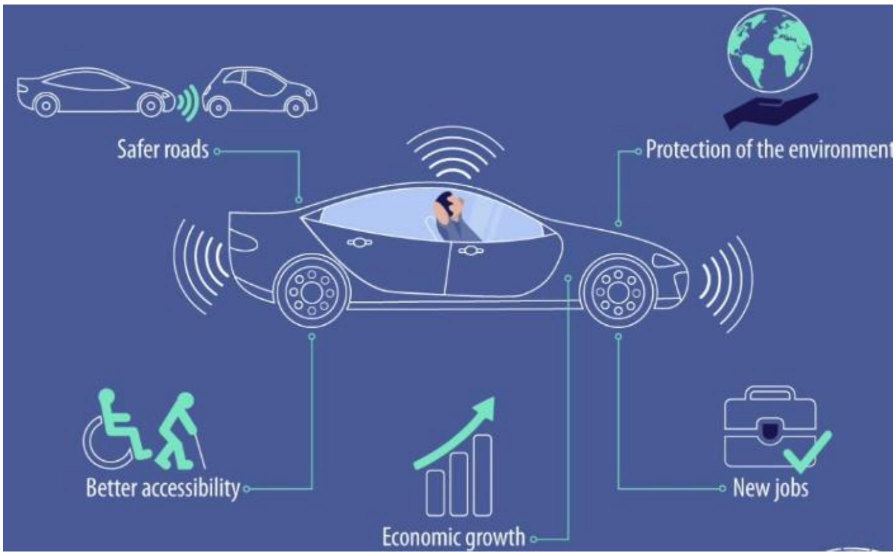
In order to understand the impact of autonomous vehicles on society, the environment or the economy, the next chapter describes the most relevant risks and benefits associated with the technology. This chapter gives a partial response to why there might be differences among regulatory strategies between the EU and the USA or why consumer attitude might differ. Risks and benefits can be perceived differently, not only by legislators but by individuals as well. While one might feel comfortable with allowing the self-driving car to bring them to work while they are preparing for their first meeting of the day during the ride, others might not value the extra time if it comes at the cost of feeling safe and in control. While the way how society and legislators perceive risks and benefits of new technologies influences the chance for success, it is not the only indicator. If different stakeholders perceive the risks and benefits differently, a disconnect can occur among them. In order to identify potential disconnects, I will first identify the most important risks and benefits associated with autonomous vehicles.

In the previous chapters it became clear, that the technology currently available is touching on many different policy fields. It is also remarkable how quick regular cars are transforming into potentially driverless vehicles. Looking at the development of the automotive industry earlier, it was clear that up until the very recent years, developments were mainly focusing on quality of life and safety features. Up until the end of 2000's, there were only prototypes of different levels of AVs with limited success and no real potential to grow into a commercially interesting model. With increasing attention on sustainability and the booming development of technology in the field of the artificial intelligence and automotive industry, the opportunity and demand for smart solutions in vehicles became reality (Elezaj, 2019).

Within 20 years, regular cars became smart vehicles, and they keep improving the technology and the speed at which they introduce them to the public. Both the complexity and the speed of development contribute to the difficulty of efficiently and effectively regulating autonomous vehicle technology. To fully understand what legislators are facing with, the following part will discuss the benefits and risks associated with AVs. This part will also present results of different surveys that measured how the public is reacting to the very real possibility of driverless cars on the roads. I discussed in a previous chapter that Level 2 autonomous vehicles are gaining market share both in the EU and in the USA, however those vehicles main selling feature is likely the use of alternative fuel option, not the level of autonomy. While potential slow legislative reaction clearly has the ability to halt technological development, fear, or mistrust among the public towards a new technology might have similar effects. It is necessary to discuss how the public perceives the idea of driverless cars to get a full understanding of the potential impact it has on the development of the technology itself.

The seemingly obvious benefits driverless cars could have on our lives, would impact several different policy areas (see Figure 5). According to the European Commission (2018) the transport system, the economy, the environment, and existing jobs would be most severely influenced by the introduction of AVs. Even though there are numerous potential benefits, the majority of the literature agrees that the impact of this new technology is uncertain. The European Commission decided to continue monitoring and assessing the expected long-term effects of AVs in 2018, sharing the opinion that the currently available information is not sufficient to be the base for immediate action. It is difficult to model exactly whether or not the benefits mentioned in this chapter would actually have the assumed and expected positive change on all of the impacted areas. Due to the fact that the technology at this point in time is not available yet, it is impossible to rely on experience or observation to determine whether or not the assumed benefits are realistic. However, a similar argument applies for the potential risks as well. The level of uncertainty surrounding AVs is high, but it is equally high for legislators in the USA and in the EU. Therefore, assuming that the potential benefits and risks mentioned below are agreed upon by legislators, studying whether or not different approaches were taken by US and European legislators is interesting.

Figure 5 Benefits of self-driving in the EU



(European Parliament, 2019)

2.3.1. Benefits

Among the potential benefits, the most influential might be the one on safety. According to the National Highway Traffic Safety Administration (NHTSA) USA, 94% of auto accidents are caused by human error in the USA. It is commonly agreed that a well-functioning machine will perform more efficiently and make fewer mistakes than humans do (Sparrow & Howard, 2017). This would impact the number of common accidents on the roads positively. The elimination of human factor from the traffic would mean that accidents due to driver fatigue, driving under the influence or reckless driving would no longer happen. The reaction time and accuracy of a machine is superior to humans' (De Bruyne & Dr. Vanleenhove, 2018). Another benefit of machine operated driving would be fuel efficiency. AVs would use less fuel which is not only cost efficient but also reduces pollution in general.

Fewer accidents mean the reduction of crash costs, and consequently, insurance premiums would be lower as well. If fewer accidents would happen, health care related costs would also decline. This would have positive influence on financial matters. According to the Federal Highway Administration and the Department of Transportation, American spends more than 12 days driving each year. Drivers in the USA are more than 80 billion hours on the road annually. If human supervision is not necessary anymore while driving and there would be essentially only passengers in a self-driving vehicle, travel time could be utilized more efficiently. Travel time could become leisure time where passengers sharing a vehicle could socialize (De Bruyne & Dr. Vanleenhove, 2018). This opportunity would facilitate car sharing. The potential of financial and environmental benefits of fewer cars on the road is high. Fewer cars mean less traffic jams. AVs have the potential to operate in a connected network which could eliminate traffic jams all together by utilizing real time communication among the vehicles on the road.

AVs would be beneficial for non-drivers by improving independent mobility. The need for chauffeurs would be lower. The potential for platooning would rise. Platooning means that a group of vehicles are traveling close together. This would allow for narrower lanes and reduced intersection stops (Geonovum, 2017). On the long run it reduces the costs of building new roads since less material is needed for smaller roads. The building time would be shorter as well which also saves costs. Space would free up in and outside of the urban areas which could be utilized otherwise. Another way to save cost and space would be by the declining need for parking places. AVs can drop off their passengers without needing a parking place close by the destination. It also reduces parking costs for those traveling. A drop off point is sufficient after which the car can search for a free parking place further away (Geonovum, 2017). The expected impact on urban planning is substantial. According to the report written by Geonovum (2017), a 15-20% increase in urban space could be achieved just by the elimination of redundant parking spaces.

The potential for new jobs in the production of AVs is impactful. While reschooling is most likely necessary, the estimation is that hundreds of thousands of new jobs would open up in manufacturing and production (Geonovum, 2017). With the AVs entering the roads, speeding would be eliminated. If humans are not the drivers anymore, vehicles will be following the traffic rules without an exception. This reduces the need for police officers to spend time on writing traffic violation tickets and dealing with car accidents. Intelligent Speed Assistance (ISA) technology already exists, and there is debate among EU legislators whether or not new vehicles should already come with this safety feature equipped. As described by Keating (2019) “ISA uses sign-recognition video cameras or GPS-linked data to automatically cap the speed of the vehicle and adapt it to the legal limit in force”. Such system alone is expected to reduce collisions by 30% and death by 20% in the EU (Keating, 2019).

2.3.2. Risks

Among the most often mentioned risks of AVs are the legal uncertainties, cyber security and privacy concerns, consequences of the failure of technology and economic costs. Additional costs can arise from the equipment that is needed for driverless cars, their maintenance and the costs of extra services that might be necessary for the efficient and effective functioning of AVs. Currently lacking roadway infrastructure to support the changing needs associated with the new technology might be taxing on the governments (Geonovum, 2017). The gasoline industry would be heavily impacted by the arrival of AVs, since this new technology goes hand in hand with electric drive. Loss of jobs in the gasoline industry would be imminent due to the change in demand for the old technology. Reschooling of workers whose jobs become obsolete adds to the economic costs of AVs.

According to the European Parliament (2019), the self-driving vehicles introduce new risks related to software failure or system failure. Such failure can cause fatal accidents. If AVs enter the roads, they will have to coexist with cars driven by human drivers until the phasing out of traditional cars is complete. While the two technologies are sharing the road system, additional difficulties may arise from the fact that human drivers are not predictable for machines at all times. It may cause conjunctions, crashes, or loss of efficiency. It has thus a negative impact on convenience and safety as well. AVs might not operate at the highest level of safety at all times. Weather conditions might damage the radar/camera system of the vehicle which will then be unsafe to operate (Geonovum, 2017). It is also concerning, that once traffic lights are not functioning, the AVs are expected to react to situations on the go without guidance. This is seen as a safety hazard by the European Commission (2018). Assuming the human drivers are expected to take over driving tasks in case the vehicle instructs them due to weather conditions for example, it is possible that the loss of skill amongst humans will be a real issue. If human drivers are not driving regularly or might not even need a driver’s licence to travel in fully autonomous vehicles, their driving skills will deteriorate over time, or not even exist the first place. That will cause a safety hazard, if the vehicle tries to rely on the human driver to take over the control of the vehicle in case of emergency (Etrac, 2019).

Self-driving vehicles are subject to hacking which poses serious risks to safety, traffic management or privacy. Cyber terrorists or criminals might hack AVs causing problems from traffic jam to the more extreme cases of fatal accidents (Geonovum, 2017). Data sharing and GPS data can be interesting for criminals as well, putting privacy of the owners of AVs at risk. Besides criminals, the vehicles itself are collecting an enormous amount of data about their passenger's habits. The protection of that large sum of data has a high priority (European Parliament, 2019).

While AVs create jobs in many related sectors while research and development is at full force, the decline in demand for traditional jobs like driver or auto-vehicle body shops will have a negative economic impact. According to Taeihagh and Lim (2019) technological advancements always pose a threat to low-skilled, manual jobs. Reschooling people that find themselves without a job is costly and the additional cost from having to adjust the current road system will add to the costs as well. Those workers that will be pushed out of their current low-skilled job and spill over to other low-skilled occupation, will cause an overall reduction in wages in that sector. While the total economic effect of AVs is expected to be positive, the loss of low-skilled jobs is likely to cause wage inequalities (Taeihagh & Si Min Lim, 2019). If AVs will be the only type of vehicles on the road, narrower lanes and less parking places will be sufficient. As explained previously, it has a positive impact on urban space, however it also has a rather high costs of rebuilding existing infrastructure to fit the new requirements.

Liability concerns are part of the legal risks associated with autonomous vehicles (Parker, Shandro, & Cullen, 2017). Traditionally it is the driver of a vehicle that is causing accidents by being negligent. In regular traffic, the driver that failed to exercise due care can be liable for certain losses caused by the accident. In case of AVs, it is likely that accidents would be caused by a fault or defect in the vehicle. According to the website of the driverless commute, "Current legal frameworks are ill equipped to determine who is at fault—the owner, operator, passenger, manufacturer or coder" in the USA (Dentons, 2019). Questions that arise in case of an accident where AVs are involved might be difficult to answer. How do you divide the blame between a human driver and a car's automated system? Is the software to be blamed or rather the hardware? What if a car made a decision that its human driver would have not made? According to Parker, Shandro & Cullen (2017), attributing liability and fault is a difficult subject that will have to be tackled by legislators before AVs can enter the public roads.

Ethical issues are important to discuss when talking about the risks that AVs introduce into our lives. The European Commission (2018) argues, that "automated vehicles will have to be safe, respect human dignity and personal freedom of choice" in order to be considered ethical. An example is given, where the decision making of the vehicle has to represent the decision the human driver would have made in case of an unavoidable collision. However ethical/moral decision making of individuals differ between cultures which might result in controversial moral preferences (Joint Research Centre, European Commission, 2019). Sparrow and Howard (2017) explains a different kind of ethical dilemma. According to them, if human driven vehicles are safer at this point in time than machine operated ones, it is unethical to allow AVs to be sold. However, the moment it becomes clear, that AVs are safer than vehicles driven by a human driver, it becomes unethical to allow humans to perform any of the driving tasks. Taking this into account, it is questionable how to regulate - without risking ethical injustice - the overlapping period while human driven cars and AVs should be sharing the roads.

2.4. Conclusion

Chapter 2 highlighted the most relevant technological advancements in the field of self-driving car development. The current state of the AV technology allows cars of level 2 to early level 3 autonomy to enter the roads. Fully autonomous vehicles have level 5 autonomy. These vehicles function without a driver in all driving modes without human supervision by executing all tasks belonging to a driver currently in traditional vehicles. Tesla has been making the quickest progress among those manufacturers that focus on perfecting the self-driving technology during the past two decades (Wang J. , 2019). The larger batteries, allowing the vehicles to travel longer distances with one charge, more refined Autopilot system, a self-developed processor, and autonomous data tenfold of its competitors distinguish Tesla from other, often traditional car manufacturers located in the EU. The overall speed of the technological development is high but if we compare the different actors, it is clear, that Tesla is far ahead in the race. Therefore, looking at the scenarios presented in chapter one, I determined that in the USA Technology is fast, while in the EU, compared to the USA, technology develops slower. This has implications to the time society needs to accept the new technology and regulators get to react to the development in technological advancements. This picture can be altered by the findings in Chapter 3, where, besides manufacturers, other actors in the self-driving car ecosystem will be examined as well.

Chapter 2 also highlighted the most relevant risks and potential benefits of the AV technology. Both have impact on the way how the other two actors may react on the development of self-driving vehicles. Risks associated with AVs may reduce consumer trust and social acceptance and may as well result in a rather restrictive regulatory environment. The most influential risks are legal uncertainties (liability or insurance problems), privacy and cyber security concerns, loss of traditional jobs within the car manufacturer/transport sector, economic implications to for example the gasoline industry, safety concerns and ethical dilemmas (Geonovum, 2017). On the other hand, the wide range of opportunities such technology can offer was highlighted in this chapter. Traffic safety could improve drastically once human drivers are replaced by AVs, fuel efficiency would improve having appositive impact on the environment, AVs would indirectly influence insurance prices positively, would allow a more efficient time management for passengers, would open the door for new, more efficient city planning, would improve mobility, and it could provide new job opportunities (Sparrow & Howard, 2017).

3. Who is involved and how?

Chapter three intends to answer SQ 2.1 and SQ 2.2. These are the followings:
Who are the key industry, legislative, and societal actors on the autonomous driving landscape and what impact do they have on the AV ecosystem?
Are there differences between the EU and the USA regarding the attitude of the studied actors towards the AV technology?
The three sub-parts of this chapter all discuss one of the main actors within the self-driving vehicle ecosystem. By studying which industries besides the obvious car manufacturers are involved in developing AVs, the complexity and relationships among the different industry actors are highlighted. Examples of different approaches on cooperation or patenting between European and US-based industry actors is described as well in this chapter. The last part of the Chapter 3 focuses on societal acceptance and the change of it in the EU and USA over time. It offers an early adapter profile describing who are the most likely customers to purchase a self-driving car in the future. The most relevant concerns standing in the way of societal acceptance are also discussed in part 3.3. The goal of the chapter is to complete the initial picture of the state/speed of the technological development, presented in Chapter 2 and to lay down the basics on the state of the legislative environment in the USA and in the EU concerning the self-driving technology. Finally, the chapter also highlights where the third major actor, the Society stands in the question and provides a look into the future to see where it is more likely for the society to welcome AVs as they become available. This will allow me to place them in the 3D model presented in chapter 1, to see whether we observe an accepting or rejecting social opinion on AVs in the EU and in the USA.

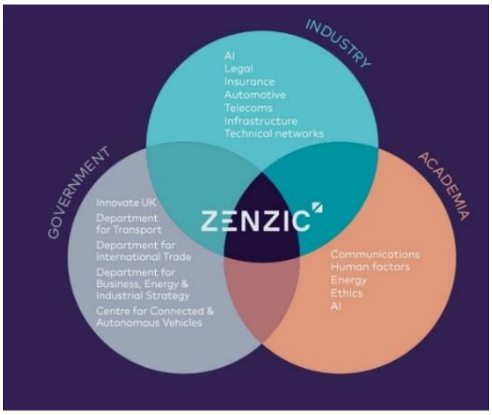
The impact of AVs will be far-reaching (Maunsell, Tanguturi, & Hogarth, 2014). Due to the complexity of the various technologies that form the backbone of self-driving vehicles, a variety of different stakeholders are involved in the development and will be affected by the widespread usage of AVs. Raj et. al (2020) identified that the attitude of consumers, the actions of legislators and the cooperation among different industry actors are the most relevant variables influencing the potential future of the autonomous driving technology. The emerging technology has in fact quickly drawn the attention of policymakers, manufacturers, and consumers as well (Raj, Kumar, & Bansal, 2020). According to Maunsell et. al (2014) there is a need for extensive collaboration among these stakeholders to create the right environment for autonomous vehicles to thrive. An open and connected ecosystem would ensure the creation of relevant products and services to keep consumers engaged. The ecosystem of a new and rapidly changing technology like the AV technology is evolving and expanding together with the technology itself. As milestones are achieved in the degree of autonomy, new stakeholders appear in the autonomous vehicle community (Geonovum, 2017).

During the early stages of AV development, car manufacturers started working closely with OEMs (Original Equipment Manufacturers) and other suppliers to create the hardware, the software, and additional consumer-centric services. An example for such a cooperation between a traditional automotive industry stakeholder and a new partner from a different field is described by Maunsell et. al their report from 2014 on “Realizing the benefits of autonomous vehicles in Australia”. Ford announced a new program in 2014 where they partnered with MIT and Stanford University to explore how to provide their future vehicles with common sense. The goal of the partnership was to advance autonomous vehicle development with the help of a group of experts on scenario planning. If the cars were to accurately predict the actions of other vehicles and humans around them, they were able to engage in advanced manoeuvres if needed. Paul Mascarenas, Ford’s chief technical officer and Vice President in an interview with the Los Angeles Times described a situation where a truck ahead of a self-driving car would slam on its breaks, the vehicle Ford was developing would predict if the area around the truck is clear to safely change lanes and continue with its desired speed similarly to how a human would evade the slower vehicle in this situation (Hirsch, 2014). Ford’s engineers had worked closely with MIT researchers on generating a real time 3D map of the vehicle’s surrounding environment with the use of LIDAR sensors. This information would then be processed using advanced algorithms to create a self-driving car with intuition similar to those of humans. This partnership is just one of the many examples on how non-traditional actors claimed a spot in the self-driving vehicles ecosystem during the early stages of development.

