Strategic Analysis of an Accelerated Introduction of Cooperative, Connected and Automated Mobility (CCAM)

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A dissertation submitted for the Degree of

Doctor Rerum Politicarum

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Date of Dissertation Defence: 1st March 2022

Dedicated to Heike Baumgärtner-Edye, Dr. Christian E. Edye and Leon M. Thomsen

Acknowledgements

The last four years have been the most challenging and yet rewarding years of my academic career. While the intention behind the PhD was to follow my curiosity about artificial intelligence and self-driving cars and to push myself to my academic limits, my experience reaches further than I had ever imagined. I travelled in Europe and America, was part of a government project, made presentations about our research, built my network, and realised that artificial intelligence will be a game-changer not only for the automotive industry, but for any business and industry in which it is applied.

None of this would have been possible without my supervisor Prof. Dr. habil. Wolfgang H. Schulz. Thank you for taking me on as a PhD student, encouraging me to participate in the KI Plattform government project and then allowing me to work at the Centre of Mobility Studies. Making me present at the ITS World Congress in 2018 in Copenhagen threw me into the centre of knowledge sharing and underlined the importance of research itself. Together we presented at the TRB in Washington, D.C. not only once, but twice, and at the CTRF in Vancouver. The opportunities to share our knowledge and broaden my own AI horizon drives my desire to learn more about the topic and hopefully apply it in the industry in the future.

I would like to thank Prof. Dr.-Ing. Silja Hoffmann for accepting the role as my second supervisor and for telling me to embrace the pressure and thrive on it. Further, I would like to thank Dr. Sophia von Berg for connecting me with Prof. Dr. Lutz Göcke, who kindly took on the role of the third reviewer. Prof. Dr. Göcke provided me with a new perspective of drivers of technological change that I had not previously considered. Also, Dr. Oscar Gallego played a crucial role in my pursuit of this PhD. Thank you for making me challenge my concerns about AI in 2016. Without him, I may have never considered self-driving cars in the first place. I would also like to thank my co-workers at the Centre for Mobility Studies and external PhD students at the Department for Mobility, Trade and Logistics for motivating and supporting each other's endeavours.

A special thanks goes to my parents Heike Baumgärtner-Edye and Dr. Christian E. Edye for enabling me to pursue this PhD. With your endless support, I was able to research, travel and broaden my AI and self-driving car knowledge, even secluded from everyone in a small cabin in a tiny Norwegian fishing town. Last but not least, I would like to thank Leon M. Thomsen for encouraging me to continue when I was willing to give up. Your encouraging words allowed me to push myself to continue my research and finally complete this dissertation.

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List of Abbreviations

AAA	American Automobile Association
ADAS	Advanced Driver Assistant System
AMOD	Automated Mobility on Demand
CAV	Connected Automated Vehicle
C2X	Car-to-Everything
EU	European Union
GDP	Gross Domestic Product
IRM	Institutional Role Model
ITS	Intelligence Transportation System
IoT	Internet of Things
IRM	Institutional Role Model
MaaS	Mobility-as-a-Service
MLP	Muli-level Perspective
PEOU	Perceived Ease of Use
PU	Perceived Usefulness
SCP	Structure Conduct Performance
SD	Social Distancing
TAM	Technology Acceptance Model
TRB	Transportation Research Board
USA	United States of America
UK	United Kingdom
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything

Abstract

For over 80 years the idea of self-driving cars has influenced our perception of the future transport mode. While in 1939 people were excited, they did not believe it would ever become reality. In 2021 we are now closer than ever to bringing these cars on the road. But the vast number of stakeholders and the various aspects that must be considered for the execution of self-driving cars makes it even more complex than at first glance. The creation of a proper artificial intelligence infrastructure, the integration of AI within the automotive industry and lastly, getting society to accept self-driving cars, are the focus of this dissertation. Through a literature review, a qualitative and a quantitative study these key aspects have been considered. At the centre is the over one century old German, and European, automotive industry. The European automotive manufacturers and suppliers need to act together, take risks, educate future self-driving car users and overall see the European automotive industries as allies. Europeans would benefit from pooling financial capabilities and data gathering to execute technological improvements faster and better. To bring autonomous vehicles on the road, and to create a transport mode capable of competing with Chinese, American and other competitors' products, and to simply not be outsmarted by them, Europeans have to work together and become strategically bold. As the COVID-19 pandemic hit in 2020, integrating AI within our automotive industry may not be on companies' minds, but we need it now more than ever. Through AI, processes, such as information gathering and handling, can be improved and machinery supporting workers can be introduced. In addition, the fundamental assumptions on which our future mobility world is based have changed and, as a result, strategies must be reassessed. While the introduction reflects on pre-COVID-19 times, the papers included in this dissertation highlight the changes and the opportunities the virus brought upon the industry and tries to encourage it to expand AI integration and self-driving vehicle execution. The pandemic may have resulted in lower financial capabilities for the research and creation of self-driving cars, but it has also allowed for an increased acceptance rate of this future transport mode. Overall, it is time for the automotive industry to reconsider its self-driving vehicle deployment approach drastically in order to reinvent itself and usher in a new era where AI within automobiles is not feared but preferred.

1 Introduction

1.1 Background

In 1886, Karl Benz created the first automobile, the Motorwagen. Within ten years, it had replaced most carriages. In 1934, General Motors introduced the world to the first concept of autonomous vehicles. At the time, it was a sensation, but it was also wishful thinking. In 2022, the ideas and concepts of self-driving vehicles are finally coming together, technologically, politically, and infrastructurally, to make fully automated vehicles more easily accessible and ready for mass production. Looking back on 1934, we now know it is not just wishful thinking but an industry shake-up that will change the way we approach mobility entirely.

The existing oligopoly surrounding the German automotive industry is being broken apart by new entrants, displacing well-established companies such as BMW or Volkswagen. These new innovative companies offer new products, adapt to market trends, display creative thinking, and have a quick turnaround time between research, development and road readiness. In 2019, Tesla's Model 3 was not only the most sold electric vehicle but the most sold car of any fuelling type in Switzerland (Schmidt, 2019). Further, with China's eagerness to continue its rise in the technology industry and the United States' entrepreneurial focus, the established German and European automotive industries are being challenged. The future automotive market consists of alternative, more environmentally friendly, and sustainable fuel sources and (fully) automated vehicles. To receive their share of this new market, the European automotive industry must act now.

The key component of the changing automotive industry is artificial intelligence (AI), as it enables future cars to drive and the industry to improve itself. The German automotive industry must learn about and integrate AI in an accelerated time frame to keep up with its challengers by successfully introducing fully automated vehicles. Due to autonomous driving being based on software developments and AI being deeply rooted in the technology industry, the technology industry has become a key component and is even establishing itself as the rival of the existing automotive industry.

The development of autonomous vehicles requires many stakeholders. Governments need to provide legal frameworks for testing and driving self-driving cars. Automotive industries need to integrate AI to produce better AI-driven vehicles, and future users need to accept and use the new transport mode and recognise its benefit to society as a whole. Overall, the German automotive industry must not only adjust to the new approach of vehicle creation, but also, in order to remain competitive, it must work with its European competitors to bring self-driving cars on the road.

1.1.1 CCAM and Technological Advances

Whether passenger cars, buses, or lorries, vehicles have evolved over the past decades into connected machines that send information to outside sources, resulting in improved driving experiences. This interconnectedness of vehicles has laid the foundation for the cars of the future. Following the definition of the European Commission, ‘Cooperative, Connected and Automated Mobility’ refers to “vehicles that can guide themselves without human intervention” (European Commission, 2020). The vehicles’ cooperative aspect will “significantly improve road safety, traffic efficiency and comfort of driving, by helping the driver to make the right decisions and adapt to the traffic situation”. Further, cooperation, connectivity, and automation “reinforce each other and will over time merge completely” (European Commission, 2020). The European Commission refers to this transport mode as self-driving vehicles (European Commission, 2017).

1.1.2 Dissertation Focus

The acceptance of self-driving cars was the focus of my expose in February 2018. In mid-2018, Prof. Dr. habil. Wolfgang H. Schulz asked me to join the AIP Project (see 1.2 History of Electric and Autonomous Vehicles for details). As a result of participation in this project, we saw the opportunity to structurally assess and highlight the importance of AI as the foundation of any self-driving vehicle development. This included considering the improvements within the industry necessary to speed up production processes, vehicle developments, and, ultimately, the creation of a fully functioning self-driving vehicle and its software. Without AI, the German automotive industry would fall far behind its foreign competitors. Because of this, I decided to expand the dissertation focus from the acceptance of self-driving cars to the assessment of critical stakeholders for the introduction of self-driving cars on our roads. Additionally, through the focus on an accelerated introduction, the title recognizes the need to act quickly in order not to be left behind by competitors.

Over the past century, the automotive industry established itself as a vital component of many countries’ economic success. Germany, China, the United States, and India, to name a few, have influential automotive manufacturers and suppliers that employ a vast number of citizens and contribute to the nations’ GDPs. Several leading automotive manufacturers, such as Volkswagen, BMW, and Mercedes-Benz, and suppliers, such as ZF Friedrichshafen and Bosch, are located in

Germany. With over 800,000 workers directly working in the German automotive industry, 4% of the entire German workforce overall being directly and indirectly linked to it, and an economic performance of over €130bn, the German automotive industry is the nation's most important contributor (Statistisches Bundesamt, 2019). Thus, it is crucial that the success of the German automotive industry is upheld. However, due to an increasing threat of the technology industry taking over the automotive industry, and the German car reputation being challenged by new vehicle producers in the market, Germany must re-think its automotive approach. Instead of focusing on the single market, Germany should expand its cooperation efforts to foster Europe-wide development activities. While beneficial to many industries, expanding AI integration will be a vital foundation for the development and expansion of self-driving cars and thus the competitiveness of the automotive industry. Due to the many stakeholders important for the creation of self-driving cars, such as governmental legal frameworks, infrastructure investments and population for data collection, Germany needs the European Union to remain competitive. Overall, the German automotive industry needs the European Union to become more agile and thus adjust to new trends. Therefore, while the focus of this dissertation may be textually oriented on the European Union, at the centre lies the German automotive industry.

1.1.3 Dissertation Framework

Management can be split into goal formation, development of a strategy to obtain these goals, and handling of daily activities and employees for actual goal fulfilment. Operational management considers short-term undertakings, focusing on the day-to-day activities of individuals or small teams. Strategic management, on the other hand, aims at forming companies' long-term goals. To form a company's strategy, its environment must be assessed through a strategic analysis. Cambridge Dictionary defines strategic analysis as "an examination of how successfully an organization is operating and how well it is using resources to achieve something over time" (Cambridge Dictionary, 2022). Due to the high frequency of innovations in the field of AI, as well as the interdependence of technological and economic research for the automotive industry with the development of AI, such strategic analysis has many facets.