As the development process accelerated and self-driving cars entering the roads quickly becoming reality, other actors from outside of the traditional automotive industry began showing interest as well. Once we move on from development to possible roll-out -among others- insurance providers, energy providers and mobile service providers entered the expanding ecosystem of self-driving vehicles (Geonovum, 2017). Maunsell et. al (2014) explained that AVs might serve as a catalyst for mobile network development. The connectivity features of AVs (real-time monitoring of the surroundings, positioning, traffic information etc) will likely have an impact on the required data transfer speed or data storage capacity and the vehicle-to-vehicle or vehicle-to-infrastructure data exchange speed. This increased need for speed and capacity can be met if mobile service providers react to the changes in consumer needs and behaviour and offer new products and services tailored for AV users (Maunsell, Tanguturi, & Hogarth, 2014). In order to be able to do so, a systematic reshape and innovation of the existing telecom network architecture and technologies is needed (Wang J. , 2019). An example of a newly formed partnership within the scope of the self-driving car ecosystem involving the telecom industry is the cooperation between Huawei and Volkswagen group dating back to 2015 (Bicheno, 2015). Under the scope of this partnership, the Chinese telecom giant and the German car manufacturer focused on the development of an interconnected car technology by means of embedded modems. Richard Yu, CEO of Huawei Consumer Business Group expressed excitement to enter a market previously untapped by Huawei by partnering with an industry-leading automobile company. Their goal was to create seamless communication experience among vehicles (Bicheno, 2015). Huawei since has also been working in close cooperation with leading global operators to create an Autonomous Driving Network that can support the needs of AVs in order to allow the technology to operate in its full potential (Wang D. , 2018).

The high degree of uncertainty about the risks and the various opportunities the development and potential roll-out of AVs pose on society (see part 2.3) makes government agencies a prominent stakeholder in the self-driving vehicles ecosystem. The position of government agencies within the self-driving vehicle ecosystem is complex (Maunsell, Tanguturi, & Hogarth, 2014). There are numerous opportunities and benefits AV technology would have on city planning, healthcare providers or transport service providers. Besides the potential social benefits, advances in science and technology often drive significant economic growth (Walport, 2014). According to Walport (2014), innovation is becoming increasingly important for governments due to its impact on the competitiveness of countries externally and the well-being of its citizens internally. However governing agencies must balance benefiting from these opportunities while limiting the risks that the new technology poses on the public. Creating efficient policies that foster the right type of innovation the society will benefit from is crucial. Regulating emerging technologies is often difficult due to the potential disconnect between the speed of technological innovation and the speed of regulation or the required level of technical expertise needed to develop appropriate policy responses. A closer cooperation between private sector and public sector actors can have a positive influence in mitigating the potential disconnect (Malyshev & Kauffmann, 2019). An example for a partnership between the private and the public sector within the self-driving vehicle ecosystem is the ZENZIC project in the UK. ZENZIC was created by the UK government in cooperation with industry actors and academia (figure 6). Its goal is to lead the self-driving revolution by bringing together the different actors in order to foster the development of a safer, more inclusive, and productive mobile future (ZENZIC, 2019). The funding for the project is evenly provided by the government and the industry. Among the many features, ZENZIC provides a unique CAM testbed where innovative new ideas can be perfected, and it fosters private-public cooperation to define a long-term Roadmap for the development of autonomous and connected mobility in the UK. The testbed is unique in the world in providing within 3 hours drive several different road types, surface terrains, rural, highway or urban roads and parking facilities. The testbed has the unique ability to cross-share data with high-speed communications and offers a collaborative way of working (ZENZIC, 2019) virtually or on the physical test roads.

Figure 6 ZENZIC multi-stakeholder collaboration



(ZENZIC, 2019)

The above-mentioned examples of partnerships formed among the different actors in the self-driving vehicles ecosystem meant to give a general idea of how new stakeholders grow an interest in the AV technology. It gives a glance at the complex web of relationships among various actors and how close partnerships fuel the development of this cutting-edge technology. It is far from a complete overview of stakeholders, but it is mapping out the main group of actors who are interacting in the AV action arena. Following up on this general outline this chapter will focus on three main actors in the ecosystem of self-driving vehicles. To determine more precisely who belongs to these three main categories, the upcoming part will contain a description of:

- The wide range of industries that are relevant in developing the technologies (detailed look on the technology in chapter 2)
- The complex web of legislators that are part of regulating the issues concerning the development and roll out of AVs in the EU and in the USA (more details on legislation in chapter 5)
- The potential group of consumers (more details on societal acceptance in chapter 4)

This chapter will give answer to a number of “who?” questions. Who is involved in developing the technology that makes self-driving cars a reality? Who is involved in regulating the process of testing and the potential roll-out of self-driving cars? Who is the potential consumer that will be interested in purchasing a self-driving car?

3.1. Industry

Following up on the previously described evolution of how different industry actors grow an interest in entering the self-driving vehicle ecosystem, the upcoming part will describe the specific fields that are being represented by various actors on the AV landscape. In an early report from 2014, Maunsell et. al (2014) identified seven main actors that would be in some form impacted by the development of AVs. As presented in Figure 7, out of the seven actors, two belongs to the public sector and will be discussed in part 3.2. The remaining five actors are the ones that were to be impacted the most by the rapid development and future roll-out of autonomous vehicles.

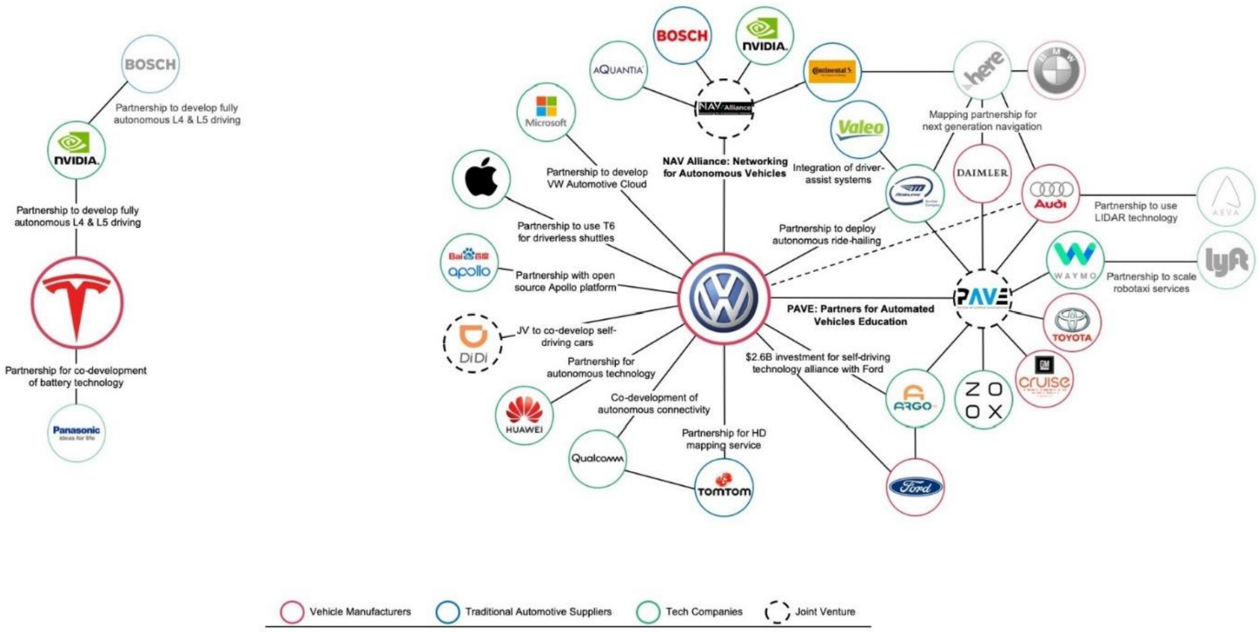
Figure 7 Expected industries to be impacted by AVs

(Maunsell, Tanguturi, & Hogarth, 2014)

The highest impact was assumed to be on the **Automotive industry**, the OEMs, and the suppliers. A close cooperation among this group was essential to maintain the speed of development in the early stages of AV history. Traditional auto manufacturers are often developing their autonomous prototypes in cooperation with OEMs and other relevant actors from the self-driving vehicle ecosystem. However, the example of **Tesla** shows that manufacturers can commit to work individually or with very limited number of partnerships on creating autonomous vehicles. The difference between partnerships of a manufacturer from the USA and one from the EU is shown in Figure 8. From the visual comparison it is apparent that while Tesla has been or is working with only two direct partners from the tech industry, **VW** is working with a wide variety of industry professionals to achieve their goal: developing a level 4 and later a level 5 autonomous vehicle.

Tesla used to be working together with Nvidia until 2018. Three years ago Tesla switched to working with in house developed chips instead of using the one provided by Nvidia to the vast majority of car manufacturers that are working on developing AVs (Cardinal, 2018). The one remaining partnership between Tesla and another actor in the self-driving ecosystem is with Panasonic. They work together on co-development and production of the battery technology fuelling the current semi-autonomous and future autonomous Tesla vehicles (Lambert, 2020). Contrary to the preliminary in-house approach of Tesla, Volkswagen is working with a wide variety of actors and participating in joint ventures as well. The two main joint ventures VW is part of are PAVE and NAV. PAVE (Partners for Automated Vehicle Education) is a coalition of automotive industry actors, non-profits, and academics to educate the public about the potential future involving AVs in order to facilitate public acceptance and support (PAVE, 2020). NAV (Networking for Autonomous Vehicles) has been founded by leading auto manufacturers and technology providers in order to create a platform for cooperation to develop in-vehicle network infrastructure for autonomous vehicles (NAV Alliance, 2020). Besides these two joint ventures, VW has several partnerships with leading technology providers (Argo AI), mobile service providers (Baidu) or cloud provider (Microsoft) as well. In order to develop a fully autonomous vehicle, VW must coordinate different partnerships and work together with several actors who are not specifically producing parts for VW but are manufacturing generic ingredients for autonomous systems used by several car manufacturers. Contrary to this approach, Tesla is developing the full package and as of now seems to be faster in achieving milestones towards a fully autonomous vehicle (Wang J. , 2019).

Figure 8 Autonomous driving partnerships of Tesla and of VW



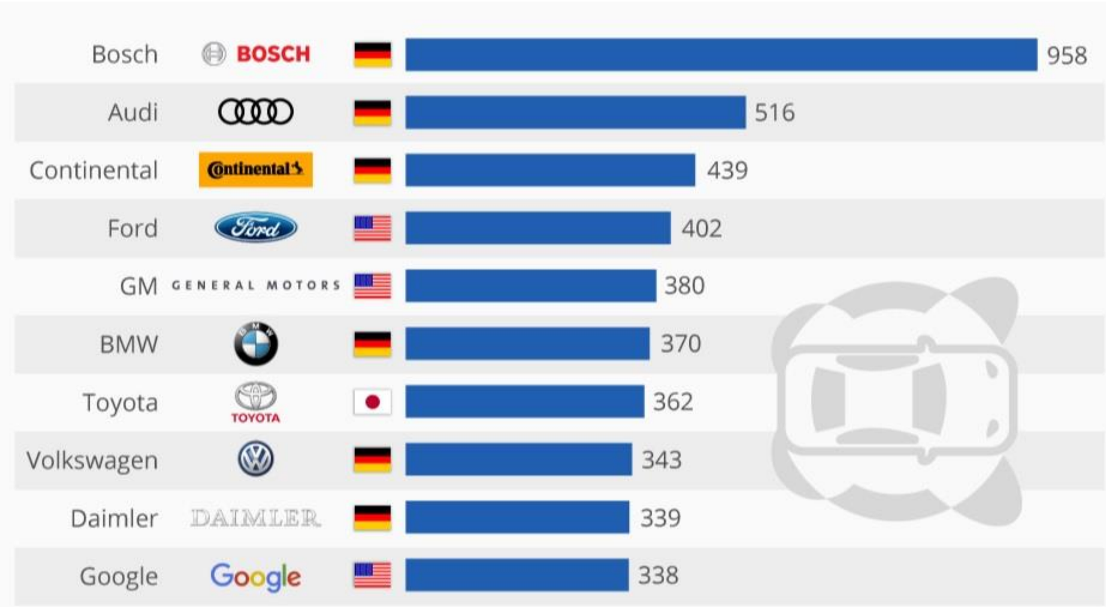
(Firstmile VC, 2019)

Besides VW and Tesla, there are other prominent actors from the automotive industry that are active in the autonomous vehicle ecosystem. An example from the US market is **Ford**. Ford is one of the most aggressive players on the market, aiming to launch self-driving vehicles by 2021 (GreyB, 2020). While other manufacturers have launched vehicles that have level 2 or 3 self-driving capabilities, Ford decided to take a different approach and launch their vehicle once it is capable of level 4 self-driving. Ford has been working closely in a global alliance with VW since 2019 when they committed to a 7-billion-dollar investment to the Argo IO autonomous vehicle technology platform (GreyB, 2020). Ford is also partnering with Walmart to explore how to utilize delivery with autonomous vehicles in the future. Throughout the past years Ford has established partnerships with several technology providers and OEMs and it has spent more than 1 billion dollars on acquisitions of Argo AI and Journey Holding in order to strengthen its position within the autonomous vehicle ecosystem.

General Motors has been active on the self-driving landscape and is one of the contenders to launch autonomous vehicles ahead of the previously mentioned competition (GreyB, 2020). Their main strength lays in aggressive test plans in partnership with Lyft. While General Motors has been testing thousands of autonomous electric Chevrolet Bolts since 2018, other manufacturers only recently caught up to this scale of testing. BMW aimed to launch a level 5 autonomous vehicle by 2021. Contrary to VW, **BMW** used to rely on in-house development instead of partnerships when it came to creating the technology for their iteration of autonomous vehicle. This has changed in July 2019, when BMW partnered up with Daimler for a joint development project. The focus of the cooperation is to create next-generation technologies for driver assistance systems, automated driving on highways and automated parking (GreyB, 2020).

While the above-mentioned actors are in fact the most prominent ones in the self-driving vehicle ecosystem, they are not the only ones. Due to the limited scope of this thesis, I have made the choice to focus on actors whose headquarters are located in one of the two markets I focus on (EU or USA). Tesla, Ford, and General Motors operate from the USA while BMW and VW are prominent German car manufacturers residing in the European Union. The most apparent difference between the approaches highlighted above is the lack of excessive joint research/development projects in case of Tesla (and initially in case of BMW). The other car manufacturers make use of "stock technology" and engage in multi-actor cooperation in order to develop the technology needed for AVs. Another major difference can be observed looking at worldwide patent filings related to autonomous driving. The Cologne Institute for Economic Research analysed 5,839 patents related to autonomous driving in 2017 to conclude that Germany's traditionally strong car industry is leading in the number of self-driving related patents (see figure 9). 6 out of the top 10 patent holders are located in Germany (Richter, 2017). Among the traditional car manufacturers, Audi is leading with 516 registered patents, followed by Ford (402), GM (380), MBW (370) and VW (343).

Figure 9 Number of patents filings related to autonomous driving between 2010 and 2017



(Cologne Institute for Economic Research, 2017)

A remarkable absence from this list is the one of Tesla's. According to intellectual property experts Tesla has not filed any autonomous driving related patents until 2017 (Rosenbaum, 2018). Most of the patents of Tesla are in battery technology and energy storage. While this practice is unique among the main industry stakeholders, it is in line with the ideology Elon Musk shared in a blog post on tesla.com in 2014. The blog, titled "All Our Patent Are Belong To You" shares that Tesla won't be patenting their technology related to AVs in order to enhance the speed of advancement of the electric vehicle technology (Musk, 2014). The decision was made in the spirit of open-source movement. Musk described that initially he felt compelled to file patents to protect Tesla from big car companies. He assumed that they would be able to copy Tesla's technology and produce electric cars on a major scale that would overwhelm Tesla due to the massive manufacturing, marketing and sales power other, more established manufacturers possess. However, the reality was different. Traditional car manufacturers showed little interest in the early days to develop vehicles that do not rely on burning hydrocarbons and using advanced technologies regarding self-driving features. In order to stay true to Tesla's goal to "accelerate the advent of sustainable transport", Musk took a step back from the initial idea of patenting technology developed by Tesla and decided to create an open, common, rapidly evolving technology platform where other manufacturers can freely use technology created by Tesla as long as they do so in good faith. Musk believes that "technology leadership is not determined by patents but by the ability of a company to attract and motivate the world's most talented engineers" (Musk, 2014). There is a clear difference between Tesla and its competitors' mindset when it comes to patenting and collaborations with other industry actors. Collaborations among different actors from the automotive industry within the self-driving vehicle ecosystem are frequent and it can help with speeding up the process of developing AVs. However traditional car manufacturers are just one industry among many active within the self-driving vehicle ecosystem when it comes to AV stakeholders.

Mobile service providers are impacted highly by AV development and deployment. The need for improved data transfer speed, greater storage capacity, better infrastructure and improved data exchange could inspire the mobile service industry to match the pace of AV development and try to benefit from new revenue opportunities. Once AVs are to be rolled out, the industry providing the infrastructure to communicate among devices, vehicles and their environment will play a very important role. To enable a fully autonomous ecosystem, the 5G communication system is crucial (Firstmile VC, 2019).

Maunsell et. al (2014) argued that mobile service providers are greatly impacted by the rapid development of AVs. They will be enabling connected cars to communicate with the infrastructure along the road (V2X communication) that can manage vehicle speed on smart motorways or facilitate vehicle to vehicle communication (V2V communication) to allow collision avoidance devices to make self-driving cars even safer (Sutcliffe, 2020). V2V communication allows cars to be aware of their surroundings and essentially could allow traffic lights to become obsolete if communication among vehicles can happen without latency. Besides their contribution to possible safety measures, mobile network providers can play a crucial role in the self-driving vehicle ecosystem by easing the way cities can bill vehicles for using toll roads and for entering cities with congestion charges as well. V2X communication with the help of high speed 5G networks could make parking meters the past as well.

The role of mobile service providers in the self-driving vehicle ecosystem is very impactful and rather new (Sanders, 2019). The development of 5G mobile networks is still in a relatively early stage of deployment and according to Sanders (2019) it is still years away from allowing 5G connected driverless cars to fully benefit from the technology. Mobile carriers are investing billions into the 5G technology to keep up with the development speed of autonomous vehicles which are expected to be the main users of widespread 5G networks. By the time self-driving is available on public roads, the nearly full availability of the 5G network will be an absolute must in order to allow the full potential of the autonomous technology to be utilized. At the moment Tesla uses networks only as a secondary means of communication in their semi-autonomous vehicles (Sanders, 2019). This is due to the low availability of 5G connection nationwide. Currently 5G is utilized on a smaller scale in local areas like campus networks or factory floors. On large scale 4G is the norm. In order to facilitate the development of technologies that benefit from 5G connectivity, the coverage of the 5G network must drastically improve. Therefore, the role of mobile service providers is absolutely essential in providing the necessary infrastructure needed to advance the technological development of countless features of autonomous vehicles. An example of a partnership among a mobile service provider and a traditional car manufacturer is from July 2019 when BMW partnered up with China Unicom to test autonomous cars using 5G networks. This is the first of such partnerships among a global car manufacturer and a state-owned mobile carrier and it shows the leading role China is willing to take in introducing the great potential 5G offers for autonomous vehicles (GreyB, 2020).

Technology providers & OEMs were expected to be feeling a medium to high impact (Maunsell, Tanguturi, & Hogarth, 2014). The AV ecosystem opened new opportunities for application developers, big data and analytics companies, cloud, and IT services, but also security software developers and OEMs providing self-driving specific parts for traditional car manufacturers. This is a big group of diverse actors that provide various hardware, services, and software to enhance the working of several features of autonomous vehicles. Data generated by the autonomous vehicles could be stored in the cloud provided by actors in new industries providing a supporting role to enable autonomous driving by connecting different actors within the ecosystem with each other. A cloud storage would allow transportation agencies to access the information gathered by self-driving vehicles, sent on a 5G network to the cloud storage and use it to develop smart roads and more efficient transport systems (Maunsell, Tanguturi, & Hogarth, 2014).