The strategic elements chosen for this dissertation are among the most critical stakeholders for the analysis of the accelerated introduction of cooperative, connected, and automated mobility at the government, industry, and user levels. These elements are covered in the following three papers:

- "Are USA's and China's artificial intelligence activities outsmarting Europe? – A critical analysis of AI and Europe's approach to it" is a competitor analysis, illustrating the role and current integration of artificial intelligence within the European infrastructure and automobile industry in comparison to China and the USA;

- “The Knock-On Effect of Introducing AI as a Supply Risk Optimiser - How Implementing AI Can Assist Companies to Endure a Crisis” investigates the perception of the automotive industry’s supplier risks and the integration of AI to overcome them; and,
- “Social distancing, autonomous vehicles’ unexpected supporter – How COVID-19 has changed future mobility behaviour and perception in Europe” focuses on the influence of COVID-19 on the acceptance of robo-taxis and how the assumptions on which our future mobility world is built are being contradicted.

The government must provide an AI infrastructure for any industry to thrive. The industry in turn must understand and use AI in order to produce the best possible AI-driven vehicle. But why does the German/European automotive industry need to integrate AI in the first place? First, it must understand the benefits AI can provide the automotive manufacturers. AI can help an automotive manufacturer improve its products, including driving down costs through production optimisation, improving product designs, or reducing error margins. Second, driving down the purchasing price can increase consumer demand. With the high estimated costs of a self-driving vehicle, price reduction is crucial to enabling as many interested users as possible to purchase and use the technology. Third, competitors across the globe are integrating AI in the automotive industry. To remain competitive, the German and European automakers must integrate AI to remain competitive. Lastly, if the automotive manufacturer claims to create an AI product, but has not recognised the potential of AI for its own business operations, how is an already sceptical consumer supposed to trust the producer to build the best possible vehicle? Nevertheless, all stakeholder efforts will have been fruitless if the user does not accept and use the technology. Thus, our development and integration efforts must go beyond merely producing a self-driving capable vehicle to understanding the perceptions, concerns, and benefits from the users’ point of view in order to get them out of their manual cars and into autonomous ones.

Artificial intelligence is the critical component for the future driver of autonomous vehicles. To ensure the German automotive industry’s competitiveness, both software and hardware must be adapted accordingly. Having deployed autonomous vehicles on the road is not sufficient if the potential consumer does not accept and use the technology. The papers show that autonomous vehicles’ deployment is not only about the technical realisation, but also the various stakeholders and disciplines and their interdependency.

1.1.4 Theoretical Framework

This dissertation is anchored in the microeconomic field industrial economics. In particular, the structure-conduct-performance paradigm (SCP) plays a key role in this dissertation. The SCP reflects that “the performance of the companies within every industry is affected by their conduct (generally understood as management), which in turn are conditioned to a large extent by the structure of the sector in which companies operate” (Matyjas, 2014). Ferguson describes the SCP as reflecting on the “causal relationships between the structure of a market, the conduct of firms in that market and their economic performance” (Ferguson, 1988). The development of the automotive industry as a whole thus depends on the relationship between the various stakeholders, as shown in Figure 1.

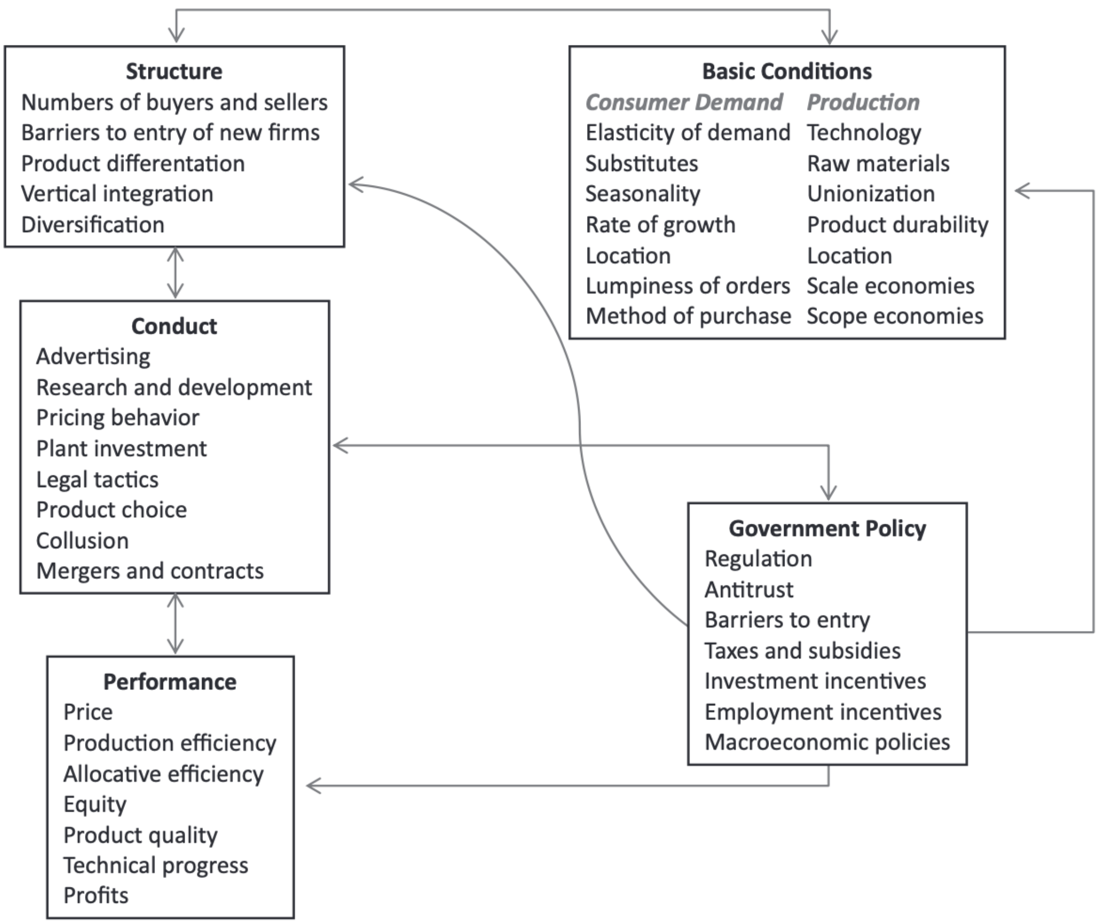

Figure 1 Structure-Conduct-Performance Paradigm (Matyjas, 2014)

Transferring the SCP to this dissertation, government policy is reflected in Paper 1. The activities of the government to create the foundation for a functioning AI environment will affect the structure of the market. In particular, product differentiation and diversification will benefit from

AI. Furthermore, if the government can provide AI expansion subsidies or even an infrastructure that can allow less financially able firms to enter the market, barriers to entry of new firms will be affected. The structure in turn affects the conduct of individual firms. Paper 2 reflects on the research and development efforts of automotive manufacturers. As mentioned, if these companies can integrate AI, they can improve their product quality, production efficiency, technical progress, profits, and price. Lastly, basic conditions are considered in Paper 3. Consumer demand is assessed to understand the perception of a currently still hypothetical product. Overall, the SCP paradigm reflects the various stakeholders considered in this dissertation and highlights their interdependency.

Lastly, two research methods have been applied in this dissertation. Paper 2 is a qualitative study due to the personal interviews held with 25 top-level managers of various OEMs, TIER 1, and TIER 2 companies across the DACH region. Paper 3 is a quantitative study with almost 1600 European participants in an online survey. This data was evaluated using the Technology Acceptance Model (TAM) tool.

1.1.5 Sociology of Technology

A particularly interesting perspective on technology, and thus ultimately self-driving vehicles, was provided by Geels in his 2002 paper. From the sociological point of view of technology, "technology, of itself, has no power" (Geels, 2002, p. 1257). A technology's meaning is created through the use by and integration in society, societal structures, and organization. The technology "only work[s] because … [it is] embedded" (Geels, 2002, p.1258). Thus, integrating a new technology requires complex, multi-level actions to overcome barriers in user adoption and practice, infrastructure integration — if such infrastructure even exists, and regulatory frameworks, in particular for a technology such as autonomous vehicles. Figure 2 shows the stakeholders involved in integration a new technology. Transferring Geels' perspective onto self-driving vehicles, these cars will not be accepted by society simply because vehicle manufacturers produce a fully functioning self-driving vehicle but because they are given meaning and purpose. One could argue that based on this, autonomous vehicles are not a technology push, but a societal pull effect. If their use is recognized and integrated into every-day activities, autonomous vehicles stand a true chance of being accepted. Nevertheless, to allow full integration, the various actors have to pull on the same strings.

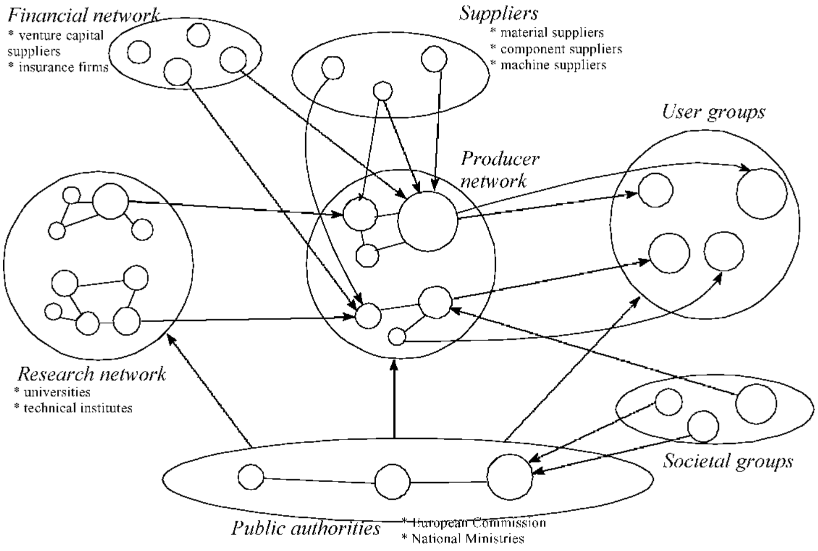

Figure 2 The Multi-actor Network Involved in Sociotechnical Regimes (Geels, 2002, p. 1260)

Further, autonomous vehicle integration should be assessed based on the multi-level perspective (MLP), shown in Figure 3. According to Geels (2002), the multi-level perspective consists of the regime level where existing technologies are integrated, the landscape level, reflecting on external factors, such as rules and regulations that influence the existing technologies, and the niche level, referring to novelty developments. These novelties are "produced on the basis of knowledge and capabilities and geared to the problems of existing regimes" (Geels, 2002, p. 1261). Between these three layers is, once again, an interdependency. While niches are impacted by an existing regime, the regime itself is steered by the landscape.

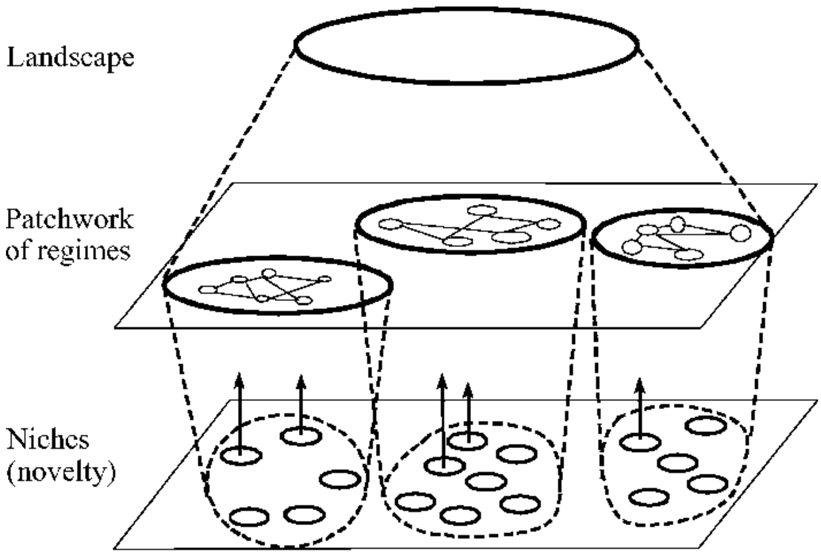

Figure 3 Multiple Levels as a Nested Hierarchy (Geels, 2002, p. 1261)

Literature has frequently shown that technological integration depends on the interdependency of multiple actors, not just the development of the technology itself. Geels' approach also underlines the complexity of self-driving vehicle introduction and highlights that it is crucial to consider various aspects of this new transport mode. Based on his paper, self-driving vehicles are at the niche level, the current mobility industry and its users are located on the regime level, and infrastructure and regulations, aspects that are crucial to the integration of autonomous vehicles but that are slow at creating and adopting to change, are at the landscape level. As such, Geels' approach is also reflected by the three papers of this dissertation: Paper 1 reflects the landscape level, by assessing national AI integration. Paper 2 and Paper 3 give an insight into the regime level through the AI integration approach of the automotive industry and future users. The niche level is considered in the synopsis by highlighting the necessary aspects of self-driving cars, such as their electric foundation or the ADAS features required to make the cars drive.

Fraedrich, Beiker, and Lenz also assess the MLP in their 2015 paper by considering three different development scenarios of autonomous vehicles and their origin within the MLP. They argue that the actual usage of vehicles may not change, but instead the way we move within these vehicles changes. The authors describe three scenarios, described as evolution, revolution, and transformation, to describe the possible ways of introducing self-driving cars on the roads. The "evolution of the personal automobile" (Fraedrich et al., 2015, p. 5) focuses on the automotive industry's slow transition from being the driver of the car to becoming the user of a car through an increased integration of ADAS. Looking at the MLP, this would mean a transformation from within the already established regime level. The less we actively drive, the more we can use our time for other tasks such as activities that may require the use of laptops and mobile phones. This highlights the interest in non-automotive manufacturers, such as Apple and Google, to get self-driving vehicles on the roads. Technology companies may see self-driving vehicles as a way of driving demand for their other products. While this could be considered as coming from the niche level, it could also be the regime level of a different system, the "system of information and communication" (Fraedrich et al., 2015, p. 7). The '"transformation of personal mobility" (Fraedrich et al., 2015, p. 7) perspective originates in the niche level of the MLP. This scenario considers start-up companies providing "automated mobility on-demand" (AMOD) (Fraedrich et al., 2015, p. 7), which would enable a personalized public transport use with the benefits of a private vehicle without requiring the ownership of it. The perspective of Fraedrich, Beiker, and Lenz sees the regime and niche levels as the driver of autonomous vehicles. While the landscape level naturally plays a role in the transformation towards self-driving vehicles, such as the impact of petrol vehicles on the environment and consideration of society and the automotive industry to change vehicles to reduce emission, the key drivers seem to be the other two MLP levels.

Unlike Geels' perspective on how the different stakeholders play a role in the development of a technology, Fraedrich, Beiker, and Lenz consider the already existing approaches to automated vehicle introduction from the developer perspective. However, both MLP approaches show that the development of future mobility does not rely only on the automotive manufacturers but on an array of stakeholders, ranging from external factors such as climate change to manufacturers trying to remain competitive and competing industries entering the automotive sector, as well as the users changing their mobility behaviour, and, as such, create a demand-pull effect for future automotive technology. Again, in order to get a better understanding of how we can remain competitive and drive future mobility forward, we must consider the various stakeholders such as government, industry, and future users.

1.2 History of Electric and Autonomous Vehicles

1886

Carl Benz patented a "vehicle powered by gas engine" - the first automobile.

1913

Henry Ford introduced the assembly line for automobile vehicle production. Through this, he was able to decrease the vehicle production time from 12 hours to 90 minutes on average per vehicle (Cronin M. J., 2014). Ford revolutionised production, created a smoother workflow, and thus was able to meet consumer demand for vehicles.

1939

During General Motors' Futurama, a World Fair exhibition, where GM demonstrated their vision of the future, Norman Bel Geddes revealed his concept of a self-driving car. The vehicle was envisioned to have "radio-controlled electromagnetic fields generated with magnetised metal spikes embedded in the roadway" (Cronin & Scoble, 2020).

1987

The lighthouse project of autonomous driving, PROMETHEUS ('PROgraMme for a European Traffic of Highest Efficiency and Unprecedented Safety'), ran from October 1986 until October 1994. The project, led by Daimler-Benz and carried out by various European automobile makers, suppliers, universities, and institutes, addressed important economic, environmental, and societal questions: “What must be done for cars to also enable maximum mobility in the future? How can we increase safety despite an increasing number of vehicles to reduce the number of accidents? How can we boost efficiency?” (Daimler, 2016). The project received the equivalent of €749m from members of EUREKA, which is the intergovernmental network for research and development (EUREKA, 2020). Results of the project led to the creation of well-known features, DISTRONIC PLUS, an adaptive cruise control system, and PRE-SAFE, a collision warning system. While these specific features are built into Mercedes-Benz cars, other automakers offer similar advanced driver assistant systems (ADAS), which are the foundation of automated vehicles, such as BMW’s Active Cruise Control. While PROMETHEUS has been a great success and is considered to have been “well ahead of its time” by Werner Breitschwerdt (Daimler, 2016), ex-CEO of Daimler-Benz AG, it was conducted 30 years ago, underlining the long development process and complexity of autonomous driving.

1994

VaMP and VITA 2 were twin vehicles created during the EUREKA Prometheus Project and were two of the first autonomous vehicles worldwide. Both vehicles drove a distance of over 1000 km at a speed of 130 km/h. With minimal human intervention, the vehicles were able to detect their surroundings, including other vehicles, able to change lanes, and overtake other cars, thereby proving their autonomous capabilities. (Dickmanns, 1997)

1995

The vehicle VaMP was able to drive 1758 km at a maximum speed of 180 km/h (Dickmanns, 1997).

1996

Chauffeur aimed at safely increasing the use of existing roads by developing and testing an ‘electronic tow bar’ system. The requirements of such a system were assessed and the system itself was created and integrated into lorries, tested and evaluated. (CORDIS, 1996) The related cost-benefit analysis of the Chauffeur-System revealed optimisation possibilities of routes and load factor. Additionally, a reduction in fuel consumption could be achieved (Baum H. , Geißler, Schulz, & Schulze, 1999). This system was the predecessor of today’s lorry pooling system.

2001

CarTalk2000 focused on inter-vehicle communication. This included the consideration of a cost-benefit analysis and legal aspects, as part of a proposed market introduction strategy (Schulz, Reichardt, Miglietta, Moretti, & Morsink, 2002). Further, the project focused on developing a cooperative driver-assistance system based on inter-vehicle communication and the corresponding software and algorithms. This was done by following a six-step undertaking, including analysing the requirements, development, integration, and validation of the application and standardisation planning. The project was coordinated by the Daimler Chrysler AG and involved members such as Robert Bosch, Siemens Mobile Communications, and Cologne University (Prof. Dr. habil. Wolfgang H. Schulz). The project ran from August 2001 to July 2004 and was funded within the IST Cluster of the 5th Framework Program of the European Commission (Cordis, 2005).

2003

Tesla Motors was founded by Martin Eberhard and Marc Tarpenning. Tesla is an electric vehicle and battery company aiming to make the automotive industry greener and self-driving. *See more in 1.2.1.1 Tesla – Challenger of a long-established market.*

2008

07/2008

Pre-Drive C2X aimed at prototyping a European C2X communication system. While it was led by the Mercedes-Benz Group, partners from across Europe included, but are not limited to, the Fraunhofer Institute, Volkswagen, and the European Center for Information and Communication Technologies (Germany), but also Hitachi Europe SAS (France), University of Surrey (UK), TNO (Netherlands), and Volvo Technology (Sweden). Prof. Dr. habil Wolfgang. H. Schulz also participated in the project with the IERC. Pre-Drive C2X ran from July 2008 to June 2021, with almost 60% of the costs covered through EU contributions. The project resulted in developing, testing, and verifying a proposed vehicle-to-infrastructure communication system. In addition, the project contributed to the formulation of standards surrounding ITS and vehicular communication (Cordis, 2017). Lastly, the Pre-Drive C2X Deliverable underlined that the "implementation of C2X communication technology in Europe might be viable from a socio-economic and a business economic point of view" (Rappold, Claes, Schulz, & Schulz, 2010).

09/2008

SimTD was "the world's largest field project of vehicle-to-infrastructure communication and investigated the possible contribution of intelligent communication systems to improving traffic safety and mobility" (EICT, 2020). Conducted in Germany from September 2008 until June 2012, the project was funded by the Federal Ministry of Economic Affairs and Energy (BMWi), Federal Ministry of Transport and Digital Infrastructure (BMVi), Federal Ministry of Education and

Research (BMBF) and the State of Hessen, as well as private sources. A total of 17 partners, ranging from public bodies (e.g., Hessian State Office for Road and Traffic Affairs), industry bodies (e.g., Daimler, BMW, and Bosch), research institutions (e.g., the German Research Center for Artificial Intelligence (DFKI), and universities (e.g., Technical University of Munich) were involved in the project. The project included 400 vehicles that successfully tested a car-to-everything (C2X) technology. In addition, the project showed that C2X communication can positively influence traffic awareness and improved identification of traffic relevant events (simTD Consortium, 2016).