Technology providers play a key role in the development process of AVs. They provide the framework for the proper functioning of the autonomous vehicles (Geonovum, 2017). In order to enable the new, innovative functions of autonomous vehicles, technology providers are working in close cooperation with traditional car manufacturers. Their increasing involvement in supporting the traditional actors is an example for the ever-expanding ecosystem of self-driving vehicles. The need to rely on cutting edge software in order to achieve fully autonomous driving capabilities allowed the world's top computing companies like Apple, Google, or Cisco to become key stakeholders. Their main roles are:

- "Boosting software reliability and cyber security
- Securing the software that runs the car and integrating all the components that need connection to the internet
- Securing applications running within the vehicle
- Establishing communications between vehicles and internet enabled devices" (Geonovum, 2017)

Besides providing the software that functions as the framework for self-driving vehicles, the above-mentioned companies benefit from the development of autonomous vehicles by creating new apps to satisfy the needs of the passengers. While in the status quo, a car is being driven by a human driver, once fully autonomous vehicles become the norm, the present human driver will become a passenger. It opens the possibility to utilize travel time in different ways. The vehicle can function as a mobile workstation or even as entertainment/leisure area. App developers can target autonomous vehicles when developing workspace productivity products or have a new revenue stream when it comes to apps that can be utilized while traveling either for work or leisure purposes (Maunsell, Tanguturi, & Hogarth, 2014).

When it comes to hardware, OEMs can tap into a new marketplace. Autonomous vehicles require advanced sensors, GPS, image recognition, light detection and ranging systems, ultrasound, cameras, chips, and computer vision which are developed by technology providers and are used by traditional car manufacturers. Sophisticated diagnostic and predictive tools are provided by actors in the deep learning and artificial intelligence industry. They play a key role by providing the means to the machine to imitate human neural networks (Geonovum, 2017). Deep learning algorithms help making traffic safer once AVs are rolled out by providing a more accurate functioning than humans are capable of when it comes to object recognition and perception. Besides offering increased safety, these algorithms can reduce power consumptions by increasing efficiency as well. They can be utilized during the manufacturing production line and in crash testing to help reduce time and costs associated with the development and testing of autonomous vehicles (Geonovum, 2017).

An example for a new actor is Mobileye x Intel providing vision-based driver assistance systems to 25+ global automakers (Yuan, 2018). 13 out of those automakers specifically rely on Mobileye to enable fully autonomous driving. Nvidia, who is traditionally known by its GPU's, developed a system that can accurately analyse and understand the surrounding environment of a car using cameras, LiDAR, radar, and ultrasonic sensors (Yuan, 2018). Nvidia is partnering with a growing number of traditional car manufacturers, including VW, Audi, and Mercedes Benz as well. Their revenue generated from automotive-related business tripled in 2018 and accounted for 19% of the company's total revenue. The speed of the growth indicates evolving opportunities for non-traditional, technology providers in the self-driving ecosystem.

Energy companies are also impacted by the development of autonomous vehicles, so they have to be considered as a major stakeholder when it comes to industry actors (Maunsell, Tanguturi, & Hogarth, 2014). Once autonomous vehicles will become the norm, the impact on the energy industry can be disruptive (Geonovum, 2017). AVs will likely serve a dual purpose in the form of consumption and provision. During the day, when the vehicles are on the road, they will likely not consume motor gasoline as they will likely rely on alternative fuel sources. During the night, when the vehicle is often idle, it could serve as a cheaper energy source for a household, or it could deliver energy back to the grid. All of these imply a considerable impact on the status quo of providing energy to consumers (U.S. Energy Information Administration, 2018). In 2017, passenger vehicles in the USA used 21% of the total delivered end-use energy consumption, and 99% of the energy used by passenger vehicles was motor gasoline. This also accounted for 88% of the total motor gasoline consumption in the USA in 2017. The impact of AVs is uncertain, but the assumption is that it could reduce the total energy use by 60% (U.S. Energy Information Administration, 2018).

While the emergence of AVs likely will create a reduced need for traditional energy sources, it also creates opportunities for energy companies to remain relevant in the self-driving ecosystem. By using alternate energy sources to generate power, energy companies can remain benefiting from passenger transport energy usage. By exploring the possibility of developing an in-road charging systems or other alternative service stations, the role of the energy industry is very relevant when it comes to the optimal use of AVs (Geonovum, 2017). As AVs become more prevalent, energy providers will likely partner with car manufacturers to better understand the changing energy needs of passenger vehicles if they want to remain relevant within the self-driving vehicle ecosystem (Maunsell, Tanguturi, & Hogarth, 2014). An example for such initiative is of Castrol innoVentures who is tasked with exploring several new opportunities in smart mobility, to shift the current focus from internal combustion to new, more sustainable products. They have been partnering up with universities to foster development and they used venture capital investments to position themselves on the AV roadmap (Mueller, 2018).

Financial Services can be impacted by the future deployment of AVs in various ways. While the expected impact on this sector is milder compared to the previously discussed industries, it is relevant enough to include the financial sector as one of the prominent actors in the self-driving ecosystem. The potential change in ownership models may alter the current car financing practices and introduce new revenue streams for the banking and the insurance sector (Maunsell, Tanguturi, & Hogarth, 2014). As discussed earlier, the new space created by self-driving vehicles allows the passengers to utilize the time they spend in the vehicle. This may open a new stream of revenue for the banking and financial industry. In-car purchases or payments for fuel and tolls utilizing the AVs advanced infrastructure are examples of new ways the banking sector can benefit from the emergence of this new technology. This however imposes an increased risk of information security that has to be mitigated by the industry in question in order to generate trust in these new opportunities (Maunsell, Tanguturi, & Hogarth, 2014). Machine-to-machine security and alternative authorisation technologies are on the top of the priority list before AVs can function as payment devices during a journey.

Driverless cars can disrupt the current ownership model by encouraging frequent ride sharing or shared ownership. Both would result in a reduced number of car ownerships which would disrupt the current nature of car financing. Consumers would stop or reduce the amount of money they borrow for car purchases which is a loss in revenue for the banking sector. Banks are expected to react on this change by turning their interest towards the previously mentioned opportunities the AVs development offer for the financial sector. Banks will likely work in close cooperation with other relevant actors, like energy providers and fleet providers to create a new business model that ensures a continued revenue stream for the banking sector (Maunsell, Tanguturi, & Hogarth, 2014).

The insurance industry is similarly impacted by the changes of the nature of car ownership and risks associated with AVs. Keeping up with the developments requires changes in insurance models. Accident trends are expected to change radically. The widespread usage of AVs will reduce the number of accidents occurring on the roads (Ciuffo & Raposo, 2019). However, in case of such an accident occurring, it is more complicated to determine who is liable. The current uncertainties around liability issues require the insurance sector to become an active actor in shaping the future of AVs, in order to be fully prepared for their arrival. Due to the reduced number of accidents, insurance revenue is expected to drop 15-40% by 2050 (Ciuffo & Raposo, 2019). There are also opportunities associated with the deployment of AVs regarding the financial sector. Insurance providers could benefit from the additional data available to them to reshape and optimise their products and premiums which could result in higher revenue and reduced costs (Maunsell, Tanguturi, & Hogarth, 2014). Motor insurance could be replaced by product liability insurance and liability could shift from driver to software manufacturers. That in turn will eliminate the risks associated with different driving skills and driving experience. The target customer of the insurance companies will change, opening a new market which they can benefit from.

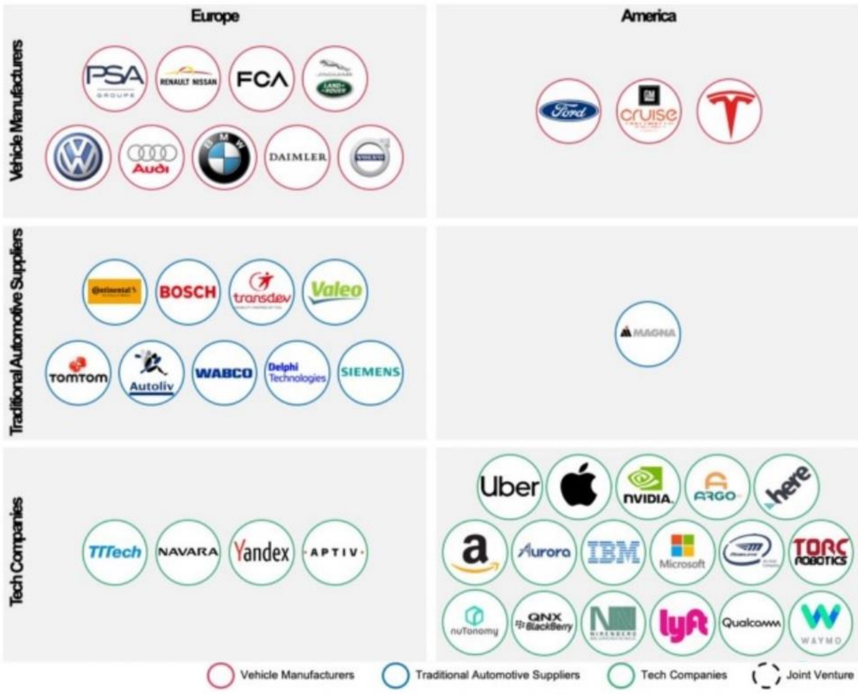
An example for a partnership within the self-driving ecosystem formed between a traditional car manufacturer and a new actor from the financial sector is the State Farm-Ford-University of Michigan’s cooperation to research AVs. In 2013 the partnership presented the automated Fusion Hybrid that served as a research platform to study and develop long-term solutions for potential societal, legislative, and technological issues raised by the rapid development of AVs (Ford Motor Company, 2013). State Farm was a crucial partner in this cooperation that has aimed to develop the infrastructure needed to support a sustainable transportation ecosystem. The role of State Farm in this three-party partnership was to provide to and analyse data with Ford about rear collisions in order to assess how the AV technology could reduce the number of such accidents. State Farm had a major interest in participating in the research as it offered them an opportunity to get a deeper understanding on how to meet the changing needs of their future customers (Ford Motor Company, 2013).

Chapter 3.1 described the five main actors within the self-driving vehicle ecosystem. Examples for partnerships between different actors from different sectors were given to demonstrate the complexity of the driving force behind the remarkably speedy development of autonomous vehicles. While the previously discussed five actors are expected to play the most important role in the development process, there are several minor industry actors that will be impacted by the changes resulting in the deployment of fully autonomous vehicles. As the Dutch Safety Board (2019) determined, in order to ensure a successful deployment of this new technology, actors that are less influential during the development phase will play a significant role in the distribution and aftercare of AVs. Importers, dealers, and car repair shops are expected to have to adjust their current practices to meet the requirements of dealing with the challenges of the autonomous vehicles. If AVs will become the norm in passenger vehicles, the required number of battery-cells will rise. This opens opportunities for manufacturers to fill the gap on the EU and US market, as currently the majority of batteries used in semi-autonomous vehicles are imported from Asia (Ciuffo & Raposo, 2019).

Earlier in this chapter, a notable difference between the approach of Tesla and all other car manufacturers was highlighted. While generally all AVs are being developed in multi-actor partnerships, Tesla uses in-house developed and produced technology to create their iteration of autonomous vehicle. However, this comparison does not allow me to draw conclusions about systematic differences among EU and USA actors, since Tesla seems to be an outlier. Therefore, after determining the main industry related actors in this chapter, Figure 10 compares how those actors compare based on their base of operation. Looking at this figure, I observe significant differences when it comes to how the AV technology has been developing in the EU and the USA. While Europe has significant manufacturing ability when it comes to traditional car manufacturers or OEMs (Continental, Bosch, or Siemens), it lacks when it comes to the technology providers. In such a fast-moving industry, where software is crucial to keep the development process moving, it is remarkable that European actors have missed the opportunity to take a significant role when it comes to the high-tech side of developing AVs. Europe’s self-driving landscape consists mainly of the same major actors that have been significant since car industry began developing (Firstmile VC, 2019)

As seen in Figure 10, in the USA, most of the relevant actors in the AV landscape belong to the tech industry. This is the opposite of what we observed in Europe. America seemingly adapted to the fast-changing landscape of AVs much better, and companies that wanted to be part of the autonomous driving revolution turned their focus on various ways to contribute to the process by providing much needed technological development focusing on the self-driving capabilities of the car industry. There are only a few traditional car manufacturers (Ford and GM) actively developing AVs and even fewer (MAGNA) OEMs that should be mentioned on the US market. Companies like Microsoft, IBM, Nvidia and Aurora, among many others have a strong history of contributing to the development of AVs, in the form of partnerships with other actors on and outside of the US market. The difference in the type of actors among the EU and the USA is clear. Additionally, Tesla, as the only actor on the market generally opting out of any kind of partnerships while keeping the platform their develop open to share with other actors in order to advance the AV development speed is an interesting exception.

Figure 10 Notable driving clusters in the EU and in the USA



(Firstmile VC, 2019)

3.2. Legislators

The second main group of stakeholders influenced by and influencing the development and the potential deployment of AVs consists of legislators. Innovative technologies such as autonomous vehicles create risks and uncertainties especially if they develop rapidly (Raj, Kumar, & Bansal, 2020). The impact of the testing and future launching of the self-driving technology is far reaching. It can have positive, negative, and unknown influence on a number of different industry actors (see chapter 3.1), the society (see chapter 2.3) and inevitably on the governments as well. In order to get a step closer to be able to assess whether or not the AV technology is more likely to hit the road in the EU or in the USA first, Chapter 3.2 focuses on describing the different legislative bodies that are involved in regulating the AV technology development in the EU and in the USA. This chapter will map the main governmental sectors that are impacted by the technology. I compare how the EU and the USA approaches the challenges associated with regulating this specific emerging technology, and what the main principles are based on which the EU and the USA is formulating their legislative strategy.

The importance of legislators in making AVs a success or failure is unquestionable. The policy response to the emerging technology can enable, advance but restrict or completely shut down a new initiative. In order to determine whether observable disconnects are present between legislators and technology or society, determining the main governmental actors is key. Comparing the policy landscape in the EU and in the USA helps create a deeper understanding of where adjusting the current regulation is needed, how legislation comes to life, and who the most relevant governmental agencies are. Chapter 4 will describe the relevant past and current legislation in the EU and the USA, the current chapter only introduces the most important legislative actors in the self-driving vehicle ecosystem, and the relevant principles that shape policies dealing with autonomous vehicles.

According to Walport (2014), the role of the government in relation to risk and innovation is multifaceted. Firstly, the legal framework, policies and government institutions determine the environment in which non-governmental actors can innovate. Depending on the existing policies, innovators can face risks or can be encouraged by incentives. Second, it can be the government or their agencies that carry out the innovation if private agents are unable or unwilling to do so due to risks or uncertainties. Finally, government can take on the traditional role to react on innovation by managing the risks that a potential new technology can bring with itself. Governments can facilitate the development of a new technology by investing in research. Besides the different ways governments can impact the development of the technology, Walport (2014) emphasizes another major role government policies and regulations play in influencing the volume of demand for the innovative new technology. On one hand, the government itself is a large consumer, on the other hand it may use regulation or taxes/subsidies to generate demand for the desired product. Governments can contribute to the success of a currently unknown technology by providing information to the public in order to facilitate building trust or by ensuring the necessary, basic infrastructure is available (Schreurs, 2016).

Regulating an emerging technology is rarely straight forward due to the high degree of uncertainty attached to it starting from the very beginning of the development/discovery process. The need for regulators to evaluate the possible impact on the status quo due to the new technological discoveries often results in the technology outpacing government policy and regulation, resulting in potential disconnect among two of the studied actors, the Legislators, and the Technology. This is increasingly the case looking at the challenges regulators are facing when dealing with autonomous vehicles (Ramsey, 2015). The development of the autonomous vehicle technologies ranges from incremental (for example cruise control) through more invasive (autonomous valet parking) to revolutionary changes (fully autonomous vehicles). Incremental technological changes can be addressed relatively quickly with minor changes to existing regulatory frameworks. The larger the technological innovation is, the higher the need for deeper regulatory intervention tends to be (Schreurs, 2016).

In case of fully autonomous vehicles, the change in technology is revolutionary. The speed at which the car industry arrived at the real possibility of deploying AVs from just having cruise control widely available in vehicles is remarkable. The combination of the degree of technological change and the speed at which it occurred makes some form of regulatory intervention necessary (Schreurs, 2016). What complicates this already challenging situation, is the number of policy areas that are in some form impacted by this emerging technology. A growing number of actors now play a role in shaping transport policies, where industry actors are both in competition to be the first one to achieve fully autonomous technology and in cooperation with each other to try to ensure a favourable regulatory environment for AVs (Schreurs, 2016). However, regulating autonomous vehicles is not limited to adjusting transportation related policies. AVs have the potential to improve or endanger several areas of our everyday life not only once available but during the development phase already. Therefore, taking a closer look at the role of governmental actors, and the principles that shape their actions is of value to this research.

When it comes to formulating policy, politicians and bureaucrats make decisions based largely on facts provided by experts or based on the lack thereof (Fenwick, Wulf, & Vermeulen, 2017). As described in Chapter 2.3, the autonomous driving technology is surrounded by many potential benefits and risks which ensures that regulating it is already on the agenda in the European Union and in the USA as well. Main policy areas to consider regarding AVs include:

- infrastructure management
- land use and urban planning
- public transportation
- liability issues regarding vehicle ownership
- health and safety
- environmental protection
- employment
- energy consumption
- cybersecurity
- tax and insurance
- ethics (Pucher, Schausberger, & Wernech, 2018).

In order to prepare for the roll-out of autonomous vehicles, changes in the current infrastructure are often necessary. Since AVs rely on observing the environment to manoeuvre the car, it is important that roads and traffic signs are suitable for self-driving vehicles. Major highways, but also side roads in rural areas will have to satisfy the same standard of requirements. Legislators are accountable for taxpayer's money, and public investment should be based on robust cost-benefit analysis (Silberg & Threlfall, 2016). While the costs are to be made in the present day to prepare for the roll-out of AVs, the full benefits of autonomous vehicles will only be available once every vehicle on the road has full self-driving capabilities. The timeframe is unknown, but it will likely take a minimum of 50 years before traditional vehicles driven by humans are phased out (Silberg & Threlfall, 2016).

AVs have the potential to improve city planning and encourage the creation of intelligent cities (Maunsell, Tanguturi, & Hogarth, 2014). The vehicles are collecting traffic data that can help local authorities to tweak their revenue models and improve urban network planning. AVs would need narrower roads which frees up considerable amount of space in urban areas. The need for public transportation might decrease as self-driving vehicles eliminate many of the obstacles for those that currently have no means of driving a car (due to for example health reasons or lack of driver's licence). The impact of AVs on car ownership is expected to be radical (Geonovum, 2017). If car-sharing becomes the norm and car ownership does radially decrease, legislators will face a reduced revenue from tax. Liability is a key area where a complete restructuring is needed since AVs do not have human drivers. Accidents might occur, with only AVs on the roads or during the transition period when both AVs and traditional vehicles share the roads. In order to create a strong legal framework, current liability laws must be adjusted.