2009

The electric adventure vehicle company Rivian was founded. The manufacturer initially developed adventure SUVs and pick-up trucks. In 2019, the manufacturer received a order for 100,000 delivery vehicles from internet giant Amazon.

2011

The DRIVE C2X Integration Project aimed at testing various cooperative systems. While many communication systems had been created, no large field tests had taken place at that point. In six test areas across Europe, including in Germany, Sweden, and France, the impact, technical functionality, and system robustness were assessed. To create a market introduction strategy, user feedback was collected and a business model was prepared. A total of 35 participating companies and research institutes from across Europe participated in the project. Led by Daimler AG, the members included Fraunhofer (Germany), Renault SAS (France), Centro Ricerche Fiat SCPA (Italy) and Technische Universität Graz (Austria). The project ran from January 2011 until July 2014 and received funding from the 'Specific Programme "Cooperation": Information and communication technologies' (Cordis, 2019).

2016

PEGASUS (Project for the Establishment of General Accepted quality criteria, tools and methods as well as Scenarios and Situation for the release of highly automated driving functions) resulted in a set of standards surrounding autonomous driving. Funded by the Federal Ministry of Economic Affairs and Energy (BMWi), the project focused on crucial aspects, such as safety and reliability standards for the vehicles (PEGASUS, n.d.).

2017

L3Pilot tested conditional-automation (Level 3) vehicles in ten European countries. A total of 1000 drivers used 100 cars to test the vehicles' viability (L3Pilot, n.d.). Partnering OEMs included

Volkswagen AG, Audi AG, BMW AG, Ford, Toyota and many more. Research centres included BASt (The Federal Highway Research Institute), DLR (German Aerospace Center), and TNO (Netherlands Organisation of Applied Scientific Research), as well as suppliers, SMEs, insurers, authorities, and user groups. Funding for the project was provided by the European Union's Horizon 2020 programme (L3Pilot, n.d.).

2018

05/2018

On 25th May 2018, the new General Data Protection Regulation (GDPR) came into effect (European Commission, n.d.). It "applies to data controllers and data processors established inside and outside the EU, whose processing activities relate to the offer of goods and services to the individuals in the EU" (BearingPoint Insitute, 2017). While the regulation provides greater protection from gathering data about individuals and sharing them with third parties, it also created a large roadblock for artificial intelligence and autonomous driving. Citizens within the EU now have to consent to their data being gathered and shared. The execution of AI software and machinery requires collecting and using data. Thus, the new regulation makes it more difficult to obtain all relevant information needed for AI application. Solutions must be found to enable the use while being GDPR compliant. For example, facial expressions play a crucial part in human roadside behaviour assessment. Through the new law, vehicle cameras may no longer gather this information for behaviour predictions. Brighter AI (https://brighter.ai), a start-up company focusing on facial expression and number plate anonymization, has found a possible solution. But the problem persists for those not including the software in their vehicles.

09/2018

The project 'AI Platform for storage and processing of training and test data (AIP concept) (KI-Plattformkonzept zur Ablage und Verarbeitung von Lern- und Testdaten (KIP-Konzept)' focused on creating a concept for an AI platform for the automotive industry (Bundesministerium für Bildung und Forschung, n.d.). The project, conducted from September 2018 until April 2019, was funded by the Research and Federal Ministry of Economic Affairs and Energy (BMWi – Bundesministerium für Wirtschaft und Energie). While this project focused on the concept, the actual creation of the platform will be conducted in the second project 'AI Platform for pre-competitive research and development of autonomous driving functions (AI Platform) (KI-Plattform zur vorwettbewerblichen Forschung und Entwicklung autonomer Fahrfunktionen (KI-Plattform)'. Less than six months passed between the project application process and the start of the project. The short turnaround time highlighted the urgency of the topic to ensure the German automotive industry is leading the way for cooperation by creating an enabling system to bring the industry together.

The platform will be the marketplace for buying and selling data related to autonomous vehicle development in the long run. The aim is to accelerate and expand the development of autonomous mobility by enabling researchers and companies to exchange and train data. Led by Volkswagen, the project included various suppliers, research centres, and universities. The project's five sub-groups focused on the legal framework, data and process security, technical aspects of the platform, including AI toolchains, data-related topics, such as data acquisition, and the operating model and introduction strategy. The Center for Mobility Studies (CfM) of Zeppelin University considered its economic aspects and applied Prof. Dr. habil. Wolfgang H. Schulz's institutional role model (IRM) approach to the platform scenario (Zeppelin Universität, n.d.). Through the IRM development and application, AIP's business structure considered all business and technology-related topics, as well as acquisition and maintenance topics. Overall, lawyers, engineers, computer scientists, and economists came together to create a holistic approach to digitalising the automotive industry further.

2021

07/2021

UN-R157, a standard setting regulatory body of the United Nations specialized in Level 3 automation in vehicles, approved Mercedes' Level 3 automated driving capabilities. It is the first automaker to meet the requirements and to officially receive L3 driving rights in the world.

1.2.1 Electric Vehicle Development

While the search for an alternative mechanical power for vehicles was already underway, the Volkswagen Emission Scandal (Dieselgate) shed further negative light on the conventional internal combustion engines in the automotive market. It underlined the need for an alternative mechanical power. Through the introduction of mass-market produced electric vehicles, governments' campaigns to reduce the number of cars in city centres (Freie und Hansestadt Hamburg, 2015), and strong efforts to increase the number of public transport users, the combustion-engine automotive industry is facing challenges.

In 2020, a record number of 194,000 electric vehicles were sold in Germany (Kords, 2021). This is almost a 50% increase compared to 2019, when a total of 136,617 new electric vehicles were registered (Kraftfahrt-Bundesamt, 2020). In 2019, almost 4.8 million electric vehicles were already in use worldwide (Wagner, 2020). Despite Volkswagen having a more than 30-year experience with electric cars, after having released the first electric vehicle model in 1989 with a total of 94 produced Golf CitySTROMers (Volkswagen AG, n.d.), foreign manufacturers have been able to establish themselves at the forefront of the electric vehicle market. In 2019, the American company Tesla sold over 300,000 Model 3 vehicles, and Chinese BAIC sold over 111,000 BAIC EU Series vehicles (Wagner, 2020) worldwide. In the European market, Tesla was the leading electric vehicle manufacturer with 95,247 cars sold. However, in second and third place were the French brand Renault with the Zoe model and Germany's Volkswagen e-Golf (Ahlswede, 2020). While the European manufacturers' market position may be secure for now, Germany's automotive industry has a long way to go if it wants to establish itself at the forefront of the global electric vehicle market.

Car manufacturers' future mobility expectations do not align. BMW focuses its electric vehicle development on creating a lightweight car for everyday city driving (BMW, n.d.), whereas Tesla focuses on long-range and automation (Tesla , n.d.). However, regardless of their intended use, electric vehicles still take some time to be perceived more useful than internal combustion engines, with possible driving distances being a fraction of diesel or petrol-fuelled cars. A BMW i3 can reach a distance of up to 260 km (BMW, n.d.) with a single full battery charge. This distance would only be under ideal weather conditions (neither too hot nor too cold) and with the minimal use of additional features such as air conditioning (Office of Energy Efficiency & Renewable Energy , n.d.). However, as time passes and electric vehicle distances expand, electric vehicles may gain a higher acceptance rate. Horváth & Partners predict a 10% increase in electric vehicle distance, with a potential reach of 491 km in 2022 (Horváth & Partners, 2019). Furthermore, electric and autonomous vehicle development is moving in the right direction because the number of electric vehicle charging stations having more than doubled in two years. There was an increase from 8.805 stations in Q2 2018 to 19,417 stations in Q2 of 2020 in Germany (Statista, 2020), further showing that the nation is preparing for a shift of fuel source.

Yet why is the consideration of electric vehicles important for autonomous vehicles? The interest and adoption of electric cars is increasing, and their actual use is more environmentally friendly than combustion engine vehicles (Federal Environment Ministry (BMU), 2019). Governments are also providing financial incentives to buyers of electric cars (European Automobile Manufacturer Association, 2020), reflecting on the importance for governments to bring this type of vehicle on the road. All current fully automated vehicle prototypes are electric vehicles. These developments hint at electric batteries being the fuel source of the future and thus the physical foundation of self-driving vehicles.

1.2.2.1 Tesla – Challenger of a long-established market

Tesla is one of the most interesting success stories of the automotive industry of this decade. The American manufacturer has been in the market for less than 20 years. Tesla Motors, as it was originally called, was founded in 2003, and Elon Musk became chairman of the board of directors in 2004. Tesla aims to create an electric vehicle that is affordable to the mass market. In 2008, Tesla produced its first vehicle, the Roadster. Twelve years later, the company has become one of the leading electric vehicle producers (JATO Dynamics, 2020).

On 10th March 2020, Elon Musk announced that Tesla had produced its one-millionth car (Musk, 2020). While the milestone may be less than what century-old vehicle manufacturers build in a year, Tesla's success signals a changing automotive industry. The manufacturer displays vital risk-taking initiatives, mimicking the American technology industry behaviour. Tesla saw the opportunity to enter the market for a highly-anticipated-but-challenging-to-execute product and over the years has managed to increase its market share steadily.

Tesla also raises the question of how dependent companies are on the state. The company was not satisfied with the local charging network, so the company introduced its own charging stations for Tesla vehicles, the Supercharger. While the government must approve of the installation, the charging stations are part of the manufacturer's energy supply network. Tesla drivers have exclusive access to them, instead of being dependent on countries and cities to set up stations accessible to every electric vehicle driver (Tesla, n.d.). By minimising the influence of roadblocks to future mobility developments and adoptions themselves, Tesla is showing that they are a risk-taking company on which the German industry should orient itself. Tesla's rise in the automotive industry sets an example for the German automotive sector for how to challenge an established market by introducing a product that meets consumer demands and expected future market developments.

1.2.2 Industry Cooperation

Over the decades, various projects addressed many issues related to the development of self-driving cars. Chauffeur focused on bringing the lorry industry forwards. Prometheus provided the automotive industry with many vital ADAS features also integrated in today's vehicles.

CarTalk2000, Pre-DriveC2X and DriveC2X highlighted the importance of inter-vehicle communication. While CarTalk2000 proved the benefits, Pre-DriveC2X showed the viability and DriveC2X the physical possibility of such systems. PEGASUS led the way for self-driving vehicle standards. Through the AIP project, the intention was to advance the competitiveness of the German automotive industry. Tesla is showing the existing market how to succeed by being proactive instead of waiting for governments to improve infrastructures. One could also argue that the order numbers for Rivian vehicles is a reflection of the changing automotive industry and the lack of trust of customers in the traditional automotive industry's efforts to keep up with the changing vehicle market.