Legislators must ensure that once AVs hit the road, they are failsafe and protected from external attacks. Regulating testing regimes is crucial to ensure the development of the new technology and to safeguard the health of the public (Silberg & Threlfall, 2016). While currently it is the driver that has to own a valid licence to legally be allowed to drive a car, once the responsibility to operate the vehicle shifts to the machine, the certification of the vehicle's ability to safely drive on the road will replace the certification of the human driver. An adjustment in practices and in the legal framework is necessary to ensure the safe testing and roll-out of AVs. Similar concerns occur regarding privacy and cybersecurity. The amount of data produced by self-driving vehicles is currently unknown in the traffic industry and legislators will have to safeguard consumer rights when it comes to setting standards for the handling and storage of the data.

Protecting those that will not have the financial means to participate when the new technology rolls-out is an important consideration for legislators to ensure social inclusion

(European Commission, 2018). Similarly, the need for re-education will rise as traditional jobs regarding the automotive industry might disappear. In order to mitigate the negative impact and act pre-emptively, government action to inform the public and promote education that will ensure long-term employment in the automotive industry is crucial (Geonovum, 2017) It is also the responsibility of the government to uphold environmental standards and ensure that the sustainability goals set today are viable if AVs become the new norm. The positive impact of autonomous driving on the environment due to the use of alternative fuel sources is expected to be significant, ensuring legislation to reap the full environmental benefits of this new technology is the responsibility of the government (Pucher, Schausberger, & Wernech, 2018).

The final policy area that I considered relevant is the responsibility of the government to ensure ethical standards when it comes to the "decision making" of the machine operating the vehicle. It is inevitable that situations will occur in the traffic when a collision is imminent. Currently it is the human driver who reacts in such situation and steers the car to avoid hurting themself or others. Once vehicles are making the decision, the need for an ethical code is needed (European Commission, 2018). Legislators have to consider dilemmas regarding one universal ethical profile or options to choose from when it comes to AVs. Can manufacturers program their own way of decision-making machine, or will the passenger be allowed to choose a "profile" when it comes to ethical questions? Complex ethical issues that are currently not regulated yet will become the topic of serious discussions among legislators before fully autonomous vehicles can roll-out (Schuelke-Leech, Jordan, & Barry, 2019).

3.2.1. EU

There is currently no legislative framework specifically aiming to regulate automated vehicles on the EU level, however, existing EU legislation is partly suitable for regulating the roll-out of AVs. Policies on the EU level are formulated in the European Commission, within five directorate generals:

- DG GROW, who oversees vehicle legislation, competitiveness of the automotive sector, product liability, intellectual property, GNSS-Galileo system, etc.
- DG CONNECT, who is tasked to look for synergies with the telecommunication sector
- DG MOVE, who is responsible for traffic management and road safety
- DG RTD is facilitating research into AVs and funding
- CLIMA is promoting sustainability (European Union, 2016)

In 2015, GEAR 2030, a High Level Group was set up to analyze the future of the automotive sector. GEAR 2030 provided a platform for member states, industry stakeholders, consumers, and members of the European Commission in order to develop AV policy recommendations (Acosta, 2018). The European Council has a coordinating role when it comes to AV policies. Presidencies encourage member states to harmonize their AV policies within the scope of the strategies set by the European Union. The European Commissioner for Transport is tasked to coordinate research and promote international standardization while ensuring data protection and cybersecurity (European Commission, 2017). The European Committee for Standardization (CEN) supports standardization activities on the EU level among others, regarding the emerging autonomous vehicle technology as well. The European Telecommunications Institute (ETSI) makes standards specifically for communication and information technologies. The European Union Agency for Network and Information Security (ENISA) is tasked to meet with car manufacturers, suppliers, and national agencies regarding cybersecurity since this policy area used to get less attention than other aspects of AV deployment (European Commission, 2017).

Regulation on the EU level covers all modes of transport, however the new challenges, risks and uncertainties regarding the autonomous driving technology encourages the EU to work on a comprehensive regulatory framework. The area which is currently lacking the most is regulating the testing of AVs. There is no clear regulation that allows testing on public roads or in testbeds on the European level. Member States can regulate testing on the national level which results in a fragmented landscape when it comes to AV testing regulation in Europe. While countries like Germany and the Netherlands decided to implement a forward approach and allow road testing of AVs, other member states opt-out of this practice. This creates a confusing and not welcoming environment for AV developers. VW decided to relocate to California to do the testing and to launch their AV there instead of in Europe due to the much more restrictive regulatory landscape when it comes to testing AVs (Jacobs, 2018).

Regarding the main principles in the EU that is shaping the formulation of AV policies, the most prominent value seems to be safety. It can be either enabling or slowing down the potential roll-out of autonomous vehicles in Europe. The European Commission is promoting the Vision Zero safety project **-** which aims at there being no road fatalities on European roads by 2050 (European Commission, 2018). The potential of self-driving cars promises a drastic decrease on road traffic accidents which is in line with the goal of the Vision Zero project. On the other hand, the risks and uncertainties associated with the AV technology may considerably slow down the roll-out in Europe as safety is the most essential principle for the European Union (Schreurs, 2016). Looking at the European Commission’s main priorities outlined in the 2018 communication over the EU strategy for mobility of the future, the guiding principles regarding regulating the autonomous vehicle technology in the EU are legal certainty, investment in relevant technologies and the protection of citizens from new risks. The most relevant tool to achieve this is to guarantee a real internal market. It is clear, that the EU recognizes the potential autonomous driving can offer to society, but unlike in the USA, the focus is not primarily on gaining a competitive edge but on ensuring safety.

3.2.2. USA

In the USA, the federal government and the individual states share the responsibility of regulating vehicles operating on public roads (Canis, 2019). At the federal level, the National Highway and Transportation Safety Administration (NHTSA) is responsible to provide guidelines for the states and the industry regarding the deployment of autonomous vehicles. The fact that the NHTSA does not have legislative power means, that there is no harmonized legal framework on the federal level when it comes to the testing or the deployment of AVs. This results in a fragmented policy landscape that differs from state to state from no regulation (Wyoming) to extensive regulation (California) regarding the testing and deployment of the autonomous driving technology (National Conference of State Legislatures, 2020).

The NHTSA falls under the Department of Transportation (DOT). The DOT determines the main policy direction when it comes to regulating transportation issues and shares the responsibility to maintain and build highways (Lyons, 2015) with the states. According to the website of the DoT, “The top priorities at DOT are to keep the traveling public safe and secure, increase their mobility, and have our transportation system contribute to the nation's economic growth.” Safety is the highest priority of the U.S. DOT which was established in 1966 (U.S. Department of Transportation, 2020). The DOT controls and allocates the federal transportation funding to states and it is responsible for evaluating and providing policy guidance to the states if a new technology emerges. Besides the NHTSA, the Federal Highway Administration (FHWA) has authority when it comes to AV legislation. The FHWA is responsible for the construction and maintenance of bridges and tunnels, and it can provide technical assistance to states regarding improving safety, mobility and encouraging innovation (Lyons, 2015).

The guidelines provided by the NHTSA are just a tool to help state legislators formulating appropriate policies and it is in no way restricting states from implementing a more encouraging or restrictive set of legislation regarding AV testing and deployment as they see fit. Federal law does not prohibit the use of autonomous vehicles hence it is considered to be legal in the absence of restrictive legislation on the state level (Lyons, 2015). The lack of federal legislation encouraged state legislators to put the issue of autonomous driving on the policy agenda in order to ensure appropriate regulation in harmony with their own norms and values. States’ responsibilities regarding AV legislation are clearly defined by the 2016 NHTSA Federal Automated Vehicles

Policy. States are licensing human drivers and are registering motor vehicles; are enacting and enforcing traffic regulations; are conducting safety inspections and are regulating motor vehicle insurance and liability. The NHTSA is responsible for setting standards for motor vehicles for manufacturers to comply with; enforcing compliance with said standards and communicating with and educating the public about motor vehicle safety issues.

The National Transportation Safety Board (NTSB) is responsible to investigate all civil aviation accidents and significant accidents in other transportation modes. Accidents with fatalities involving autonomous vehicles fall under the jurisdiction of this independent federal agency (Canis, 2019). In November 2019, the NTSB issued a report on an accident caused by a test vehicle operated by Uber Technologies in Tempe, Arizona in 2018 causing an infant to be fatally injured. In this report, the NTSB concluded that the vehicle operator failed to monitor the driving environment due to being distracted by her cell phone. Besides the human error, the NTSB concluded that deficiencies in state and federal regulation contributed to the circumstances leading to the fatal crash (Canis, 2019). Chapter 4.2 will further discuss AV regulation in the USA in order to give a clear picture whether or not AV regulation is indeed lacking while autonomous and semi-autonomous vehicles are tested on public roads daily.

The leading principles when it comes to AV legislative efforts in the USA are described by the US DOT's report titled "Ensuring American Leadership in Automated Vehicle Technologies" from January 2020. The report establishes that the main goal of the US Government is to foster innovation to ensure the US leads the world in automated vehicle technology development while ensuring safety, security, and privacy of its citizens (United States Department of Transportation, 2020). AV 4.0 establishes three main principles each with several sub-categories. These are the followings:

- "Protect Users and Communities
  - Prioritize Safety
  - Emphasize Security and Cybersecurity
  - Ensure Privacy and Data Security
  - Enhance Mobility and Accessibility
- Promote Efficient Markets
  - Remain Technology Neutral
  - Protect American Innovation and Creativity
  - Modernize Regulations
- Facilitate Coordinated Efforts
  - Promote Consistent Standards and Policies
  - Ensure a Consistent Federal Approach
  - Improve Transportation System-Level Effects" (United States Department of Transportation, 2020)

These three principles are guiding the US government's effort to ensure their leading role when it comes to the development and the roll-out of autonomous vehicles. The main objective is clearly determined by the AV 4.0 report to enable the speedy development of the AV technology while ensuring safety, security, and privacy. The emphasis remains on voluntary consensus standards and other guidance provided by the federal government. The US government facilitates collaborative efforts between federal and state legislators. The government aims to create an environment in which innovation can flourish and new technologies emerge to meet the market requirements (United States Department of Transportation, 2020).

3.3. Society

Besides industry and governmental actors, society is the third group of stakeholders to consider in the self-driving vehicle ecosystem. Autonomous vehicles have the potential to take over the entire transport sector, including passenger transport. When it comes to necessary conditions regarding the success of an emerging technology like autonomous vehicles, the willingness of the consumer to purchase the product is crucial. A potential disconnect between society and either one of the two other stakeholders would likely mean that AVs would fail. In case of a disconnect between technology and society, consumers could refuse to make use of self-driving cars. While other sectors (for example freight transport) could still utilize AVs, most of the benefits described in Chapter 2.3.1 would not be applicable anymore.

If there is a disconnect between legislators and society, two scenarios should be considered. On one hand, the EU's more restrictive approach towards AVs can be conflicting with an overwhelming public support for the new technology. In this case, a potential delay in the roll-out of AVs would not be supported by public opinion. On the other hand, if the USA's more allowing policy pushes the roll-out of AVs faster than society is willing to accept it, the technology is likely to fail due to lack of interest from consumers. A disconnect between society and the other two stakeholders during the development phase does not mean that the technology is determined to fail. It is however important for the legislators to develop appropriate strategies to inform and educate society and encourage building trust with the new technology. As AVs are still in the development phase, consumer attitude is still forming. The following part will highlight the importance of societal acceptance and will compare the changes in public opinion towards AVs over time in the EU and in the USA.

3.3.1. Societal acceptance in the EU vs in the USA

Literature suggests, that both European and American legislators find it important to have consumer acceptance of the new technology before moving forward with creating legislation for it. The United States Transportation Secretary, Elaine Chao has indicated support for changes to relax existing restrictions applicable for testing driverless vehicles on public roads, stating that she wants "consumer acceptance," rather than federal regulations, to be the main constraint on autonomous vehicle adoption (Dentons, 2019). The European Commission states in their communication, titled: On the road to automated mobility: An EU strategy for mobility of the future in 2018, that "Initial studies show that a majority of Europeans citizens have a good acceptance of driverless cars with 58 percent willing to take a ride in a driverless vehicle. The Horizon 2020 transport work programme 2018-2020 includes projects to undertake in-depth analyses on behaviour of users and public acceptance and to assess the medium- and long-term impacts of automated and connected driving."

It is clear, that legislators find it important that the public is positive towards AVs when forming a strategy how to deal with regulating this emerging technology. Therefor it is important to look at how the public opinion used to be when AVs have been first introduced as a viable option for transportation in the near future and if there is a positive or negative shift in the public opinion in the EU and USA. According to Fortunati et al. (2019), this is an area of research that is lacking severely. Only 3% of the research on questions associated with autonomous vehicles are contributed by social science literature. There is a heavy imbalance when it comes to the origin of those studies. Most data are available from countries where large ICT or car manufacturers are present. The USA, Germany, France, and the UK are among those countries. Those studies that are available are lacking in presenting realistic scenarios to participants which is problematic since the public in general has rarely any direct experience with AVs. According to Fortunati et al. (2019), studies currently available fail to differentiate among the different levels of automation while the participant's general knowledge of AVs is often lacking as well. Bearing in mind the limitations of the available studies, the goal of this part is to get a general idea about what public perception is towards driverless cars in the EU and in the USA. I will identify possible barriers for self-driving cars and identify who are more likely to be positive towards EVs.

Societal acceptance of an emerging technology is crucial to its long-term success (Fraeddrich & Lenz, 2016). If the consumers are reluctant to accept, or do not have broader knowledge of the existence of a new technology, it is less likely that the technology will gain support among the consumers. According to Fraeddrich and Lenz (2016), technology acceptance takes place within and interplay of subject, object, and context. The acceptance subject of autonomous driving is the transport system users together with developers, engineers, politicians, or public research institutes. Those are the ones, that are currently using the road system or are involved in shaping the technology's development. Acceptance object can be an object, but it can also be something that is being offered, available or proposed. According to Fraeddrich and Lenz (2016), an "object acquires its significance only from what individuals or society ascribe to it." To identify the acceptance object, one has to discover, what functions autonomous driving can fulfil, and what significance the society places into the technology. Acceptance context "refers to the environment in which an acceptance subject relates to the acceptance object. The context of autonomous driving is determined by the current individual and social significance of car usage." (Fraeddrich & Lenz, 2016).

According to Fraeddrich and Lenz (2016) acceptance has different dimensions (attitudes, actions, and values) and levels. Examples of what attitudes dimension can be measured include mindsets, values, and judgement. Actions dimension of acceptance represents the measurable behaviour. In case of AVs, action can manifest in purchasing or using the available technology. The values dimension represents the norms and values that determine certain actions taken by the individual. The controversial aspect of acceptance of autonomous driving is according to Fraeddrich and Lenz (2016), that it is often explained that "such vehicles will only be accepted if, on the one hand, they drive "better" than humans, and on the other, if the vehicle user can override the autonomous functions as a last line of control".

To measure acceptance, it is necessary that the subjects have sufficient knowledge of the technology. Until recent years, AVs were neither a short-term realistic options, nor excessively covered by the mainstream media. This has changed recently, and surveys directly testing potential user are valuable bases for analysis. Fraeddrich and Lenz (2016) conducted research where they analysed attitude towards AVs on German and American forums to determine the likelihood of the technology being accepted by the public on the long run. In the research of Fraeddrich and Lenz (2016), they found that on an object-related level, the exact features of autonomous driving were discussed by the participants. In general, both American and European (German) subjects were positive about the features of AVs. 61% and 70% of the mentions were positive in the USA and in Germany respectively. In Germany the most controversial topics included liability and insurance concerns. The US participants discussed a country specific aspect of the problem, namely the potential negative impact of insurance and liability lawyers on the successful roll out of the AVs.

On a subject-related level, mistrust and scepticism characterised both the German and the American subject's statements. Two third majority was concerned whether or not the technology would be ever ready to be implemented, while subjects also discussed the technical, social, and infrastructural hardships implementing the technology would cause (Fraeddrich & Lenz, 2016). It was an interesting outcome of this research, that those that associated with freedom, fun and control talking about driving a car were mostly negative about AVs, while those that identify car driving with flexibility and comfort were in general more positive towards AVs. 79 % of the American, and 43 % of the German mass media comment had an attitude of refusal, while liability was the most controversial issue on both markets. In general, German comments were slightly more positive on the websites studied by Fraeddrich and Lenz (2016). The study was conducted in 2016, before the first viable Level 1 and 2 autonomous vehicles hit the roads.

In order to see if the general public attitude towards AVs have changed positively or negatively in the past years, I will shortly present the outcome of a more recent study on the European and the American markets. Bike PGH (an organization that advocates for safer communities for bikers and pedestrians) conducted a survey in late 2017 with 798 respondents from the general public, and 321 respondents of Bike PGH's own members. It is interesting to note, that members of the association were more informed about AVs in general (41% interacted with an AV, while in general public only 35%) and their attitude towards the technology was overall more positive. While 72% of the members agreed that AVs have the potential to reduce injuries and fatalities, this number was 10% lower in the group that wasn't a member of the association. 49% of the general public approves the use of Pittsburgh's streets as test ground for AVs. While only 4%

of the respondents felt safe on the street around human drivers, this number was 21% around AVs. 70% agreed that regulatory authorities should come up with regulations regarding testing AVs on public roads (Wood, Penmetsa, & Adanu, 2019).

The results of the study suggested that interaction with AVs increases perception of safety and approval which is key to build public acceptance. Wood et.al (2019) explained that the attitude towards EVs is in general positive, but it is considerably more positive among those that had the chance to interact with EVs on public roads. While AV testing on public roads is only legal in a handful of states in the USA, if the government aims to facilitate trust building, the author suggested that "policy makers should provide opportunities for the public to have interaction experience with AVs (Wood, Penmetsa, & Adanu, 2019)".

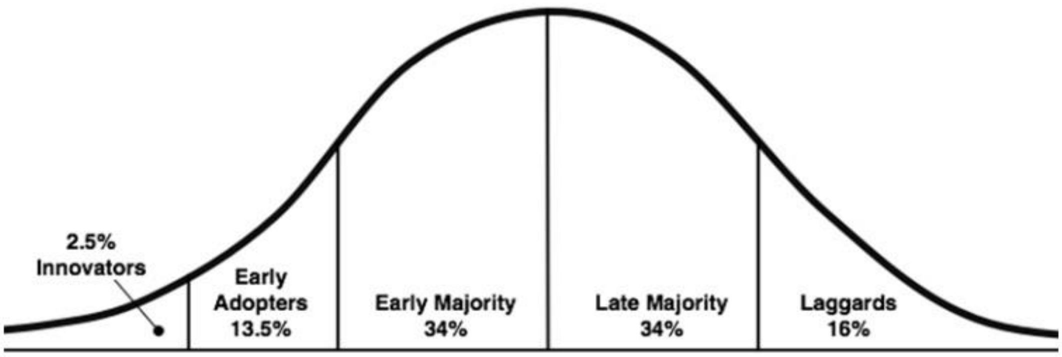
A survey conducted by Capgemini Research Institute in 2018 interviewed 5500 consumers from all around the world and 280 executives working in the automotive industry. The general knowledge among the participants on the AV technology was high. 93% have already heard of self-driving before. The survey suggests that 36% of the emotions invoked by a self-driving car in the USA were positive, while 33% were negative. This number in Germany is 38% positive to 30% negative. Urban consumers had the most positive outlook towards self-driving cars. In Europe the attitude among millennials is slightly higher towards AVs than in the USA. The survey found that consumer acceptance of self-driving vehicles is steadily increasing. As of 2018, 30% of the American respondents prefer self-driving cars over traditional vehicles. In 2028 this number is expected to rise to 63%. In Germany only 17% preferred autonomous vehicles at the time of the survey taken but 61% could imagine using AVs in 10 years' time.

When discussing the expected future of societal acceptance, the Diffusion of Innovation Theory (DOI) developed by E.M. Rogers in 1962 can provide interesting background in order to fully understand the possible dynamics of societal acceptance of a new technology like self-driving vehicles. Rogers argued that adapting a new idea, product or behaviour does not happen at once in a society (Rogers, 1962). Instead, an innovation may gain momentum and diffusion over time among a specific group within a society (LaMorte, 2019). If such momentum is gained, the innovation will be adopted by people which is the outcome of diffusion. If adoption has occurred, it means that a change in previous behaviour can be observed. In case of AV technology, purchasing and using self-driving vehicles would be the desired outcome. The DOI theory by Rogers argues, that adaption of an innovation like the AV technology happens over time, where some people are more likely to adopt the new technology sooner than others. Those who adopt an innovation early have different characteristics than those that adopt innovations later (Rogers, 1962). If Legislators or Technology actors want to ensure the success of the AV technology, it is important for them to understand what the most likely characteristics of those who are open for or are rejecting the idea of self-driving vehicles are (LaMorte, 2019).

Rogers (1962) argued that adopters can be divided into five categories by the speed at which they are willing to adopt innovation. Figure 11 illustrates the division of adopters among these five categories. Since adopter distributions closely approach normality, the total can be divided into five distinctive slices (Rogers, 1962). From 2 standard deviations right from the mean, approximately 2.5% of the population belongs to "Innovators". They are people that are eager to try new things and they can be described as venturesome. They are willing to take risks and often they are the ones coming up with new ideas. Innovators can be gatekeepers in the flow of new ideas into the social system, as they are the ones launching the new idea in the social system. There is little effort needed to convince them to try out something new as innovation mostly naturally appeals to this group.

One to two standard deviations to the left of the mean, approximately 13.5% of the population belongs to “Early Adopters”. This group is a more integrated part of the local social system compared to Innovators. Early Adopters can be categorized as respectable. They have often a high degree of opinion leadership within the community, and they are often the ones giving advice to later adopters about the technology at hand. They can function as change agents in order to speed up the diffusion process. Early adopters are often role models and to maintain this role they must continue adopting innovations ahead of others. By doing so they decrease uncertainties for the rest of the community. In order to appeal to this group, how-to manuals and information sheets on implementation are the ways to go (LaMorte, 2019).

Figure 11 Adopter categorization on the basis of innovativeness



(Rogers, 1962)

The following approximately 34%, one standard deviation left of the mean, are the “Early Majority”. They are characterized by Rogers as deliberate. They do adopt new ideas earlier than the average member of the society, but they do not tend to hold leadership position. They are an important link in the diffusion process by positioning between early and relatively late adopters and ensuring interconnectedness of the system’s network (Rogers, 1962). The Early Majority wants to see evidence that the new technology works before they are willing to adopt it. In order to appeal to this group, it is important to provide them with success stories and evidence that the new technology at hand is effective (LaMorte, 2019).

One standard deviation right of the mean, approximately 34% of the population belongs to the “Late Majority”. Rogers described them as sceptical. They are likely to adopt a new technology but only after the average member of the community did it already. The main motivators to adopt are often economic necessity or increasing network pressure. They are likely to be cautious towards new technologies and they tend to wait with adoption for a longer period of time until all uncertainties about the new idea are cleared up and they can feel safe to adopt. To appeal to this group, LaMorte (2019) argues that regulators or industry actors should launch information campaigns on how many people have already tried and successfully adopted the new technology.

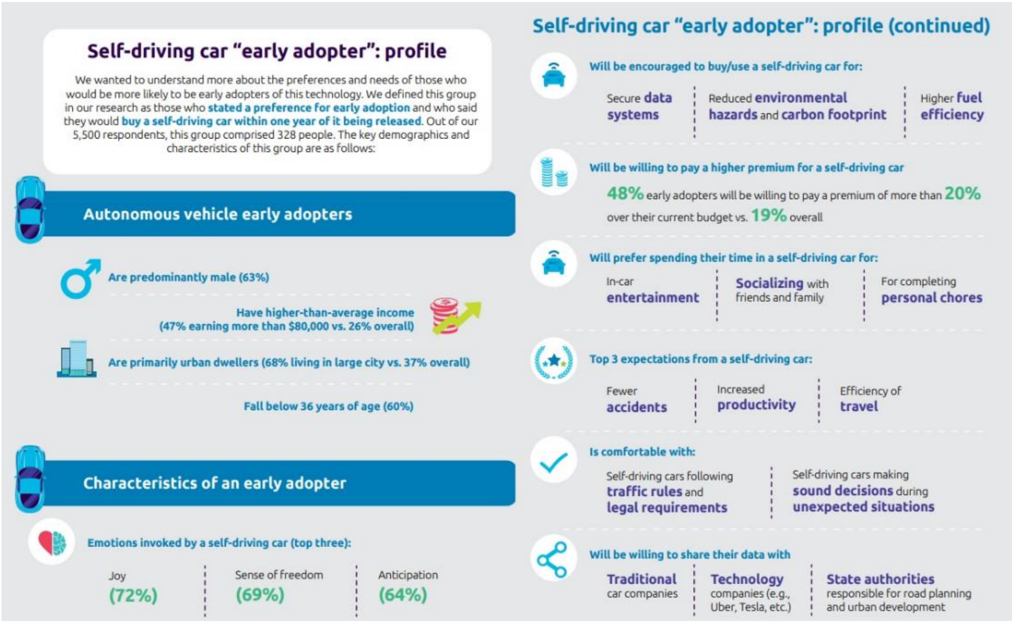
The fifth group consists of approximately 16% (one to two standard deviations right of the mean) of the social system. They are the “Laggards”. They are described as traditional by Rogers as they tend to be bound by tradition and are conservative. They are often sceptical of change, and they possess no opinion leadership. They can be seen as almost isolates in the social network. Laggards tend to rely on the past and use technologies that have been proven to work by previous generations. By the time they may adopt an innovation it is often already replaced by a new idea in the Innovators group. Laggards have limited resources and are not willing to risk investing in an innovation that may not be working as they would like it to. They resist innovation until they can, to ensure they are not wasting their resources. According to LaMorte (2019), in order to appeal to this group, pressure from people in other groups might be needed, they might react on statistics or fear appeals.

The people in the five different categories have different socioeconomic characteristics, different personality variables and different communication behaviours according to Rogers (1962). “The relatively earlier adopters in a social system are no different from later adopters in age, but they have more years of education, are more likely to be literate, have higher social status, a greater degree of upward social mobility, larger-sized units, a commercial rather than a subsistence economic orientation, a more favorable attitude toward credit, and more specialized operations. Earlier adopters have greater empathy, less dogmatism, a greater ability to deal with abstractions, greater rationality, greater intelligence, a more favorable attitude toward change, a greater ability to cope with uncertainty and risk, a more favorable attitude toward education, a more favorable attitude toward science, less fatalism, higher achievement motivation, and higher aspirations for education, occupations. Finally, the adopter categories have different communication behavior. Earlier adopters have more social participation, are more highly interconnected in the social system, are more cosmopolite, have more change agent contact, greater exposure to mass-media channels, greater exposure to interpersonal communication channels, engage in more active information seeking, have greater knowledge of innovations, a higher degree of opinion leadership, and are more likely to belong to highly interconnected systems” (Rogers, 1962).

Knowing more about the expectations on who is most likely to adopt AVs, it is interesting to return to the Capgemini Research Institute’s survey. They identified the most likely characteristics of an early adopter of the AV technology. Early adopters are defined being those, who are willing to buy a self-driving car within one year of it being released. Figure 12 illustrates that a male (63% of all potential early adopters), with higher-than-average income (47% earning 80.000 dollars or more vs 26% overall), living in urban areas (68% vs 37% overall) and younger than 36 years of age (60%) is the most likely to purchase a self-driving car within 1 year (Capgemini Research Institute, 2019). Similar to the previously presented survey, the profile of the early adopter confirms, that a person who focuses on travel/fuel efficiency and safety is more likely to have a positive attitude towards AVs. What would encourage people to buy a self-driving car were predominantly secure data systems, reduced carbon footprint/environmental hazards and fuel efficiency. The early adopters identified by the research claimed they have positive emotions right now towards AVs. The top three emotions invoked by a self-driving car was joy (72% of the respondents), freedom (69%) and anticipation (64%).

According to Rogers, “innovations that are perceived by receivers as having greater relative advantage, compatibility, trialability, observability, and less complexity will be adopted more rapidly than other innovations. These are the most important characteristics of innovations in explaining rate of adoption”. In case of self-driving cars, the above presented surveys on how EU and USA citizens feel about AV technology indicate, that both regions’ citizens are acknowledging the advantages and the compatibility of self-driving cars. Trialability is a main concern. Chapter 4 will be giving more information on whether EU or US citizens are more likely to be exposed to AVs via testing on public roads. The complexity of the AV technology is rather high, which can have a negative impact on the adoption of the technology. Information campaigns are an effective way to reduce the unknowns the public might experience regarding the AV technology.

Figure 12 Self-driving car early adopter



(Capgemini Research Institute, 2019)

Change in public perception towards the autonomous driving technology in both the US and European market over the past years is indicated by the survey results discussed above. The most noticeable barrier to acceptance seems to be a lack of knowledge or real-life experience with autonomous vehicles. Among those that consider driving a pleasant and adventurous experience, the willingness to accept AVs is lower. Trust in the technology is a main issue. Lack of trust results in lower likelihood of accepting AVs (Fortunati, Lugano, & Manganelli, 2019). As explained, gender, age, living area and financial situation have an impact on how one perceives AVs as well. Both in the US and in the EU, consumers are rather positive towards the opportunities this technology might have on their day to day lives. The willingness to try autonomous vehicles is increasing. It is so despite the limited interaction between consumers and AVs due to the limited testing opportunities manufacturers have on public roads. Before I look at the history and the current state of the AV legislation in the EU and the USA, it is important to highlight that public perception is indeed different in the two studied regions. Whether or not this difference can partly explain the way how legislators look at the challenging task of regulating the AV technology and what other factors are shaping the policy making process is the focus of the next chapter.

3.4. Conclusion

Chapter 3 highlighted the most important industry, regulatory and societal actors and how they influence the self-driving vehicle ecosystem. Chapter 2 introduced the AV technology, and the most relevant actor in the scene, Tesla. Chapter 3 built upon this basis by introducing various additional actors in the automotive industry and beyond it who are both impacted by and are shaping the development of the self-driving technology. Using the typology presented by Maunsell et al. (2014), five main industry actors were discussed. Automotive industry, OEMs and technology providers, mobile service providers, financial sector, and the energy sector. Looking at the automotive industry, the main differences between actors with headquarters in the USA and those in the EU were in the number of partnerships and patents. Tesla, and initially BMW relied on in-house development of a full package AV. The rest of the studied manufacturers (GM, Ford, VW, and today's BMW) use stock-technology and rely on multi-actor cooperation to create their version of a self-driving vehicle. Maunsell et al. (2014) argued, that a close cooperation among different actors within the AV ecosystem is crucial for the success of such intrusive and fast-developing technology. This would suggest that essentially Tesla should fall behind other manufacturers due to the lack of close partnerships with other industry actors, however this does not seem to be the case right now.

The number of patents and type of industry actors show a considerable difference when comparing the EU and the USA. Patenting is happening on a higher scale in the EU. While the USA is heavy on tech companies, there are more active traditional car manufacturers and OEMs operating from the European market. This however does not mean that all the mentioned players are not present globally. This only shows the focus of the different regions on different parts of developing AVs which they all aim to make globally available for use later. An important difference is observed in the available infrastructure. 5G is currently not globally available but comparing the EU to the USA, the USA has a slight advantage. The EU consists of many separate member states, which makes it more complex for insurance companies or financial services to prepare for the changes that AVs may facilitate in the near future.

The chapter introduced 11 policy areas which will be impacted by the development, testing and the roll-out of AVs. While it is not a complete list, it does show the complexity of regulating the AV technology by describing many ways society will be impacted by self-driving vehicles. It is the responsibility of the second major actor, the Legislators to ensure the appropriate legislative response to such an emerging technology to maximize benefits to the society and minimize risks in the meantime. The role of the Legislators in the self-driving vehicle ecosystem was the focus of chapter 3.2. The EU has taken a more coordinating and facilitating role by providing platforms for other actors to cooperate on without having the authority or the willingness to create an EU wide approach when it comes to AV legislation. In the USA a more harmonized regulatory environment was observed, where the main policy direction is determined on the federal level by the Department of Transportation. While individual states can formulate their own policies, the main direction of regulating AVs is set on the federal level. This ensures a more harmonized regulatory environment which is favoured by industry actors and can have a positive impact of societal acceptance as well. Comparing the main regulatory principals, an interesting difference in the EU and in the USA was observed. The EU's main goal when formulating AV related policies was to ensure safety by applying a more precautionary approach to achieve legal certainty and to protect the citizens from new risks. Contrary to this, the main principle in the USA is to ensure American leadership in AV technology. They intend to achieve it by the protection of users and citizens, the promotion of efficient markets and the facilitation of coordinated efforts. While safety does appear in both studied region as a driving force, the USA has chosen a much more allowing/facilitating approach contrary to the restrictive EU policy direction.

Chapter 3 concludes with the comparison of how society reacts to the emergence of the AV technology in the EU and in the USA. While it is difficult to predict how society will react to something they have yet to experience in the real world, with the help of Fraeddrich and Lenz (2016), certain indicators were clarified. One of the most influential factors to societal acceptance is whether or not the subject has sufficient knowledge of the technology. Uncertainty and lack of information lowers public acceptance. Both in the EU and in the USA legislators as well as industry actors are actively present in organizing information campaigns to ensure information spread about AVs. Early studies from 2016 show that public attitude towards AVs was more positive in the EU than in the USA (70% vs 61%). Later, once Level 1 and 2 AVs entered the roads of the two studied region the difference in consumer attitude in the EU and USA narrowed. The projection is that by 2028, 63% of Americans would prefer AVs over traditional vehicles, while this number is 61% in the European region.

It is very important to note, that knowledge and real-life experience with AVs have the most impact on consumer acceptance. Therefore Chapter 4 will study in which region it is more likely for citizens to meet with self-driving vehicles on the road while testing in the near future. This means, that based on the findings of this chapter, the Society seems to be accepting in both regions. Early on the society was more accepting in the EU, but as AVs are closer to become reality, the opposite is expected to be true. In order to be able to make more precise predictions, Chapter 4 will discuss what kind of exposures to the AV technology are allowed in the two studied regions.

4. AV legislation in the USA and in the EU

This chapter gives an answer to a series of "how" questions represented by SQ 3. It reads as follows: *How has the development of the AV legislation in the EU and the USA been evolving and what are the main similarities and differences that can have an impact on the tempo of the rollout of autonomous vehicles in these two regions?* How has the AV legislation been developing in the EU, and how does it look like currently? By building a timeline of legislative actions in the EU and in the USA, I can compare the two region's regulatory strategies, speed, and impact on attracting industry actors. The chapter highlights whether legislators were able/willing to engage in bottom-up processes besides the traditional top-down regulatory practices. Outstanding states and member states will be discussed to see the decentralized efforts as well, since the regulatory landscape is far from homogenous in either one of the studied regions. Chapter 4 completes the description of the last main actor I focus on, the regulators. Together with the findings in chapter 3.2, I can draw conclusions on the nature of regulation observed in the two studied regions, allowing me to place them in the 3D model presented in chapter 1. Classifying the regulatory environment in the EU and the USA to be rather restrictive or allowing towards the AV technology is the final goal of this chapter.

Chapter 3.2 touched upon the complex nature of regulating the AV technology by providing an overview of the many different policy areas that are directly or indirectly related to the rapidly developing self-driving technology. Therefore, it should be no surprise that there is no worldwide regulatory framework applicable to AV testing and deployment as of 2021 (Connectedautomateddriving.eu, 2021). However, there are relevant multinational treaties and conventions coordinated by the United Nations that aim to harmonise the different national legal approaches on mobility and transportation (Winkler, 2019). Some of these are directly applicable to the AV technology and could possibly be influencing the legislation adapted in the EU and the USA.

The **Convention on Road Traffic in Geneva** from 1949 is an international treaty that aimed to promote the safety and development of road traffic via harmonising various rules among the contracting parties. The USA and all EU member states have signed and ratified this treaty which defined minimum mechanical and safety requirements on board and "established an integrated global system for the mutual recognition of vehicle-related product and subsystem approvals" (Connectedautomateddriving.eu, 2021).

The **Convention on Road Traffic in Vienna** from 1968 was not ratified by the USA while it was signed and ratified by all current EU member states (United Nations, 2021). The relevance of this Convention regarding AV legislation comes from the principle established in the treaty, which always requires the driver of the vehicles to be fully in control and responsible for the behaviour of the vehicle in traffic (United Nations, 2021). The Vienna Convention set standard traffic rules, road standards and traffic signs to facilitate mobility around the world (Winkler, 2019). The original iteration of this treaty would have been completely preventing the testing and roll-out of driverless cars since it does require a driver to be present and in control in traffic. While the Vienna Convention on Road Traffic has been amended in 2016 to allow the use of automated driving technologies it does still prevent fully automated vehicles to enter traffic and only permits partially automated vehicles onto the roads (Winkler, 2019).

In 2018, **Regulation No 79** of the Economic Commission for Europe of the United Nations was implemented. It is a very influential piece of legislation that "uniforms provisions concerning the approval of vehicles with regard to steering equipment" (United Nations Economic Commission for Europe, 2018). This regulation focuses on specific requirements for auto **-** steering in vehicles in the EU. It requires the vehicle to warn the driver if for a period of 30 seconds the steering wheel was not held. It requires the driver to initiate and continuously hold the activation button for the remote-controlled parking function. The remote parking function is limited to a 6m range by this regulation. In case of lane changing assist, the regulation limits the car's ability to steer by defining a maximum speed (63 km/h) at which a given turn can be taken. Lane changing can only happen by a deliberate action of the driver and if a gap of at least 35m can be achieved compared to the vehicle behind. (In the USA a requirement of 6m is defined) (Alvarez, 2019). Critics of the regulation mention that the unrealistic requirements hinder the safe functioning of the impacted system or require car manufacturers to entirely turn off certain available functions in order to comply with these strict regulations in the EU (Alvarez, 2019).

In 2020 a milestone was reached on the international scene, when three landmark UN vehicle regulations were agreed upon by 54 countries, including all EU member states but excluding the USA. Regarding AV development, the **UN Regulation No. 157** is the most relevant, which for the first time acknowledges and permits the use of level 3 automated vehicles in certain traffic situations (Stradalex, 2021). The conditions attached to allowing level 3 automation into the traffic are rather strict, however it is a huge step towards creating a homogenous environment when it comes to testing autonomous vehicles in traffic in the EU and other participating countries. The regulation restricts the autonomous system to take control only until 60km/h speed, and a human driver must be always present in the car with the seatbelt on behind the steering wheel. The level 3 system can only be enabled on roads where cyclists and pedestrians are prohibited and only allowed on roads "which are equipped with a physical separation that divides the traffic moving in opposite directions" (UNECE, 2020). The agreement which was co-drafted by the government of Japan and Germany entered into force in January 2021.