The various funding ministries and the large number of partners in each development project show the extensiveness and complexity of the topic at hand. Most projects include lawyers, engineers, economists, and computer scientists who create holistic approaches to the projects' focus areas. These large-scale approaches reflect on the interest and need to adapt to the fast-moving automotive and technology world and the desire to bring the automotive industry forward and prepare for the imminent change brought by creating and introducing self-driving cars.

1.3 Artificial Intelligence

Artificial intelligence (AI) is defined as "the ability of a digital computer or computer-controlled robot [...] to solve problems that are normally associated with the higher intellectual processing capabilities of humans" (Encyclopaedia Britannica, 2020). AI can be applied in the form of software or as a machine. It can help companies improve their products and business flow and help set them apart. However, the integration and execution is complex and a lot of uncertainty remains around the new technology.

1.3.1 What is AI?

AI can be split into three groups: artificial narrow intelligence (ANI), artificial general intelligence (AGI), and artificial super intelligence (ASI). ANI is the simplest form of AI and can only conduct one task at a time. Siri (Apple) and Alexa (Amazon) are forms of ANI. They are virtual assistants created to make our daily lives more comfortable using speech recognition and natural language processing. To date, it is the only form of AI commercially available. The next level of AI is AGI. Once fully developed, it will perform tasks like humans, including analysing and interpreting emotions and conducting deductive reasoning. However, many experts believe we are still decades away from achieving AGI (Müller & Bostrom, 2016). The final stage of AI is ASI. ASI is "an intellect that is much smarter than the best human brain in practically every field, including scientific creativity, general wisdom and social skills" (Bostrom, 2006). ASI is a level of skill that exceeds human comprehension and speed and has the highest chance of spiralling out of control. This level is the expectation of a layman regarding AI; however, it is even further away from becoming a reality than AGI.

Sylvain Duranton, Managing Director and Senior Partner at Boston Consulting Group, says that AI is "10% Algorithm + 20% Technology + 70% People & Processes" (TED BCG Mumbai, 2020). This thought is an important aspect to consider, since many fear that AI will take away our jobs. First, AI will most likely take away high routine, low creative tasks (Chui, Manyika, & Miremadi, 2016). Second, while a replacement of human workforce with machine workforce may be the case after AGI has been successfully developed and integrated into companies, in the beginning, humans are essential for the creation of AI. The development requires skilled workers to write algorithms and experts to create elaborate plans about how AI can be integrated within companies (Lipson & Kurman, 2016). Therefore, AI will not make humans redundant and instead not only companies, but also employees should strive to integrate AI and take advantage of it as soon as possible.

1.3.2 AI Requirements

No matter the level of AI, they all require the same components: data, algorithms and GPUs. Algorithms are written by programmers and can be seen as the rules of what AI can and cannot do. The greater the complexity of the desired outcome of an AI application, the higher the number of algorithms and the more time required to code them. Furthermore, the more complex the AI software a company is running on its servers, the more important GPUs are for handling the large volume of algorithms running simultaneously (Seif, 2019). Lastly, contrary to regular supply and demand theories, the bigger a data set, the greater its value (Rea & Sutton, 2019). More data (i.e., examples of what you do and do not want to achieve with your AI system) will allow a more specific end result. Artificial intelligence is not only changing the way we work but fundamentally challenging long-standing economic theories and perspectives.

Large investments are required to acquire computer systems fast enough to run several algorithms simultaneously. The maintenance of cooling systems for the servers and the hiring of computer scientists and AI experts also add to the sum needed for AI adoption (Bergstein, 2019). A possible solution to soften the financial impact could be a joint European AI server. The computer server would be initiated and funded by multiple nations, allowing each other access, and ultimately enabling governments and companies to integrate AI. In total, Europe has 747 million inhabitants.

A more significant potential data pool could be accessed if countries act together instead of focusing on single market solutions. Therefore, it is essential that Europe pools its AI activities, focusing on the whole population rather than just individual countries. This would enable Europe to continue to compete with the USA, China, and other AI-expanding nations.

More information on the basics of AI can be found in the paper 'Are USA's and China's artificial intelligence activities outsmarting Europe?'

1.3.3 Application Types

AI integration possibilities within the automotive industry are vast. Meticulous Research predicts that the automotive artificial intelligence market will reach $15.9bn by 2027. According to them, application areas of AI within the automotive industry can be split into four parts: component (hardware and software), technology (e.g., machine learning), process (e.g., image recognition), and application (e.g., partially automated vehicles) (Meticulous Market Research, 2020).

AI applications can be split between integration inside the car and the use of AI for production and process optimisation outside of the car. An example of the production side would be BMW's Munich factory streamlining its quality control of vehicle components by using the 'iQ Press' for recording vehicle component parameters (BMW Group, 2020). Through this, BMW can reduce mistakes, resulting in higher consistency and improving its quality control. Looking at the information handling side of AI, supplier risks can be minimised by using AI for data collection and evaluation (Kinzler, Schulz, Schulz, & Edye, 2020). Also, employees can be supported during the production process: Hyundai's assembly line workers use wearable robots to support their tasks, such as Hyundai's Exoskeleton Vest (Hyundai, 2019), making it easier for them to build the physical vehicle. Lastly, General Motors uses AI-based generative design technology to redesign vehicle components; as a result, their seatbelts have become 40% lighter and 20% stronger (General Motors, 2018).

The integration possibilities of AI within the automotive industry are vast. By integrating AI, manufacturers can reduce production costs, support their workers, optimise their processes, and create new businesses. Vehicle occupants can also become better protected within the cars, receive better product offerings with more personalisation options, and may even be able to buy vehicles at lower prices than without AI driving down production costs. Looking into the vehicle, AI will be the critical component making the vehicle drive. Through sensors, cameras and / or LiDAR systems, the vehicle collects important information. Using AI, this data is assessed and a driving decision is made. *See more under 1.4.1 Levels of Vehicle Automation.*

The automotive industry is only in its early days of AI integration, as shown by the paper

'The Knock-On Effect of Introducing AI as a Supply Risk Optimiser - How Implementing AI Can Assist Companies to Endure a Crisis'.

Despite the clear application benefits of AI, companies are avoiding sharing information about whether AI is used. Through this, companies are creating the illusion that AI is not important or beneficial enough to be considered for integration within their business, underlining that companies are trying to keep any strategic advantage a secret for as long as possible. At the same time, those that do not use AI are concerned about letting their competitors know their lack of consideration of AI. As long as the industry does not consider the complex technology investment on a public stage, late adopters may not see the need to do so, allowing early adopters to create a more significant strategic gap.

1.3.4 Governmental Approaches

Bal and Gill compared China, the United States, and the European Union's approaches to AI. They argue that China has the "most aggressive approach" by exploiting the abundance of domestic data they can gather. Further, they aim at developing AI talent through central education scheme, as well as mass money injections by the government into the development of AI. The USA's aim is to strengthen links between business and AI–related research, while Europe is "driven by building citizen trust by safeguarding privacy" (Bal & Gill, 2020). However, there are major challenges to each approach. China is focusing on three company giants, Baidu, Tencent, and Alibaba, instead of focusing on the industry as a whole. The USA gets the majority of its tech talent from foreign nations. Depending on the immigration policy, the United States may struggle to get necessary talent from abroad. Lastly, Europe's disproportionate spread of AI resources across member states is highlighted. They summarise that the three approaches reflect each states' or economic unions' strength: state control by China, focus on business practices by the Americans, and concentration on citizens' voices by the Europeans. Schneider compared the Chinese, US, and EU approaches towards the democratic governance of digital platforms and AI. She views the different approaches in a similar manner as Bal and Gill, seeing the Chinese model as authoritarian, the USA as libertarian, and the European as regulatory. (Schneider, 2020)

The biggest factor standing in the way of European technology success seems to be the lack of necessary employees. The lack of "indigenous technology companies" (West, 2016) means Europe has to 'buy' its talent, as well as heavily invest in technology education to encourage more home-grown technology talent. The lack of European technology talent was also highlighted by Anderson, Viry, and Wolff. They argue that Europe is not able to meet technology salaries offered by its competing nations. Further, as long as AI is a luxury investment not many firms can afford, Europe will not achieve its goals (Anderson, Viry, & Wolff, 2020). A study by Bitkom revealed that it takes on average six months to fill a technology-related position. As the integration of technology, in particular AI, spreads across all industries, the need for technology talent increases (Bitkom, 2019). Bitkom's president Achim Berg argued that "every unfilled IT position costs revenue, damages the innovation capability of a company and slows down the necessary digital transformation. The lack of IT Experts is risking the competitiveness of our entire economy" (Pauly & Scheufele, 2019).

1.3.5 Further Related Studies

Already in 2007, Gusikhin et al. argued that AI is a "more effective alternative to conventional engineering methods" (Gusikhin , Rychtyckyj, & Filev, 2007). Further, Gusikhin states that it is a misconception that the automotive industry does not use AI and that society is actually brought closer to AI because of vehicles. Additionally, Hoffman et al. argue that AI can make the industry more efficient. Because of the vast integration opportunities, such as in production processes and marketing, the automotive industry is only set to benefit from AI. However, while the industry has already integrated AI, they also state that the industry is just at a starting point, suggesting the full potential of AI has not yet been recognised and integrated (Hofmann, Neukart, & Bäck, 2017). While many fear that they will be replaced by AI, Tubaro and Casilli argue that the human factor is crucial in AI development. Micro-work, a process of labelling data so that AI can recognise information (such as which object is a car or a bicycle), is particularly important in the automotive industry. These labelling tasks help AI to learn and would not be possible without human input (Tubaro & Casilli , 2019). Thus, the automotive industry, for now, needs humans to develop further. Lastly, Hatani argues that in order to drive AI development, development must occur across industries. Advancing AI only in the automotive industry will not enable its full potential and the support of the government will be essential to foster change (Hatani, 2020). Here, the link between industry and government is shown and once again reveals the complexity and the several stakeholders relevant for AI development.

1.4 Cooperative, Automated Vehicles

Self-driving vehicles are a complex transport mode. The automotive industry and technology industry are creating and producing the cars. Governments are responsible for the legislative framework and establishing the needed infrastructure, whether 5G network deployment for vehicle communication or physical aspects, such as signal-sending traffic lights. AI is at the foundation of digital aspects of self-driving cars. Society should also not be forgotten as they must accept the new technology for it to be fully integrated on our streets. Overall, a fully automated vehicle is "a computer network on wheels" (Knight, 2020), involving many stakeholders in its development, implementation, and long-term use.