4.1. EU

According to Schreurs & Steuwer (2016), looking at strategy documents and European-founded research projects, autonomous driving technologies were barely present on the EU agenda until 2016. If the AV technology made it to a European Commission roadmap, green paper, or other strategic documents, it was often in relation to boosting competitiveness, innovation, climate protection or employment (Schreurs & Steuwer, 2016). The first goal setting from the policy makers regarding the automotive industry on EU level was expressed in the CARS 2020 Action Plan. In this, the Commission committed to work together with industry actors to develop a proposal on the European Green Vehicles Initiative under Horizon 2020 (Timbers, 2012). The main focus of this initiative was to help recover the European automotive industry from the crisis, and to focus on creating clean, safe, fuel efficient, quiet, and connected vehicles. While there was no mention of automated systems, the goals set by the Commission were in line with the benefits AVs could offer. Until 2017 the conversation within the EU often focused on connected rather than autonomous vehicles and EU officials expressed concerns on the feasibility of autonomous driving under European conditions for example in complicated city centres (Franklin, et al., 2017).

Transport policy does fall under the common policies of the European Union, therefore the main direction of the regulations adapted is determined by the EU. This applies to multiple sectors, for example road transport or navigation (Juhasz, 2018). However, road transport primarily belongs to national jurisdiction. It is regulated by all individual member states independently, taking into account the agreements made on the international level. This naturally can result in fragmented legislation due to differences between the member states. The EU plays an important role in coordinating and giving direction to the policies in order to mitigate the negative impact of a potentially fragmented policy landscape among the member states (Juhasz, 2018).

While there is no specific self-driving vehicle related legislation to mention on the EU level, there are regulations on other areas which do have impact on the development and roll-out of AVs. These are the followings:

"Type approval framework:

- **Directive 2007/46/EC** of the European Parliament and of the Council of 5 September 2007. A framework for the approval of motor vehicles and components of motor vehicles giving the ability to the MSs to provide type-approval exemptions for new technologies or new concepts
- **Regulation (EC) No 78/2009** of the European Parliament and of the Council of 14 January 2009 focusing on the type-approval of motor vehicles in regard to the protection of pedestrians and other vulnerable road users
- **Regulation (EU) 2018/858** of the European Parliament and of the Council of 30 May 2018 regulating the approval of market surveillance of motor vehicles and their components giving the ability to the MSs to provide type-approval exemptions for new technologies or new concepts

General Safety Regulation:

- **Regulation (EC) No 661/2009** of the European Parliament and of the Council of 13 July 2009 on type-approval requirements for the general safety of motor vehicles and their components

Connectivity/C-ITS:

- **Directive 2010/40/EU** of the European Parliament and of the Council of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport

Privacy & data protection:

- **Regulation (EU) 2016/679** of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data" (Connectedautomateddriving.eu, 2021)

Liability:

- **Directive 85/374/EEC** on liability for defective products was adopted in 1985 that applies to any product marketed in the European Economic Area establishing the rights of producers and the compensation in case of damages as well

Insurance:

- **Directive 2009/103/EC** that regulates the compulsory motor vehicle insurance and the rights to travel across borders of different member states while being insured with the insurance from the home country (Punev, 2020)

Even though none of the above-mentioned legislation is specific to AVs, the European Commission expressed the opinion in 2018, that no changes to the current legislative framework were needed due to the emergence of self-driving vehicles, since the last two mentioned directives cover the newly emerging technology sufficiently (Punev, 2020). Criticizing this sentiment, Punev argues that "it is hardly conceivable that the legislators who established the present laws and regulations were able to predict the advent of machines that operate independently of human beings". Moving rather slowly when it comes to reacting to change is no new phenomenon in the EU (Juhasz, 2018). According to Franklin et al. (2017) besides the slow speed of EU legislation, a lack of common direction can hinder the EU member states from becoming competitive when it comes to allowing AVs to roll-out once they will be available. On topics such as liability, data flows and privacy, cybersecurity safety and ethics the EU lacks firm conclusion which creates a lack of regulatory clarity potentially risking the industry actors to look for other regions to settle in for the development of their autonomous technology.

To mitigate the downsides of the lack of homogenous environment, the EU facilitates multi-level dialogue through various initiatives. The GEAR 2030 initiative has been discussed in detail in Chapter 3.2.1. Besides GEAR 2030, the EU strives to harmonise action on the international level via bilateral dialogues, the UNECE platform, or the Amsterdam Declaration on self-driving cars. The Commission provides financial support within the scope of the Horizon 2020 research framework to various R&D projects (Franklin, et al., 2017). One of the most influential Commission founded research project in relation to AVs is the Galileo project (Schreurs & Steuwer, 2016). It is a civilian global satellite-based navigation system that can facilitate the development of AV appropriate infrastructure in the EU. Other noteworthy projects are the HAVE-it project to pursue high level of automation, the European Green Cars Initiative aiming to develop efficient, safe, and environmentally friendly mobility, or the AdaptIVe project that "develops various automated driving functions for daily traffic by dynamically adapting the level of automation to situation and driver status. Further, the project addresses legal issues that might impact successful market introduction" (AdaptIVe, 2021).

In 2016, when the breakthrough in AV technology happened, the concern among EU legislators was, that a potential slow response could jeopardize the competitiveness of the entire region (Plucinska & Posaner, 2016). Some of the most pressing issues were the lack of high, steady internet speed in the region that is crucial for the functioning of AVs or the UN regulation that limited the speed of driverless cars in traffic to 10 km/h in the EU (Plucinska & Posaner, 2016). Ismail Ertug, a member of the European Parliament and founder of the Driving Future Platform indicated in 2016 that the speed of changing restrictive legislation on the EU level that prevents the testing of AVs is lacking and assumed that the UN regulation can only be changed by the end of 2017. He criticized the EU for moving slow on the self-driving technology. While in some US states testing has been happening for a while, the EU had yet to even discuss the risks and potential benefits of the technology (Ertug, 2016). Unfortunately, the prediction on wrapping up negotiations on the most relevant obstacles turned out to be rather optimistic. As described earlier in this chapter, the 10km/h speed limit was only changed in 2020. This example demonstrates that the speed at which the EU was able to react to technological innovation in case of self-driving cars was and still is slow.

4.1.1. Outstanding Member States

While Brussels might have been moving slow, individual member states have not been waiting for EU wide action to develop their own policies on creating safe testing environments for self-driving cars. Two of the most notable front runners have been the Netherlands and Germany. In the following part a brief description on the initiatives in these two member states will be presented. In the conclusion of this sub-chapter, I will highlight some of the consequences of uneven development within the EU and how it might influence possible disconnects among legislators, the industry, and the society.

4.1.1.1. The Netherlands

The Netherlands is one of the most advanced countries regarding AV legislation and infrastructure, not only in the EU but worldwide (KPMG International, 2020). It offers a unique environment for AV testing, as after exemption obtained from the local authority, RDW (Netherlands Vehicle Authority) and the appropriate road operator like RWS (Rijkswaterstaat), AVs can be tested on all public roads in the Netherlands. The RDW also has a closed proving ground for AVs. Both tests with human driver in the vehicle, and with remote driver can be carried out in the Netherlands. The application process takes approximately three months and consists of five steps. Testing has been approved by the Dutch Council of Ministers in 2015. The Netherlands was one of the leading voices behind the Declaration of Amsterdam where EU countries committed to speed up the development of self-driving vehicles (KPMG International, 2018).

The responsible authority for providing exemption is the RDW and it is working "on the basis of new insights" (Connectedautomateddriving.eu, 2021). The concept allows the RDW to alter the method and process for new applications if previous applications provided learning points in the past. The process is therefore flexible, and it can alter the policy regulating the entire process by the lessons learned from the close cooperation with relevant stakeholders. In case of issuing exemption for tests on public roads with a remote driver, the same process is followed, but extra tests are carried out during the authorisation process to ensure that the remote driver remains at all times in control of the vehicle during testing (Government of the Netherlands, 2021). The permit to carry out tests on public roads with a remote driver is issued by Dutch Ministry of Infrastructure and Water Management and the legislation allowing such testing, called "Experimenteerwet zelfrijdende auto" entered into force in 2019 (Government of the Netherlands, 2021).

Already in 2018, the World Economic Forum and the World Bank listed the Dutch road network among the world's bests. Paired with the very high density of electrical vehicle charging points and high-quality wireless networks, the infrastructure in the Netherlands ensures an inviting environment for industry actors in the region. According to KPMG's assessment of societal change readiness, the Dutch public scored the highest in 2018. Three quarters of the population lives near an area where AV technology is actively being tested. However, this did not mean that their societal acceptance towards AVs were high from the get-go. Contrary, in 2018 it was rather low in the region which can be explained by the relative satisfaction of citizens with the quality of the currently available transport system (KPMG International, 2018). However, in the past three years the societal acceptance grew considerably and now performs among the bests in the EU (KPMG International, 2019).

The Dutch government has invested 90 million euros to adjust more than 1000 traffic lights in the Netherlands in order to allow them to communicate wirelessly with vehicles. The Netherlands is among the frontrunners with a very high number of AV companies located in NL on a population-adjusted basis. The government succeeded in attracting start-ups, such as Amber Mobility and tackled the lack of public-private partnerships to boost AV-related patents and investments in the country. Relevant examples include the Automotive High Tech Campus in the Eindhoven area and the connected TU Eindhoven University with its smart mobility faculty (KPMG International, 2018). In 2018 Cora van Nieuwenhuizen, the Dutch infrastructure minister announced a close cooperation on AV infrastructure development with neighbouring countries Germany and Belgium. She announced the preparation of a Driving License for a Vehicle which would assess a self-driving vehicle's ability to drive safely and predictably, as close to a human behaviour as possible (KPMG International, 2019). While this initiative has not succeeded as of today, it shows the openness of the Dutch government to try to incorporate AVs into the traffic as soon as they will be available and safe (KPMG International, 2020).

4.1.1.2. Germany

Germany is one of the few countries in Europe that already had a national strategy for autonomous driving since 2015 and allows autonomous driving on public roads in specific settings by 2022. The original autonomous Vehicle Bill was enacted in 2017, modifying the existing legal framework on road traffic by laying the groundwork to include highly and fully automated vehicles (Level 4 and 5 automation). This legislation however did not allow for an exception to the basic legal assumption of a fully responsible vehicle driver. A human driver was to be present and had to be always in control of the vehicle. It allowed the driver to relinquish vehicle control in specific situations, but those were limited and did not provide legality to AVs on public roads (Simmons+Simmons, 2021). As early as in 2016, the German government established an ethics commission and tasked it to look at legal and ethical concerns regarding autonomous driving. The commission created a set of 20 ethics rules to guide the future development of AVs. The three main principles were determined to be: transparency, self-determination, and data security, with the most important principle being, that protecting humans always takes priority (Daimler, 2017).

In February 2021, the German Federal Government adopted a draft law on autonomous driving which opens the German roads for AVs by 2022. The plan is that this law can provide an appropriate legal framework for AVs until EU or international law supersedes it (Simmons+Simmons, 2021). The law allows AVs on public roads not only for testing purposes, but for general use in the future under the following operational scenarios:

- “shuttle transports,
- automatic passenger transport systems for short distances ("people movers")
- driverless connections between logistics centres (Hub2Hub transport)
- demand-oriented transport services at off-peak times in rural areas, and
- dual-mode vehicles for example in "automated valet parking" (driver can exit and let vehicle drive itself into garage)” (Simmons+Simmons, 2021).

The law allows level 4 AVs to operate without the need for a person to drive the vehicle during operation. However, to comply with international law, it is required for a person to be responsible for the operation of an AV. According to the new law, this person will be the “technical supervisor”. An AV must obtain an operating permit to be allowed into traffic. To issue an operating permit, the vehicle’s autonomous functions must meet minimum requirements detailed in the legislation. Tackling many grey areas when it comes to liability and data protection while operating an AV, the legislation details the obligations of manufacturers, the data processing requirements towards the vehicle owner, and accident prevention measures in an ethically responsible manner (Simmons+Simmons, 2021). It is the German Federal Motor Transport Authority that oversees the process of issuing AV operating licenses.

Benedikt Wolfers, founder and partner of Posser Spieth Wolfers & Partners considers the new German legislation ground-breaking for AV policy development worldwide. He argued that the German law will set regulatory standards which can have lasting impact on the future of AVs globally. Harmonization in legislation would have great positive impact on consumer confidence and manufacturer certainty as well. Both is crucial for the success of AVs in the long run (The Autonomous, 2021).

While Germany is clearly leading the way in Europe for AV regulation, the same can’t be said about AV deployment. According to Juliussen (2021) there is little activity on AV testing front in the country. Besides fixed-route AVs, the government struggles to attract manufacturers for testing, however the newly accepted regulation might be a catalyst in this area. Volkswagen, a local car manufacturer started testing with AVs on German roads as early as in 2019 (Silicon Canals, 2019) and the newly achieved legal framework is likely to draw the attention of oversees manufacturers looking for European test grounds (Juliussen, 2021). As of today, for testing on public roads, a permit must be asked for each vehicle, and it will be granted for a certain testing area. A human driver must be present in the vehicle while testing, and the vehicle must fulfil all safety and security standards. An additional requirement for testing AVs on public roads is the presence of a computer data recorder - a black box – in the vehicle that will be recording system data and actions to be reviewed in case of an accident (Peng, 2018).

The area where Germany is lacking compared to the Netherlands, is the infrastructure. While high-speed internet availability is lacking, Germany has a strong road logistics infrastructure. There is a high amount of industry partnerships and very high number of AV-related patents per capita, mainly due to Bosch’s activity on that front (KPMG International, 2019). The main threat to Germany’s success to attract industry actors comes from the highly devolved nature of government which makes it possibly difficult to set national standards and strategy in a timely manner (KPMG International, 2019). Financially, the government spent 100 million euro in 2018 alone for digital test beds but has only limited success in increasing consumer acceptance of the AV technology. This is due to a typical national scepticism over new technologies and the fact that driving cars tends to be an expression of freedom in the German society (KPMG International, 2020).

Reflection

“Self-driving cars hit European speed bump”, “Why Europe is losing the race for autonomous vehicles”, “Self-driving vehicles: Europe is losing the race against the USA and China, claims EPP report”, “Europe needs swift rules changes to be a leader in autonomous driving”. These are just a few of many titles of articles discussing why the EU is struggling to live up to the expectations to become a pioneer on the AV landscape. Chapter 4.1 highlighted some of the most prominent reasons why one can argue that the EU will be left behind once the AV technology becomes ready to hit the road. The lack of EU level AV policy, the slow speed to react to the rapid advances in the technology, lack of appropriate infrastructure, AV unfriendly road structure, and a rather restrictive approach when it comes to regulating autonomous technologies are all contributing to the potential failure of the European region to be the first to implement self-driving vehicles into general traffic.

The EU consists of many, relatively small countries, where crossing borders during traveling longer distances is often inevitable. Therefore, regulation that changes at the borders, requirements for testing that differ from member state to member state, inadequate infrastructure, or internet connection in parts of the EU does not provide an inviting environment for industry actors to commit to bringing their business operation into the EU region. Lack of harmonised standards and rules have a negative impact on consumer trust. The Commission encouraging individual MSs to move forward alone if the slow pace of the EU is not suitable for some of the countries indicates that there is no imminent change on the horizon that would solve these concerns short term. Regulation that is implemented on the EU level tends to be restrictive (for example UN Regulation No. 157) and caused for Tesla having to disable certain self-driving functions that were illegal in the EU but legal in the USA. This resulting in EU citizens not being able to benefit from the technological advances while sitting in the exact same vehicle as an American citizen.

On the other hand, the EU is providing the platform for the different actors in the AV landscape to engage in conversation to create bottom-up legislation, initiates the cooperation among MSs to harmonize national legislation and provides funding for R&D projects and cross border test sites. All in all, the chosen strategy of the EU seems to be lacking results, the speed of legislation is slow, and the EU is struggling to attract industry actors as of today. The hope lies in the outstanding member states that are creating a competitive environment where AVs can or will be able to enter the public roads very soon. The somewhat slower pace might have a positive impact on consumer acceptance, as the cautious approach of the EU might build trust among consumers who may believe that the technology is truly safe once it is allowed onto the roads. The EU expects AVs to hit the roads around 2030 while the industry expects an availability of AVs any moment from now on. This mismatch in expectation might explain the more relaxed speed towards regulating AVs on the EU level and it is yet to be seen when the technology is truly ready for launch.

4.2. USA

While EU agencies failed to mention autonomous driving technology until 2016 in official documents, the National Highway Traffic Safety Administration (NHTSA) issued its first statement on preliminary policy concerning automated vehicles in May 2013 (Hottentot, Meines, & Pinckaers, 2015). The communication aimed to offer recommendations for level 3 and 4 automation testing by providing the following list of action for consideration:

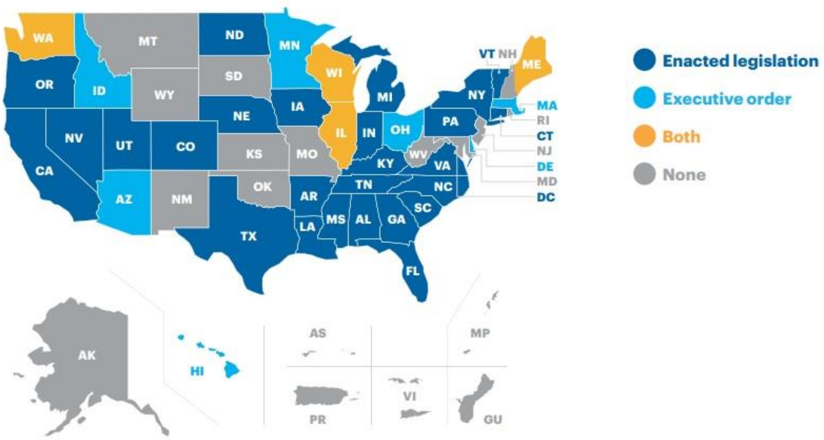
- "License drivers to operate self-driving vehicles for testing
- Require proof of safe operation of self-driving vehicles
- Limit tests to locations suitable for self-driving vehicles
- Establish reporting requirements to monitor self-driving technology performance
- Ensure that the process for transitioning from self-driving mode to driver control is safe, simple, and timely
- Require self-driving vehicles to have the capability to detect, record and inform the driver that the automation system has malfunctioned
- Ensure that self-driving vehicle technologies do not disable any required safety features or systems
- Ensure that all information about the status of the automated control technologies is recorded in the event of a crash or loss of vehicle control" (Hottentot, Meines, & Pinckaers, 2015)

Like the EU, the USA has also no harmonized regulatory framework regarding AV testing and deployment (Connectedautomateddriving.eu, 2021). AV related regulation is formulated on the state level by either executive orders or legislation or a mix of those two approaches (Dentons, 2021). There are three main strategies states are following when creating their AV testing policies:

- **Laissez-faire, hands-off regulatory approach** where very welcoming regulation is done by executive order. An example is Arizona.
- **Welcoming testing environment** is similarly welcoming than the first approach but operates through legislative process. An example is Colorado, where testing is allowed if all existing laws are followed.
- **Hands-on approach** creates a comprehensive set of legislation. An example is California.

Figure 13 shows which states opted for what type of legislative strategy. The number of states enacting AV legislation is growing. As of 2020, 29 US states have some kind of AV related policy in place. While AV specific legislation is in fact under state jurisdiction, the federal government does regulate the vehicle itself. Legislation on vehicle construction, composition and reliability falls under federal jurisdiction, while driver competence is state responsibility. AVs blur the line between vehicle and driver, and it creates a confusing set of state laws (Dentons, 2019).