1.4.1 Levels of Vehicle Automation

Self-driving cars, fully automated vehicles, or autonomous vehicles are all names given to a car using sensors, algorithms, and processors. The three key sensors are camera, radar, and LiDAR. They act as the vehicle's eyes allowing the assessment of the vehicle's surrounding environment, whether other vehicles, humans, or stationary objects (Varuna De Silva, 2018). GPS data are also essential for the car to know its location. Instead of humans actively handling the vehicles, the software is responsible for manoeuvring the hardware. According to Frost and Sullivan, an autonomous vehicle is predicted to have 300 million lines of code, three times as much code as current connected vehicles (Knight, 2020). While the concept of a self-driving car sounds simple, the technical execution ensuring 99.99% correct road behaviour is complex. Overall, a fully automated vehicle must assess its environment, make split-second driving decisions, and move simultaneously.

The SAE International (Society of Automotive Engineers) issued a guideline for automated vehicles to create a standardised and clear definition (SEA International, 2018). This guideline consists of key aspects that together will lead to fully automated driving:

- operational aspects, e.g., braking or accelerating;
- tactical aspects, e.g., changing lanes or signalling;
- monitoring the environment, e.g., the number of surrounding cars;
- control during complex situations; and,
- driving mode specificity, e.g., motorway driving or inner-city driving.

SAE divided automated driving into six levels from No Automation to Full Automation (see Table 1). Fully automated vehicles will take over operational and tactical tasks and monitor traffic circumstances. They will be able to drive in all driving environments from empty city streets over country roads to busy motorways.

Table 1 Levels of Automated Driving

Level	Description		
	Car Activity	Human Activity	Driving Mode
No automation	*None*	– Steering – Acceleration / Deceleration – Monitoring of Environment – Intervention	All
1 – Driver Assistance	– Acceleration / Deceleration or Steering	– Steering or Acceleration / Deceleration – Monitoring of Environment – Intervention	Specific
2 – Partial Automation	– Acceleration / Deceleration – Steering	– Monitoring of Environment – Intervention	Specific
3 – Conditional Automation	– Acceleration / Deceleration – Steering – Monitoring of Environment	– Intervention	Specific
4 – High-Level Automation	– Acceleration / Deceleration – Steering – Monitoring of Environment – Intervention	*None*	Specific
5 – Full Automation	– Acceleration / Deceleration – Steering – Monitoring of Environment – Intervention	*None*	All

Source: Own Table based on (SEA International, 2018)

Currently, the most advanced level integrated into vehicles is Partial Automation, Level 2, such as GM's Super Cruise (National Highway Traffic Safety Administration, n.d.). These vehicles can use multiple ADAS features simultaneously during specific driving situations. However, the majority of driving tasks still have to be done by the human driver. Mercedes-Benz's DRIVE PILOT is advertised to have Level 3 capabilities (Daimler, 2019), but it is not yet built into vehicles. *Update 20222: Mercedes-Benz was granted official confirmation to have met the necessary requirements for Level 3 automated driving.*

In addition, the AI system driving vehicles must not only be taught about everyday driving scenarios. Edge cases, which are rarely occurring scenarios, but which may have a large impact, are also critical to ensuring safe and traffic-beneficial driving of fully automated vehicles. While daily driving may be routine actions, a car must handle infrequent scenarios just as well. Programmers must think of many possible occurrences, whether between cars, cars and pedestrians or bike riders, or environmental issues that may stand in the way of a vehicle experiencing a smooth ride. The handling of these edge cases will make the difference between semi-automated and fully automated vehicles (Brooks, 2017).

1.4.2 Competition Beyond the Established Automotive Industry

Competitors are changing the standards of new vehicles, ultimately leading to higher expectations of future buyers. Over the past decades, the production cycles of vehicles have already drastically shortened, and new acceleration measures are being created continuously (Schulz & Müller, 2016). While in 1991 the American automakers' production cycle was on average 60 months (Clark & Fujimoto, 1991), the product development cycle was recently reduced to 25 months (Lipson & Kurman, 2016). Various factors can cause shorter production cycles:

1. With each technological advancement, whether vehicle-related or not, the automotive industry's ability to develop new features has improved. Thus, shortened development times are partially a natural result of enhanced technology capabilities.
2. Through continuous product updates of new technological devices, the consumer's expectation to release new products has increased and patience to wait for new products has decreased (Lee, 2020). To satisfy their customers, automakers are now releasing new models more frequently.
3. The fear of competitors being faster at developing and integrating new technologies in their vehicles makes automakers work more rigorously on new developments.

As a result, an action-oriented premise 'to adapt and implement strategic goals within a shorter timeframe' is essential for the German automotive market to remain competitive and keep up with competitors and the potential buyers' changing demand.

1.4.3.1 Competing industries

With the introduction of software/AI-controlled vehicles, the physical process of driving is changing. Future cars will not slow down or stop because a foot is placed on the break but instead because of the recognition of a software command (Lipson & Kurman, 2016). Most vehicle components thus need to be redesigned to adapt to the software driver. With the changing task of vehicle components, shifting from hardware to software-based reactions, new application opportunities for AI are arising. This shift is opening up new opportunities for new world leaders in the field of automated driving. The automotive industry and the technology industry are now going head to head in the race for autonomous vehicle leadership.

Google saw the opportunity of technology creation for vehicles in 2009. Waymo, now a subsidiary of Alphabet, has been focusing on autonomous vehicles ever since. The company originated from a project started by Google, which previously offered purely intangible products. Companies such as this one are putting a lot of pressure on the automotive industry to continue to be innovative, technologically advanced, and forward-thinking.

Another wake-up call for the automotive industry should have been the sale of 100,000 electrical delivery vans by manufacturer Rivian to Amazon (Hawkins, 2019). Instead of placing orders with an established automotive manufacturer, such as Ford or BMW, Amazon decided to invest in a new player in the industry. With Amazon's orientation towards success and innovation, the order suggests that Amazon trusts a relatively new company with low sales figures more than the established century-old manufacturers. While Rivian is an electric vehicle manufacturer and not a technology company per se, it signals a shake-up of the industry.

Lipson and Kurman argue that the biggest strength of the automotive industry is the safety aspect of the vehicles (Lipson & Kurman, 2016). With thorough processes and standards in place, the established players know how to keep a car safe and which components to consider during safety tests. The technology industry, on the other hand, due to its often intangible nature, does not have specific safety-ensuring processes in place and must acquire the knowledge to meet automotive safety standards.

The technology industry's success revolves around taking risks. John Seely-Brown described Silicon Valley, the capital of technology innovation, with the words "here taking risks around radical innovations is respected and encouraged" (Seely-Brown, 2000). While not all innovations succeed, the attitude towards finding the next significant disruption is vital for the industry's success. As previously mentioned, to prepare autonomous vehicles successfully for mass-market use, many aspects still must be considered. Based on its risk-taking activities, the technology industry may have an advantage over the automotive industry. The risk-averse behaviour of European automotive companies may prevent them from taking control of the future of autonomous vehicles. AI will require considerable financial and time investments to establish itself within companies and industries. Still, to create fully automated vehicles, this risk must be taken to gain control. Additionally, while any business's competitive nature may make companies hesitant about working with each other, automotive companies need to work together to create one autonomous driving system to prevent the technology industry from taking control of the industry.

One could argue that trying to develop a successful autonomous vehicle and its required infrastructure as quickly as possible is standing in the way of the competitiveness of automobile makers. Car manufacturers are racing to be the first to develop a road-ready (and mass-market) fully automated vehicle. However, to establish certain essential aspects, such as vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-everything (V2X) communication strategies, they must act together, rather than in their own interest.

In summary, the approach of the technology industry may allow it to take the lead in fully automated vehicles. Their risk-taking behaviour is more pronounced, helping them to develop the technology. By contrast, the automotive industry is relatively risk averse. This may allow them to minimise failures. However, learning and progressing in an accelerated way will be difficult and consequently may keep them from successfully competing with the technology industry.

1.4.3.2 Competing nations: China / USA / Europe

China, the USA, and Europe are competing with each other in the race towards autonomous vehicles. Each has some clear advantages, but also disadvantages. In 2016, Darrell West published a comparison between self-driving vehicles nations. In the paper titled 'Going forward: Self-driving vehicles in China Europe, Japan, Korea, and the United States', he argues that China is able to catch up with its international automotive competitors because self-driving vehicles are about AI, a field in which the Chinese are particularly successful, and no longer about the gearbox and engine. However, as a challenge, he sees the Chinese infrastructure. In order to test autonomous vehicles, the software needs clearly marked roads and well lit streets in order to 'see' properly. With China's road infrastructure ranked 46th in the world (compared to Germany at 7th place or Japan in 6th place), China needs to improve its road conditions to properly execute vehicle testing.

Europe is faced with the opposite challenge. With self-driving vehicles focusing on software rather than hardware design, Europe needs to improve its AI expertise. Additionally, West predicted that the (at the time the proposed) GDPR would make testing in Europe more difficult and stand in the way of self-driving advancements. Lastly, West believes that the 50 fragmented member states of the United States need "uniform guidelines across geographic boundaries" in order to enable a truly successful introduction of self-driving vehicles (West, 2016).

Jianxiong Xiao, also known as Professor X, founded the Chinese self-driving vehicle company AutoX in 2016. Their Level 5 capable vehicles are deployed in four major Chinese cities as well as Silicon Valley. On 9th February 2022, the company announced that their fleet surpassed 1000 vehicles on Chinese roads. AutoX describes this as a "significant leap forward for larger scale commercialization" (AutoX, 2022). AutoX's mission is to 'democratise autonomy' and make mobility easily accessible. They launched the first robo-delivery service in California in 2018, making it the first Chinese self-driving car developer to receive permission by the California DMV to test their vehicles publicly (AutoX, 2022). In order to make self-driving vehicles available to as many users as possible, the vehicles need to be as affordable as possible. Instead of using expensive high-end cameras, AutoX opted to using seven US$50 Logitech cameras on each of its vehicles (Metz, 2017). This simple hardware approach makes AutoX stand out from its competitors worldwide. Another crucial step in the development of self-driving cars was the approval of the Chinese government allowing the testing of autonomous vehicles without safety drivers. In 2020, AutoX allowed the general public to use its fleet completely driverless. In comparison, the United States and Germany still to date require the use of safety drivers in case of an emergency. With its cheaper hardware costs, the legal framework in which it operates, and the testing of Level 4 autonomous vehicles on Chinese roads, AutoX is at the forefront of self-driving vehicle development. However, it is unclear if AutoX is able to establish itself in the European market, due to the market's complex legal system and with GDPR hindering the free collection of data. Thus, while AutoX is leading the Chinese autonomous car market, and establishing itself in the American market, the company still has a long way to go until it will be able to navigate European roads.