Figure 13 States with autonomous vehicles enacted legislation and executive orders



(Dentons, 2021)

On a federal level, the USA has non-binding regulation on AV testing and roll-out (Vellinga, 2020). Such flexible type of regulation has the ability to keep up with the rapid technological innovation as changes can be made to it without having to go through an often time-consuming process. Like in the EU, in the USA the regulations governing vehicle construction are formulated on the federal level and they do have impact on AV development, testing and deployment. The National Highway Traffic Safety Administration (NHTSA) regulates the Federal Motor Vehicle Safety Standards. In its original form, the Federal Motor Vehicle Safety Standards require several components to be present in a vehicle that is unnecessary in a fully autonomous vehicle. For example, all vehicles must have steering wheel, foot pedals or rear-view mirrors (Dentons, 2021)

The NHTSA updated these rules in 2021. The changes were specifically designed to be more realistic for AVs to comply with them (Atiyeh, 2021). Therefor the following alteration were issued:

- The seat in which traditionally the driver sits must be equipped with smart airbags which detect if a child is seated in that seat. Since level 5 AVs operate fully without a driver, it is a realistic scenario that a child occupies the front left seat in a vehicle
- All mentions of “driver’s seat” and “front passenger” seat is replaced with “front row”

- Driver remains to be a human and will not be redefined
- Added the term “Manually operated driver controls” which implies a combination of traditional pedals and steering wheel
- The term “steering wheel” is replaced by “steering control” as AVs do not need to have a traditional round wheel to operate

There is no harmonised regulation on federal level on vehicle construction, safety, cybersecurity or data and liability which are all crucial policy areas regarding AV development (Dentons, 2021). Just like in the EU, lack of harmonized standards and requirements can complicate compliance for industry actors. However, the fact that the majority of the main industry actors are present in the USA and conduct their research and testing activity there suggests, that the lack of regulatory harmonization has less impact on attracting industry actors in the USA than in the EU. This can be explained by other, more favourable features the USA holds over the EU. Such features may include better infrastructure, more favourable road structure for autonomous driving, less old-fashioned city planning, or generally less restrictive policies due to not having to comply to international agreements similarly to how the EU member states have to comply for example with the very restrictive UN Regulation No. 157. This allows legislators to alter regulation in a speedier fashion with more freedom to change the direction of AV related legislation if desired and found responsible (Winkler, 2019).

A federal autonomous vehicle bill returns to the agenda of the federal legislators’ time and time again. Last in April 2020, when House Republicans suggested the revival of such initiative to help the vulnerable population deal with COVID-19 (Dentons, 2021). The proposal intended to create national standards for the testing and deployment of autonomous vehicles. The same SELF Driving Act has been brought in front of the House before in 2017 and it proposes serious changes in AV legislation. The bill would require cybersecurity provisions for AV manufacturers, would alter certain federal motor vehicle safety standards to fit the changed requirements of AVs and it would pre-empt states from passing new AV safety laws (Dentons, 2021). The bill failed to pass in 2017 and it failed again in 2020 but the idea is not off the table according to chair of the House Energy and Commerce Committee.

The direction of AV regulation and the role of the different actors to ensure the successful development and deployment of AVs in the USA is described in the most recent Automated Vehicles Comprehensive Plan of the Department of Transportation from January 2021. In this the desire to ensure a Consistent Federal Approach to AV research, regulation and policies were expressed. The role of the Federal Government is to facilitate coordination among the different actors to create harmonized standards in the USA and with international partners as well. The plan acknowledges that outdated regulation must be modernized in order to avoid unnecessarily impeding the development of AVs (Dentons, 2021). Such a critical view on existing regulation differs from what was observed in case of the EU, where legislation from the late 80’s is deemed fitting for regulating today’s emerging technologies (Punev, 2020).

Contrary to the situation in the EU, the USA’s strength when it comes to AV readiness lies in industry partnerships, R&D hubs, and investments (KPMG International, 2018). The greatest number of AV companies are located in the USA. The USA is able to attract industry actors from abroad as well. Japan’s Toyota has a research hub in Michigan with a budget of 1 billion dollar. 44% of all AV company headquarters are in the USA (KPMG International, 2020). In terms of patents, the USA is behind the EU by a large margin. Even though the USA has the largest number of AV test locations, due to the size of the country, only a small proportion of Americans live near by a test location. The infrastructure in the US is not outstanding, but suitable enough for AV testing. The road quality is poorer than in the EU, but the USA has a generally better mobile network coverage which is crucial for AVs (KPMG International, 2019).

4.2.1. Outstanding states

As explained above, individual states are free to determine the type and the direction of AV legislation on the state level. While this might cause fragmented regulatory landscape, it also allows pioneer states to move faster towards creating a more welcoming environment for autonomous vehicles testing and deployment. In the following part I will shortly discuss the two most successful and active states that have been among the first states to welcome AVs on public roads years before any appeared on European roads.

4.2.1.1. California

California is the earliest supporter of the emerging AV technology. The bill 1298, that passed in 2012, established the first procedures for testing self-driving cars in the state. Ever since, California opted to take a comprehensive approach towards AV legislation (Dentons, 2021). Authorities enacted various laws to establish a clear path AV developers must follow to comply. The state now allows AV testing to be conducted without the presence of a backup driver. In order to obtain a self-driving testing permit in California, the company must show proof of insurance or a bond of 5 million dollars (Dentons, 2021). A permit will only be issued, if the company complies with all federal safety regulations and demonstrates that the self-driving vehicle is in fact capable to operate without a driver. As of 2021, 60 companies hold a permit to operate AV testing in California.

In 2020 California for the first time launched an AV passenger service program which allows passengers to hail rides from AVs beyond testing purposes. Simultaneously California approved a permitting process for the monetization of AV rides which can pave the way for large scale AV monetization in California. If a company wants to obtain a permit for such purpose, it has to be in possession of an active Department of Motor Vehicles permit. Only then it is allowed to apply to the Public Utilities Commission for the permit to monetize AV rides. Currently seven companies hold such permit in California and while under the current framework they can offer AV rides, they cannot charge the passengers for the services (Dentons, 2021).

Other notable laws in California “lay out the rights of law enforcement to seize improperly licensed self-driving cars, the ability of local municipalities to charge specific taxes on driverless taxi services, and other factors relating to self-driving cars” (Connectedautomateddriving.eu, 2021). The Assembly Bill 1964 was introduced in 2020. This bill changes the current definition of autonomous vehicles to also include remotely operated vehicles and specifies the minimum requirements for a vehicle to be considered autonomous.

California issued the first deployment permit for autonomous robot deliveries to Nuro in 2021 (Dentons, 2021). While the AVs deployed will not be transporting passengers, it is still a milestone. The deliveries will be made by self-driving Priuses at first, but later Nuro’s R2 vehicles developed specifically to fulfil deliveries will take over the job (Dentons, 2021). California was ahead of both studied EU member state in allowing AV testing without a driver present in the vehicle, but it was not the first one to do so in the USA. That achievement belongs to Michigan (Vellinga, 2020). California ran a pilot that allowed autonomous vehicles without brake pedal, steering wheel, and accelerator to be tested on public roads. Building on this pilot, California today allows the deployment of AVs under strict conditions. Among those conditions, the presence of a data recorder in the vehicle is required, similar to the one used in Germany (World Economic Forum, 2020).

California is home to many of the most valuable high-tech and IT companies. In order to keep such giants in California, the state provides the industry actors with a very flexible, active, and cutting-edge legislation process. Regulation is often the outcome of strong cooperation and deliberation with industry actors and the public, which results in a bottom-up type of regulatory strategy (Winkler, 2019). To illustrate the flexibility and the responsiveness of California law makers, the initial AV legislation was reviewed and adjusted six times just between 2016 and 2018 (Winkler, 2019).

4.2.1.2. Arizona

Arizona made the strategic decision early in the AV technology breakthrough to become one of the leaders in facilitating development and offering test opportunities for manufacturers (World Economic Forum, 2020). Since 2015, when Executive Order 2015-09 was signed by Governor Doug Ducey, Arizona has chosen to take a permissive approach regarding AV regulation. So far two executive orders were signed by Governor Doug Ducey. The first one instructed all state transportation officials to "undertake any necessary steps to support the testing and operation of self-driving vehicles on public roads within Arizona." While Executive Order 2018-04 requires notification of the state if vehicle testing happens without imposing any additional requirements (Connectedautomateddriving.eu, 2021). Contrary to what has been observed in the EU, the lack of regulation is not the outcome of slow regulatory processes, inability to react in a timely fashion or a precautionary strategy towards emerging technologies. Arizona has made the conscious decision to not use heavy regulation but instead allow industry actors to innovate and test the AV technology in the hope of benefitting from the perceived positive impacts of self-driving vehicles on economic growth, transport safety or travel costs (World Economic Forum, 2020).

According to Vellinga (2020), there is a tendency in the USA among industry actors to choose Arizona over California when it comes to testing. A possible explanation is, that a more relaxed and quicker system based on granting exemptions and non - binding regulation is preferred among manufacturers over the system, based on extensive legal framework with binding regulations that is present in California. The approach in Arizona allows for a much wider room for experimentation which is beneficial for technological innovation but can feel hasty for potential consumers (Vellinga, 2020). Besides testing, Arizona also allows self-driving cars on public roads for general operation purposes (Winkler, 2019). This latter makes Arizona a very appealing location for industry actors.

Arizona is considered to be an AV-friendly state with its relaxed legislation and year-long dry weather, which quickly attracted many industry actors to test their vehicles in Arizona. It is in line with the chosen approach of the state that Arizona does not have fixed testing routes (Winkler, 2019). All public roads in the entire state are open for testing in order to attract industry actors. In 2016, already 600 self-driving vehicles conducted testing on Arizona roads which is a very high amount compared to other states/countries around the world (World Economic Forum, 2020). For example, Arizona was chosen as test location by Waymo who has been testing AVs in Phoenix, Arizona since 2017 by offering a limited public ride-hailing service for vetted passengers. In 2021 this service will be open for the public which is a huge milestone for AV testing in the USA (Dentons, 2021).

Reflection

The US Secretary of Transportation predicted in 2015, that self-driving cars will be on the road worldwide by 2025 (von Hauser, 2015). This prediction is somewhat bolder than what European legislators expect, which was earliest in 2030. Given the speed at which technology has been advancing, a gap of 5 years can be considered relevant. Besides the general prediction, chapter 4.2 described many indicators that the speed at which regulation aims to and manages to keep up with the technological innovation is considerably faster in the USA than we have seen earlier in case of the EU. The difference in speed can partly be explained by the difference in the approach and external factors as well.

While the EU and its member states are bound to comply with international treaties and standards, the USA enjoys a much higher degree of independence when it comes to their legislative procedures (Winkler, 2019). The USA seems to have adapted a generally more allowing environment when it comes to AVs, while the EU tends to move in a more restrictive direction. The USA has an advantage when it comes to the possibilities the state-level legislation offers. By being able to test many different approaches guided by a federal-level ideological direction and goal setting, the USA is widely positioned in every step of the way from development to testing and road-use of AVs (Winkler, 2019).

The advantage can however be a disadvantage in the meantime. Similarly to the EU, the problem may arise where the lack of unified rules can lower consumer trust and the willingness of industry actors to choose the USA as their base of operation. To offset this, the USA can provide a generally more modern, thus better suiting city structure for AV testing, a better infrastructure and high-speed network and the ability and willingness to change laws in a rapid tempo to ensure the smooth operation of AV-related technology development.

While the speed of the regulatory response is admirable and suggests a lack of substantial disconnect among Regulators and Industry, the consumer acceptance in the USA does not show the same forward-thinking pattern. Chapter 3.3 presented a very similar level of consumer acceptance to the one in the EU. This suggests a possible disconnect among Society and Regulators or Society and Industry, where the improvement of the readiness of the consumers to switch to the new technology once it is available and allowed by law is lacking behind in speed.

The USA has managed to attract major industry actors, including Tesla which operates from US soil and believed to be the first manufacturer to achieve Level 5 automation in the very near future. On the federal level updating policies, facilitating coordinated actions among states, and ensuring a consistent federal approach in preparing the transportation system is determined crucial in order the achieve the main goal, to remain a leader in automation (United States Department of Transportation, 2020). While the legislative approach in California and Arizona was different, both were very inviting for industry actors. As mentioned earlier, consumers experiencing AVs on the roads for example during testing can have a positive impact on consumer acceptance. The more wide-spread testing is, the more likely that consumer acceptance will be improved in the future.

Finally, the presence of many non-traditional players willing to join the AV landscape in the USA created a strong lobby scene which has had considerable impact on policy formulation as well as technological innovation in the USA. An example is Google, whose strong lobbying forced regulators early on to deal with issues they intended to set aside and wait until more clarity is available, while the industry was challenged by the entrance of a powerful new player which possibly resulted in faster innovation (Schreurs & Steuwer, 2016).

4.3. Conclusion

Chapter 4 highlighted the most relevant legislative actions in the EU and in the USA regarding the development of the autonomous driving technology. Besides state and EU wide policies, a brief description was offered on the legislative actions in the 2 most prominent states/MSs who can be considered trend setters/lessons for other, less adventurous regions. To answer SQ3, the major differences among AV legislation in the EU and in the USA are the speed of reacting on the emergence of the technology, the speed of reacting on the speed at which the technology has been developing and the general attitude towards the technology. The USA has been clear about the goal to be the most relevant region where AVs are being developed, tested, and rolled out nearly the same time when the first automated systems appeared. To achieve that, a regularly updated federal action plan is being published with clear goals and distribution of responsibilities among actors on different regulatory levels.

However, in the EU, a much slower speed was observed. Early on, AVs failed to make the priority list. Later, regulation was shaped by outdated international treaties and slow legislative actions which resulted in a fragmented regulatory landscape in the EU. While some MSs decided to implement a forward looking and more allowing legislative environment this was only possible once the limiting international agreements were amended. The EU has much more restrictive vehicle regulations and traffic rules which together with lack of harmonised infrastructure further lowers the attractiveness of the regions for industry actors. The EU has considerably less industry activity than the USA. While current consumer acceptance is nearly identical, the assumption is that direct contact with the technology can create trust. If testing remains primarily in the US, on the long term it can boost consumer acceptance considerably, leaving the EU to lag behind. In order to avoid disconnect among society and the other two actors, it is important for both actors to ensure a positive attitude towards AVs. Both in the EU and the USA, the relevant industry actors and regulators alike are aware and active in educating the public and trying to create trust among the society towards this revolutionary technology.

As similarities are concerned, both regions have differences in approaches on how to regulate AVs among the different sub-regions. Both regions have areas where testing and rollout is permitted without a driver present. Bottom-up processes were observable in both studied regions which can be explained by the lack of centralized hard legislation from top-down. The industry is working in close cooperation with the legislators in the EU and in the USA alike. Both regions agree in the basic idea that AVs bring very impactful positive change once they can be safely introduced into traffic, however the speed at which this introduction should take place according to the actions of the relevant legislators suggest a bigger disconnect among Legislators and Industry in the EU.

5. Conclusion

5.1. Introduction

The previous four chapters of this thesis each focused on one or more of the three main actors and potential disconnects between them which could have an impact on the future success of self-driving vehicles in the EU and in the USA. The technology itself is in development currently by several industry actors simultaneously. Level 2 and early level 3 AVs are on the roads already, but fully autonomous vehicles (level 5) are yet to be available for purchase. While the predictions from various actors differ on when level 5 AVs will be available, studying the speedy development history from the first iteration of driverless car in 1925 to the early use of smart technologies in the 2000's suggest, that the rapid development of this particular technology won't be halted anytime soon. AV development is in full force, and the frontrunner is Tesla. The thesis focused on Tesla and their Autopilot technology which, according to experts, is ahead of its competitors. The most likely scenario is that Tesla will be able to produce a fully functioning AV within years. This does not mean that such vehicle will be able to enter road traffic immediately. There are several obstacles that could delay the development or the roll-out of AVs. In this thesis, three main actors were studied to see how their behaviour and attitude towards AVs differ or align, and whether possible disconnects can be observed among these actors that could alter the course of the rapid development of AVs. The goal of the thesis was to identify these disconnects and analyse what kind of impact they have on a potential roll-out of AVs if they will be available soon.

The three studied actors were the following: "Regulators", "Society" and "Technology". To narrow down the focus of the thesis, these actors were studied and compared in two main territories: EU and USA to see where AVs would be more likely to be able to hit the roads as soon as they are available. Chapter 2 described the unique path Tesla had in developing AVs so far, introduced the most relevant technological advancements that make self-driving possible and gave an overview on the benefits and the risks this technology may pose to society if fully implemented in the future. Chapter 3 determined the most relevant stakeholders in the studied regions, and described the attitudes of regulators, society, and technology developers towards AVs. Chapter 3.1 highlighted major differences among industry actors and how they approach the AV development process in the EU and in the USA. It also described the complex and expanding web of stakeholders belonging to this group of actors, and how over time, as the technology keeps evolving, new stakeholders join and become crucial to the success of the AV technology. Chapter 3.2 described the various policy areas that are impacted or could potentially be impacted by AV development and future roll-out. A comparative analysis between the EU and USA legislative landscape and main regulatory principles discovered differences among goal setting and regulating AV policies in the studied regions. The final part of chapter 3 compared the last actor, the society's attitude towards AVs in the EU and USA. Since AVs are in the development phase, Roger's DOI theory was introduced to help make prediction of the future consumer attitude towards AVs in the studied regions. The last chapter, Chapter 4 focused on AV legislation in the EU and in the USA and the sub-regions that seem to be the most allowing towards AVs. With this, the picture of all three studied actors were completed, and all potential disconnects were uncovered in the EU and in the USA. The next part will summarize my findings by answering the sub-questions presented in Chapter 1.

5.2. Answers to SQ1, SQ2.1 & SQ2.2 and SQ3

The sub-questions help complete the view on each studied actors in the studied regions, so potential disconnects in attitude towards the technology or the speed at which they move towards accepting the technology can be identified. This is the last step to identify possible disconnects and explain what impact those might have on the roll-out of the AV technology.

In order to determine the pace, the direction and the potential impact of the technological development that aims to make fully self-driving vehicles a reality, I have formulated SQ1: *What* *have been the main technological advancements allowing the development of autonomous vehicles and what are the expected societal, economical, or environmental impacts of the rapidly developing AV technology?* Chapter 2 discussed the relevant findings to this sub-question, and it helped narrowing down the focus on Tesla as the most successful actor currently developing AVs. Through describing the technology that Tesla is using, and highlighting the main differences compared to other industry actors', I have discovered a few key elements relevant to SQ1. The level of autonomy of a car ranges from Level 0 to Level 5. Only cars with Level 5 automation are considered fully autonomous. At the moment Tesla has the most advanced vehicles on the road, which can be considered to have early Level 3 automation. The rest of the major car manufacturers are selling cars with at most Level 2 automation.

To arrive at the current state of development, the industry needed less than 20 years. In the early 2000's the major car manufacturers began developing AVs, two decades later we are a few years away from fully functioning self-driving vehicles according to the industry (Wang J. , 2019). This is a very fast paced development with influential technological break throughs like the use of camera systems to monitor the environment, ultrasonic sensors to help manoeuvring, radars for additional precision, adaptive cruise control and lane changing assistant to take over certain operational functions from the human driver. All this empowered by in house developed, especially for self-driving chips and the neural network. The neural network that Tesla is developing is fuelled by nearly 1 million vehicles already on the roads today to collect valuable traffic data to perfect the future Autopilot system (Tesla, 2021). This gives a competitive advantage to Tesla compared to other, traditional car manufacturers with less advanced state of AVs and considerably fewer cars on the roads and no equipment specially designed to create self-driving cars, instead using stock technology on their current vehicles (Wang J. , 2019).