Waymo is one of the key companies creating and testing self-driving vehicle capabilities on American roads. While Waymo provides the self-driving technology, the vehicles they use vary from Toyota Priuses and Lexus SUVs to Jaguar I-PACE and the Chrysler Pacifica Hybrid (Waymo, 2022). In October 2020, in Phoenix, Arizona, Waymo opened up its Waymo One driverless ride hailing service to the public (Waymo, 2022). The vehicles, just like AutoX, operate at Level 4. Waymo vehicles have now driven over 20 million miles on public roads, as well as 20 billion miles in simulation (Waymo, 2022). Through this, they were able to gather an unmatched amount of data, which benefits their self-driving capabilities further. However, while Waymo engineers were able to lower LiDAR costs from US$75,000 to US$7,500 (Moreno, 2021), they are still significantly higher than that of AutoX.

There is one more key player in the field of autonomous driving that should be mentioned. As highlighted in the history section, Mercedes-Benz's Level 3 driving capabilities received confirmation by UN-R157 for achieving all necessary requirements for Level 3 automation. If national laws allow this, Mercedes is able to roll out this feature in the respective markets (Mercedes Benz Group, 2021). It is the most advanced level of automation readily available in mass-produced vehicles. However, while Mercedes is able to take a leading position, the German government only approved the testing of Level 4 automated vehicles in summer of 2021 (Federal Ministry for Digital and Transport, 2021). If we compare this development with China and the USA we can clearly see that Germany is behind its competitors when it comes to self-driving automation beyond Level 3, at least when it comes to the necessary framework/infrastructure.

One could argue that in order for Germany and Europe to remain competitive, a proactive legal framework would be necessary to support advances. Additionally, it would encourage risk taking towards new technological developments. Instead, the German legal system is holding back the industry by lagging legally behind already existing developments. However, the potential for the German and European automotive industries to advance further clearly exists. One of the challenges but also advantages of European automotive manufacturers is the complex European driving system. Across the 27 member states 27 different driving regulations exist. If a self-driving vehicle is able to incorporate all regulations and can smoothly switch between the driving rules, it will be a complex system able to handle the many challenges of driving worldwide. This could increase the attractiveness of a European built autonomous driving system. Mercedes-Benz's exposure in the new mobility world is a crucial step towards manifesting Europe's competitiveness in the field of autonomous vehicles.

1.4.3 Economic Effects

AI has the chance of improving, accelerating, and creating new businesses. Companies can integrate AI in process optimisation, e.g., AI for information gathering to help predict supply chain risks (Kinzler, Schulz, Schulz, & Edye, 2020) and actual machinery, e.g., delivery machine Relay by Savioke, and even autonomous vehicles. Through rapid processing, AI can conduct specific tasks at a faster rate than humans, as well as operating 24/7. PWC predicts a contribution of up to US$15.7tn to the global economy by 2030 as a result of AI integration (Rao & Verweij, 2017). Through AI, labour productivity can be increased, and if coded correctly, error margins will be lower for low-skill and high-routine tasks. Through consistency, the quality of products and services can be improved. AI will allow for tasks to be done more quickly, saving costs and enabling human workers to use their time more efficiently. Lastly, despite standardisation and automation, AI will allow greater personalisation attracting a greater potential customer base (Pearson, 2019).

In Germany alone, the introduction of Level 3 automated vehicles is predicted to generate a €8.3bn annual cost reduction by 2030. Thereafter, once Level 5 automation is introduced, €15bn can be saved annually. This includes driving down accident costs, driver operating costs/wages, and fuel costs, among other aspects (Esser & Kurte, 2018).

Following the definition of a disruptive technology, "a process by which a product or service takes root initially in simple applications at the bottom of a market and then relentlessly moves upmarket, eventually displacing established competitors" (https://claytonchristensen.com/key-concepts/), autonomous vehicles are not disruptive towards standard, manually driven vehicles. They are not a simplified version of the existing product. Moreover "an innovation that is disruptive allows a whole new population of consumers at the bottom of a market access to a product or service that was historically only accessible to consumers with a lot of money or a lot of skill." (https://claytonchristensen.com/key-concepts/). During their introduction, autonomous vehicles will not be more easily accessible, particularly due to their anticipated high purchasing costs (Nunes & Hernandez, 2019). Instead, the way mobility is approached will be disrupted by large knock-on effects resulting from autonomous vehicles. MIT predicts a substantial reduction in the number of cars on urban roads as car-pooling networks grow. Fewer cars would require fewer parking spots and infrastructure maintenance and repair works, as well as less strain being put on streets and the environment (Conner-Simons, 2016). Parking space equalling 5.7 billion square meters could be freed up in the USA alone (Ferràs-Hernández, Tarrats-Pons, & Arimany-Serrat, 2017). The reduction in cars would also mean fewer car purchases, repairs, and refuelling stations (whether petrol or electric), and it would potentially create a lower demand in other business areas dependent on a large vehicle market. The imminent disruption will be a by-product of self-driving vehicles, leading to a systematic and societal shift in the way we use cars.

Self-driving vehicles could result in a strengthening of the logistics sector. The COVID-19 pandemic (further discussed in 1.6 COVID-19, the Catalyst for Technological Development) revealed the vulnerability and dependency on human drivers. To secure a fully functioning supply chain during crisis times, a self-driving lorry could ensure the distribution of food and medical supply across entire nations.

Naturally, self-driving cars create concern among professional drivers, such as taxi or lorry drivers. As previously mentioned, looking at the influence of AI and self-driving cars on workforce, the more routine and less skill is required, the higher the likelihood that this job is replaced by robots, machines, or software. However, considering Gregory, Salomons, and Zierah's findings, the introduction of new technologies will not necessarily cause a decline, but rather a fluctuation of labour. They argue that while initially employees will lose their jobs, through the rapid improvement of technology and reduction in price of this technology, the sale price of a product is reduced. This in turn causes an increase in demand for this product and thus production. Tasks that cannot be taken on by a technology must be taken on by human employees again. New employees will thus be hired to meet demand, causing a fluctuation in workforce (Gregory, Salomons, & Zierahn, 2016). Based on this, we can expect a similar cycle to occur in the automotive industry, at least in the medium term.

1.4.4 Societal Effects

Fully automated vehicles will provide many benefits. While in the USA in 2016, 94% of accidents were due to human error (National Highway Traffic Safety Administration, 2017), in Europe in 2018, this percentage reached 95% (Raposo, Grosso, Després, & Fernan, 2018). If human drivers are taken out of the accident equation, self-driving cars should result in fewer crashes. They will eventually allow unskilled users to take advantage of vehicle usage, by allowing those without a driving license, whether too young or too old, to use self-driving cars freely. Commuters would be able to use their drive to work more effectively and, based on the assumptions that self-driving vehicles will be shared with others through a car-pooling concept and owned by service providers rather than individuals, the number of cars on our roads will decline. Through this, the strain on our roads and overall infrastructure could be reduced. Self-driving vehicles would also create fewer traffic jams, resulting in a more stress-free driving experience (Conner-Simons, 2016). Lastly, autonomous vehicles would result in a more inclusive mobility world, allowing those without a driving license to use this driving mode.

1.4.5 Cost-Benefit Analysis

Cost-benefit analyses (CBA) play an important role in the strategic assessment of any new technology. Schulz and Geis argue that in particular for intelligent transport systems (ITS), we must consider the socio-economic aspects in form of a CBA (Schulz & Geis, 2015). A study by Baum, Geissler, Grawenhoff and Schulz, focusing on the cost-benefit analysis of intelligent vehicle safety systems (IVSS), revealed that the benefits outweigh the costs. As such, accident costs and accident-caused congestion costs could be reduced due to the introduction of IVSS (Baum, Geissler, Grawenhoff, & Schulz, 2006).

While costs and benefits are assessed in numerical terms, to assess the emotional acceptance of vehicles, we may have to consider factors beyond numbers. Based on their study, Howard and Dai argue that the greatest benefit of self-driving cars is the safety benefit, the convenience factor, and the possibility of multi-tasking. However, the greatest perceived cost is the price of the technology and the loss of control (Howard & Dai, 2014). A thorough comparison between benefits and costs/problems was done by the Victoria Transport Policy Institute. The author divided the two segments into internal (direct impact on autonomous vehicle users) and external (impact on other stakeholders) considerations. While internal considerations include benefits such as ‘reduced drivers’ stress and increased productivity’ and ‘mobility for non-drivers’, costs included ‘increased vehicle costs’ and ‘reduced security and privacy’. For the external perspective, benefits included ‘increased safety’ and ‘reduced energy consumption and pollution’, but also ‘increased infrastructure costs’, due to investments needed for road upgrades, as well as ‘reduced employment’ (Litman, 2022).

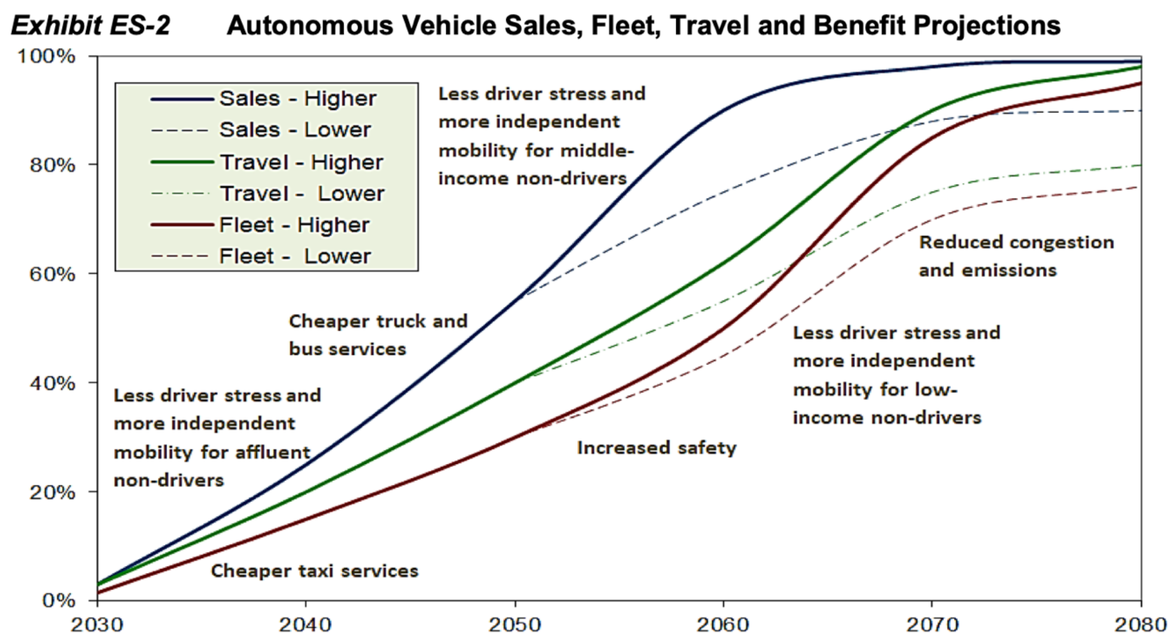

Figure 4 Analysis of Autonomous Vehicles Sales, Fleet, Travel and Benefit Projections(Litman, 2022)

Figure 4 is a projected development of autonomous vehicle integration over the next 60 years. Based on this, autonomous vehicles are not expected to make up more than 50% of road vehicles before 2045. However, Litman argues that in order to speed up deployment, we may proactively have to get rid of vehicles without automation levels in order to maximize the benefits we draw from self-driving vehicles.