The second part of Chapter 2 discussed the potential societal, economic, and environmental impacts of this emerging technology. Since the technology is not available at this moment, the actual impact can't be precisely determined. This creates a considerable number of uncertainties both for legislators and for consumers which in turn can have an impact on how these groups react on the rapid development of the self-driving technology. Among the potential benefits Chapter 2 discussed, the most relevant ones are the decrease of accidents and increase of fuel efficiency due to the elimination of the human factor in traffic; increase of productivity due to freeing up the time people spend on driving vehicles at the moment; reduce traffic due to new ways of optimizing routes and eliminating traffic jams; provide greater transportation accessibility to those that can't drive (elderly, disabled etc); economic benefits due to the need for narrower roads, fewer parking places; creating of new jobs in manufacturing and production. Besides the benefits, the potential risks associated with AVs can have impact on how society and legislators react on the rapid development of self-driving vehicles.

Chapter 2.3 introduced a number of relevant potential risks that can have an impact on the legislative strategy and societal acceptance studied in later chapters. Among the risks, the most relevant ones are the following: legal uncertainties, security and privacy concerns, ethical concerns, economic costs, and job security. The costs of creating the necessary infrastructure for AVs to function properly is high and it would require a change in current road/city planning strategy. Among others, the impact of AVs on the gasoline and automotive industries would be huge. Loss of traditional jobs and the need for reschooling could pose serious economic risks. Liability in case of software or hardware failure, hacking or the handling of big data all raise concerns among the legislators and the public as well. Finally, ethical issues around the decision making of AVs or the phasing out of traditional vehicles are important issues where lack of consensus among different actors can complicate and jeopardize the success of AVs.

In order to determine the most relevant actors and their attitude towards self-driving in the studied regions, I have formulated SQ 2.1 and SQ 2.2. *SQ2.1: Who are the key industry, legislative, and societal actors on the autonomous driving landscape and what impact do they have on the AV ecosystem? SQ2.2: Are there differences between the EU and the USA regarding the attitude of the* *studied actors towards the AV technology?* Chapter 3 discussed the relevant finding to these two sub-questions. The AV ecosystem was broken down to three main categories: industry actors, legislators, and society. Determining the key industry actors was done by using a partly altered typology by Maunsell et al. (2014). In 5 main categories (automotive industry, OEMs, technology providers, mobile service providers, financial sector, and energy sector) the most relevant actors were discussed with a focus on how they interact and cooperate with each other or expand the AV ecosystem by entering it along the development process and help existing actors with new input (both from software and hardware industry). The main actors from the traditional automotive industry from the studied two regions were Tesla, GM, and Ford from the USA, and VW, and BMW from the EU. While Tesla had very few notable partnerships, all other industry actors were working in close cooperation with several other industry actors. Apart from Tesla, the AV ecosystem presents as a web of interconnected actors using similar stock technology to create self-driving vehicles.

A notable difference between the EU and the USA was that while the EU provides several strong traditional automotive industry actors and OEMs, the USA is ahead of the EU in the number of technology and mobile service providers, and hardware industry. Similarly, Tesla had very limited number of patents registered regarding their AV technology, while all other actors actively patent their innovation. This is especially true for EU actors which suggests a different mindset and strategy when it comes to the AV technology research. The development of AVs opened a new market for -among others- software developers, big data and analytics companies, and cloud and IT services. They are now a crucial part of the AV ecosystem. The energy and financial sector conclude the main industry actors. They differ from the rest of the actors discussed in this chapter, since they don't actively participate in the development process, but they will be greatly impacted by AVs once they are available. Therefore, their lobbying activity and their relationship with other actors and status within the AV ecosystem in the two studied regions provides additional information on the expected success of AVs. At the moment only a few partnerships can be found among manufacturers and energy/financial sector actors in both studied regions but keeping an eye on the future activities is important.

Chapter 3.2 presented the most relevant legislative actors in the EU and the USA who are impacted by, while also shaping the development of the AV technology. Due to the complexity of the technology at hand, many relevant policy areas are impacted. Legislators, by being responsible for the creation of the applicable legal framework, are determining the environment in which industry actors can innovate and the society can move ahead in trying out new innovation. The main policy areas that legislators have to consider making changes in are:

- infrastructure management
- land use and urban planning
- public transportation
- liability issues regarding vehicle ownership
- health and safety
- environmental protection
- employment
- energy consumption
- cybersecurity
- tax and insurance
- ethics (Pucher, Schausberger, & Wernech, 2018).

Both the EU and the USA lack a complete legislative framework for regulating the self-driving technology testing and roll-out, but in both regions a high level of alertness and interest in the technology was expressed by the legislators. The EU took a coordinating role by encouraging MSs to harmonize their AV related legislation and provides platforms on which other actors can cooperate without having the mandate to regulate the matter on the EU level. In the USA the federal government provides the main policy direction and goals regarding AV testing and roll-out for each state to work towards. Therefore, the USA has a more harmonized regulatory environment which has a positive impact on attracting industry actors and shaping a positive societal acceptance. Regarding the attitude of the legislators, Chapter 3 presented a difference in the main principals regarding AVs in the EU and the USA. The EU is guided by safety and precaution when it comes to AV related actions to ensure that the technology can not cause harm to society in the light of the many uncertainties. While having the goal to reduce traffic accidents and acknowledging that AVs can help achieving this goal, the EU does not advocate for an overly facilitating approach and encourages MSs to move at their own pace. The USA's guiding principle is to ensure American leadership in AV technology. They will try to achieve this goal while ensuring the protection of users and citizens, promoting efficient markets, and facilitating coordinated efforts in the USA. The USA has chosen a much more allowing/facilitating approach contrary to the restrictive EU policy direction.

Chapter 3.3 studied the attitude and the role of the society, as the third main actor on the AV landscape. The impact of the society on the success of the AV technology is huge. Both the industry and the regulators have an important role in providing information and educating the society on the potential benefits and how they plan on limiting the risks of AVs. The society is more exposed to AVs in the USA, as industry actors are more active in conducting testing in that region. Being exposed to the new technology has a positive impact on societal acceptance. Early studies on societal acceptance from 2016 suggested a higher societal acceptance in the EU, but as the technology has matured, the societal acceptance in the USA suppressed that in the EU. Predictions made based on surveys and Rogers' Diffusion of Innovation Theory suggest that the expected dynamics of societal acceptance favours the USA. By the time AVs will be perfected, it is more likely that the society will react positively to self-driving vehicles in the USA than in the EU.

In order to complete the picture on the legislative environment in the studied regions, I have formulated SQ 3: *How has the development of the AV legislation in the EU and the USA been evolving and what are the main similarities and differences that can have an impact on the tempo of the rollout of autonomous vehicles in these two regions?* Chapter 4 discussed the relevant findings that help answering this sub-question. While similarities were observed between the EU and the USA when it comes to how they deal with AV legislation, the USA had a generally faster approach from early on in the AV development process. AVs have made onto the legislative agenda years ahead in USA compared to the EU. While both regions lack a strong top-down binding legislative framework concerning AV testing and roll-out, the harmonisation effort from the federal level which could be observed in the USA resulted in a more homogenous legislative environment compared to the fragmented EU landscape. This has an important impact on competitiveness, as industry actors are more likely to conduct testing/development in a region with clear, homogenous, and welcoming legislative environment. It is very relevant, where development and testing are taking place. The road structures are different enough between countries, that the technology developed in the USA for example isn't directly compatible on EU roads and it needs further tweaking before a future AV would be safely able to function there as well. This gives an advantage to the USA. Tesla, with the most advanced AV technology is doing most of its testing and development on US roads. The EU can't be considered as one territory regarding road structure, traffic signs or city planning which further complicates the universal compatibility of AVs.

The legislation in the USA can be considered speedier, and more allowing compared to that in the EU. For example, the EU participates in international agreements which slows down the speed at which they can react to technological development. The EU opted for a more precautionary approach when it comes to AV policy to ensure safety above all, while the USA is committed to be the leading actor in the AV landscape. While the discussed outstanding MS's in the EU suggest that there are sub-regions within the EU where the preparation for AV roll-out is speedier, and attracting industry actors to conduct testing is on the agenda, the prospect of having to comply with diverse rules, different traffic signs, road structure or lack of internet every few thousand kms when AVs arrive to an internal EU border, makes it less likely for industry actors to want to establish their base of operation in the EU. Seemingly, the EU is not in a hurry to update outdated legislation that is limiting the speed at which the industry can develop AV technology, while the USA is aware and willing to rework rules that are in the way of AV development. An example is the lack of requirement for a human driver to be present in the vehicle without a speed limit for testing purposes in the USA. All in all, looking at the regulatory environment, the USA is ahead of the EU when it comes to speed and approach. While this suggests a lack of disconnect among regulators and industry in the USA, it also might create a lack of consumer acceptance, if it is perceived as too hasty or unsafe by the public. Both regions invest in education and information campaigns to develop consumer trust, but since AVs are yet to be available, it is to be seen if the difference in regulatory approach has an impact on consumer acceptance in the future.

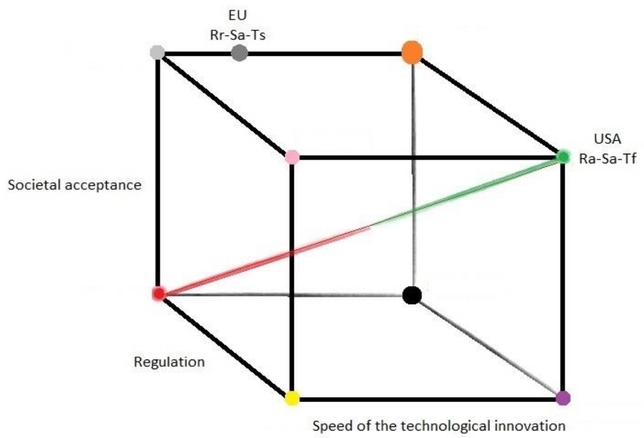
5.3. Disconnect analysis

In order to discover potential disconnects among the three studied actors in the two regions, the thesis presented detailed analysis of the actions and positions of the actors within the self-driving ecosystem. To summarize my findings, I have answered the four sub-questions. To identify the disconnects, I will attach the appropriate values to all three variables based on the findings presented previously. The attached values are relative to each other between the two regions. As for relative simplicity I have decided to work with binary variables and not a scale, the actual values will represent the position compared to the same variable in the other region, rather than an absolute value holding true if more regions are introduced.

Starting with the Technology, the industry in the EU it is less active and moving at a slower pace compared to the technology being developed in the USA where Tesla is leading the way in autonomous driving development. However, by no means is technology developed in the EU slow, but it is slower than the one developed in the USA. The Society is -at the moment- similarly accepting towards AVs in both regions. Based on the available survey data, the society is rather positive in the EU and in the USA as well. However, looking at predictions based on surveys and the Diffusion of Innovation Theory, the expectation is that the social acceptance in the USA will grow at a faster steed compared to the EU. The industry and the legislators in both regions recognise the importance of exposure and education in order to bolster societal acceptance, but due to several factors explained previously, the USA is more likely to succeed at reaching a higher societal acceptance within a shorter timeframe than the EU. As of right now however, both regions will be considered accepting on the society variable. Finally, Regulation in the USA seems to be more flexible, higher in speed, and less restrictive compared to that in the EU.

To summarise, using the typology presented in Chapter 1, the EU has the following profile: Rr-Sa-Ts, while the USA is Ra-Sa-Tf. There are no disconnects discovered among the actors in the USA, while argument was made that a weak disconnect among Regulation and Technology and a possible disconnect among Regulation and Society and Technology and Society is present in the EU. The USA's profile is the closest to Scenario 8, while the EU's is closest to Scenario 3. Placing the EU and the USA into Figure 1, the final Figure looks the following way:

Figure 14 The position of the EU and in the USA in the alignment cube



5.4. Answer to the main research question

The research question of this thesis is the following: *Which disconnects can be observed in the EU and the USA between legislators, industry, and society regarding the attitude towards the emerging autonomous driving technology and how can these disconnects influence the immediate roll-out of AVs in the studied region as the technology becomes available?* In order to help me answer this research question, I have formulated a hypothesis. The hypothesis presented in Chapter 1 suggested that "*Disconnect between any of the three studied actors (regulators, technology, and society) will hinder the roll-out of AVs but at a different degree.*"

To answer the first part of the research question, I look at Figure 14 in the previous sub-chapter. I have not identified any relevant disconnects in the USA, while I have identified potential disconnects among actors in the EU. I have in fact observed a disconnect between Regulation and Technology, Regulation and Society and Society and Technology. As seen, the regulation in the EU, compared to the USA, is much more restrictive, applies a considerable amount of precaution when it comes to AVs, and it is slow in speed compared to how fast the technology itself is developing. The society in general seems to be rather accepting towards self-driving cars, which is not in line with this slower, more reserved approach the EU has chosen. While member states do have the chance to move faster, this does not solve the problem of other member states lagging. Without a homogenous EU-wide policy, the region is not appealing to the industry. While the technology was labelled slow in the EU, it is still developing at a faster pace than Regulation can or is willing to move at. There was a potential disconnect observed in the EU: a disconnect among Technology and Society. Society was observed to be positive towards self-driving vehicles, while the technology developed in the EU is moving with a slower pace compared to technology being developed elsewhere. Looking at the technology developed in the USA by Tesla, it is clear, that the positive mindset of the society in the EU is more in line with the speed at which technology is being developed outside of the EU.

To answer the second part of the research question, I used the theory and hypothesis presented in Chapter 1. The assumption, that different disconnects have different impact on the roll-out of AVs in the studied region was strengthened by the theory presented by Raj (2020), allowing me to rank the different scenarios based on how likely it is that AVs will be able to drive on public roads once available in regions that can be described by either of the 8 scenarios. The USA was best described by Scenario 8, with a full alignment among the three different actors. The EU was best described by Scenario 3, but as presented in Figure 14, it lays somewhere between Scenario 1 and Scenario 3. Scenario 8 was described as the most likely to adopt AVs as soon as they are available, while Scenario 3 (or Scenario 1) ranked lower. It is therefore more likely that AVs will be adopted by the USA in their full capacity sooner than in the EU.

5.5. Limitations and recommendations

In the final part of this thesis, I will discuss the limitations of the study and suggest potential follow-up research to complement or challenge the findings of this thesis. Limitations can influence the interpretation of the findings of the study; therefore it is important to mention them before introducing potential points of discussions for follow-up research. Due to scope and time limitations, I have made choices in the research design to narrow down the focus of the thesis. I have decided to discuss passenger vehicles only, which is just a portion of the available fields where the emergence of the autonomous driving technology can be impactful. While this choice was necessary to avoid having to discuss a wide range of additional fields in terms of regulation, societal acceptance, and technology, it weakens the ability to generalize from the findings of this thesis. However, the decision to focus on a field which is arguably the most present and tangible in our everyday life was a conscious choice. The research provides a comprehensive view on self-driving cars from the perspective of the selected three actors. A possible follow-up research could widen the scope to include other types of vehicles which could benefit from the technology but would have different risks and benefits to consider. An example may be autonomous freight transport on land and sea.

The choice to focus on the EU and the USA was made together with the choice to focus on Tesla. Tesla is ahead in the race to achieve full self-driving capability, while it is also the most popular electric vehicle in the two studied markets. In order to determine where it is most likely to see level 5 self-driving vehicles as soon as they will be available, I chose the two markets which are currently the largest for lower-level autonomy vehicles. However, there are other relevant markets which were considered to be included in the study but were left out due to time and scope limitations. A follow up study could discuss the fastest growing market, which is Asia-Pacific to see whether or not differences in consumer attitude or the regulatory environment can be found compared to the EU and the USA. I have selected the member states and states that had the most positive attitude towards AVs to study. This choice was made to fit the focus of the research to determine where we might see AVs on the roads first. Studying areas with a more restrictive mindset may contribute to understand the future of AVs and to study how a highly fragmented world can accommodate a technology which thrives in a homogenous environment where traffic rules, road conditions, infrastructure and countless other factors complicate the development and functioning of the technology.

The choice to assign binary values to my independent variables was made to reduce the complexity of the “alignment cube” model. A more ideal approach would have been to use a scale to describe the variables, however that would introduce a level of complexity exceeding the scope of this thesis. This choice weakens the validity of my findings, as I forced myself to choose between two extremes when describing my observations in the two regions. Adding a third value could have been elevating some of the pressure to categorize my findings, but instead I chose to position my variables in the cube compared to what was observed in the other region. The findings therefore only hold true value when they are discussed in the context of these two regions, but as these are the most relevant regions currently on the AV development landscape, I found this approach to hold relevant scientific value.

The focus of this thesis was to find the most ideal place for AVs based on the current attitude of legislators and society towards the technology. However, the question whether or not it is truly desirable to allow AVs into the traffic as soon as possible could serve as follow-up research. I have identified different scenarios, but the research did not discuss how scenarios that contained disconnects among the three different actors could serve as a better long-term alternative to strengthen the position of AVs within our society. Chapter 4 touched upon the assumption that a more restrictive legislation could create trust among the society which on the long run could be beneficial for all the stakeholders on AV market. Expanding upon this assumption, the scenarios could be weighted by additional variables besides the speed of the adaptation of the technology, to determine whether a slower pace can result in similar innovations while limiting the risks such emerging technology may pose to society. The risks associated with such rapid tech-advancements can hardly ever be fully eliminated. Technology may fail in the future without any sign ahead in time, legislators may fail to successfully regulate risks and society may not be well enough informed to make the decision to trust the technology. It is therefore no guarantee, that the scenario in which there are no disconnects between any of the actors is the safest one long-term.

Finally, I would like to highlight some points of discussions which were only briefly mentioned in this thesis but could complement this research if studied more in detail. The development of AVs go hand in hand with the development of electric vehicles and connected vehicles. The global change in our society’s attitudes towards renewable energy impacted car manufacturers. The trend to focus on the development of electric vehicles was the first step towards taking innovation to the next level. EV’s were quickly equipped with the first diving assistance systems to provide safety and comfort to the driver. Just like EVs can hardly be discussed without the existence of their autonomous features, AVs will most likely be discussed by their ability to bring safety and comfort to the next level if they have connected features. Follow-up research could expand the focus of this thesis to discuss how connectivity is an essential step towards reaching full self-driving and how the different regions differ in the attitude and readiness in connectivity.

The final recommendation focuses on a finding in chapter 4. A main difference which allowed legislators to react speedier on technological advancements in the USA compared to the EU was the lack of international treaties the USA is taking part of. While the EU has to comply with strict rules agreed upon by hundreds of countries with different geographical background, infrastructure, or willingness to accommodate AVs, the USA does not have to comply with often slow to change and outdated type of legislation. However, while the USA is free to adopt legislation that is more up to date and allowing for industry actors, the manufacturers do not operate on US soil only. The AV market is a global market, where the industry wants to appeal to several regions besides the one where they have their research and testing facilities. Follow-up research could discuss some of the following questions regarding the global nature of AVs and CAVs. Can such global industry be discussed in isolation per region? Will the industry develop different technology to comply with looser rules in the USA than in the EU, or will they limit their technology to the one prescribed by EU legislation? Alternatively, will the US developed technology be banned from entering the EU market which can create a trade barrier and how would that impact industry behaviour in the development process?

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