1.4.6 Drawbacks

Car manufacturers and suppliers have realised that working together to solve problems is in everyone's interest. Instead of attempting complex situations by themselves, they have decided to combine their expertise to speed up the development process. However, the list of problems to solve is still long. Due to the high number of stakeholders required for the safe and reliable functioning of autonomous vehicles, the deployment of the mode of transport is complex. Additionally, while the development of standards is picking up, and relevant regulation bodies, such as UN-R157, have been formed, many important decisions still must be made. The issues listed below are just a small, yet essential, fraction of difficulties that should be considered.

1.4.6.1 Safety

Chander Dhawan argues that autonomous vehicles will not be 100% reliable. While the car's software must be 99.9% reliable, the hardware itself must fully function. Yet the expansion to more technologically advanced vehicles will also mean more repairs. As the amount of technology within vehicles increases, the more components may break or be faulty (Dhawan, 2019, p. 197). Today, 60%-70% of recalls are due to electronic faults, and more than 90% of vehicle breakdowns result from electrical issues (Knight, 2020). Therefore, this trade-off may have to be accepted when autonomous vehicles are deployed on the roads.

In addition, cyber security is essential to avoid the misuse of vehicles. Preventing the hacking of cars will be a continuous task for every vehicle manufacturer. Through increasing connectivity and the Internet of Things (IoT), more and more data will be stored in the vehicles. Not only personal information needs to be protected, but accidents, whether single-vehicle events or large-scale attacks, must be prevented (Payne, 2018).

1.4.6.2 Vehicle Decision-Making

Vehicles contain hard-coded behaviour rules. They must be able to predict the movement of vehicles and humans near them and must be able to react to unforeseen events. Regardless of the vehicle manufacturer, driverless vehicles must employ split-second decision-making. While start-ups and established companies have taken on the task of researching edge cases, the vehicles' brains must be able to make own driving decisions in unknown situations (Evans et al., 2020).

To avoid repeats of the same driving errors, all vehicles should immediately receive updates containing information on how to handle these situations in the future. Already today, Tesla vehicles' operating systems are constantly updated to ensure they are aware of the latest information and algorithms. Constant updating must be a key feature in all future vehicles to ensure unknown events are kept at a minimum.

1.4.6.3 Interaction Between Automation Levels

In certain situations, communication between drivers also occurs through eye contact or gestures, but the interaction of automated and fully autonomous vehicles is still unclear. Information sharing may also not be possible between fully automated and semi-automated vehicles. What issues this may cause for the functioning of fully automated vehicles are yet to be determined. Using data for traffic information and providing driving routes through such data may not be fully possible if a seemingly empty road is congested with non-information-transmitting vehicles.

1.4.6.4 GDPR

On 25th May 2018, the new General Data Protection Regulation (GDPR) came into effect (European Commission, n.d.). It "applies to data controllers and data processors established inside and outside the EU, whose processing activities relate to the offer of goods and services to the individuals in the EU" (BearingPoint Insitute, 2017). While the regulation provides greater protection from gathering data about individuals and sharing them with third parties, it also created a large roadblock for artificial intelligence and autonomous driving.

Citizens within the EU now must consent to their data being gathered and shared. The execution of AI software and machinery requires collecting and using data. Thus, the new regulation makes it more difficult to obtain all relevant information needed for AI application. Solutions must be found to enable the use while being GDPR compliant. For example, facial expressions play a crucial part in human roadside behaviour assessment. Through the new law, vehicle cameras may no longer gather this information for behaviour predictions. Brighter AI (https://brighter.ai), a start-up company focusing on facial expression and number plate anonymisation, has found a possible solution. However, the problem persists for those not including the software in their vehicles.

1.5 Acceptance

Unfortunately, creating and meeting industry standards, it is not enough to build an infrastructure in which self-driving cars can function fully and to create a legal framework that enables us not only to test these vehicles but also release them to the mass market. Consumers must be willing to drive these cars. Germany not only depends economically on the automotive industry but also emotionally. Through unlimited-speed highways, the German car lover can fully enjoy driving. A major concern for those driving a car is that the 'joy of driving' is being taken away from the driver when self-driving vehicles are introduced (ADAC, 2020). To convince those hesitant of the technology, whether it is an emotionally driven decision or fear towards the vehicles' safety and reliability, actions must be taken now. As experience increases acceptance (American Automobile Association, 2016), pioneers are key for technology adoption. We need to use these pioneers to convince more people of the benefits of autonomous vehicles by demonstrating its safety and convenience to sceptics.

1.5.1 Autonomous Vehicle Acceptance

This kind of hesitation is not new. When the Stockton & Darlington Railway, the first passenger railway line, was opened in 1825, people were scared and believed their bodies would not be able to handle speeds over 20mph (National Portrait Gallery, n.d.). Despite Tesla being at the forefront of vehicle development, their vehicles have caused issues for its industry. Accidents in 2016 (Florida, USA) and 2018 (California and Arizona, USA) have made worldwide headlines. American Automobile Association's (AAA) acceptance studies from 2016 to 2019 show a decline in acceptance of autonomous vehicles (American Automobile Association, 2019). Due to the lack of experience and the influence of negative headlines, such as those related to Tesla accidents, this result is not surprising. Despite ADAS experience having a positive effect on the acceptance of fully automated vehicles, it becomes increasingly difficult to change future end-consumers negative opinion and feelings towards the technology.

Since the first concept of a self-driving vehicle was introduced to the public 80 years ago, the development of the mode of transport has been in the public eye. As a result, potential future consumers have had the chance to form an opinion before even testing the machines. With current acceptance studies suggesting that society does not want these cars on the roads, we must conduct further acceptance research and counteract peoples' fears and concerns. So, what exactly are the worrying factors that concern people? Finding out the reasons behind the (lack of) acceptance of fully automated vehicles is essential to facilitating a smooth adoption of the cars once introduced.

In 2019, the PAVE campaign was launched in the United States. Its goal is to "educate policymakers and the public in the hopes that greater knowledge and understanding will help society fully realise the benefits driverless technology can bring" (PAVE Campaign, 2020). Adopting this kind of project in Europe could be crucial for driving European acceptance forward. Instead of scaring future consumers away with headlines about yet another accident that has happened, we must inform users about the benefits this new mobility device will bring them. Without proper information and facts, individuals are forming their own opinion of these vehicles, and emotions will end up determining the way autonomous vehicles are perceived and welcomed. Instead of focussing on what we have to give up, one could argue that we should consider the benefits it will bring to us and society as a whole.

1.5.2 Vehicle Ownership Developments

Autonomous vehicles will result in a shift from owners of cars to consumers of a self-driving transport service. Already today, Mobility-as-a-Service (MaaS) is on the rise. MaaS "relies on a digital platform that integrates end-to-end trip planning, booking, electronic ticketing, and payment services across all modes of transportation, public or private" (Goodall, Fishman, Bornstein, & Bonthron, 2017). Car sharing companies, such as SHARE NOW (formerly Car2Go and DriveNow), SIXT ride, and Miles have recognised the MaaS trend. These companies allow people with a valid driving license to register and use their vehicles, whenever and wherever available. Some car-sharing companies require a pay per minute system, while others price the ride based on distance driven. With insurance and parking fees included in rental prices, as well as a lack of obligation towards the maintenance of the vehicles, the service is used by many. SHARE NOW had over 3.4 million users in Europe in 2021, with over half a million users registering for the service in 2021 alone. Additionally, long-term car rentals increased by 23% (SHARE NOW, 2022). The commitment-free vehicle use results in future and existing car owners to rethink the need for private car ownership.

Systems such as the car-pooling services provided by MOIA or UberPool not only make users reassess vehicle ownership but allow a more economic approach to driving. MOIA uses electric vehicles, which during use are more environmentally friendly, and they enable users to cut costs compared to private vehicle ownership or the use of taxis. Using AI, the MOIA system will pool consumers going in the same direction. The previously mentioned study conducted by MIT assumes that car-pooling and autonomous driving will shift the way mobility functions, reducing private transport and increasing ride sharing. MOIA's service is only the beginning of the MaaS offerings users will be able to choose from in the future.

Yet, these systems are only in their early stages, and many issues still have to be overcome. During the introduction of MOIA in Hamburg, Germany, the taxi industry tried to intervene as it felt threatened by its new competitor. While MOIA wanted 500 vehicles to start their service, it was only allowed to deploy 200 vehicles on Hamburg's streets during its first few months, resulting in the company not being able to offer its planned city-wide service (Eckl-Dorna, 2019). This created acceptance roadblocks among users, as the service was not as readily available as expected and demanded. In less than two years, however, MOIA recorded 1.8 million rides (MOIA, 2020), showing the rising acceptance of alternative mobility transport options.

Car ownership will gradually shift from private owners to corporations offering MaaS solutions. What will this mean for the automotive industry? While fewer vehicles will be purchased, an increasing number of these vehicles will be acquired by companies rather than individual consumers. The reduced number of produced cars will not only require fewer workers; it will also affect the whole supply chain of the vehicle manufacturers. Companies must find alternatives to create revenue. A shift towards MaaS concepts will be vital for them to remain competitive in the future automotive industry.

1.5.3 Gradual versus Instant Transition

Future potential users ideally need a slow transition from non-automated to fully automated vehicles. This would allow as much time as possible to see the technology in action and accept and adopt the new mode of transport. As previously discussed, experience increases acceptance. Thus, it becomes increasingly vital to get as many potential users of self-driving cars to use the transport mode as soon as it is deployed in the market.

On the other hand, consumers must be careful when using partially automated vehicles. History has shown that drivers overestimate the ability of their own cars. In their 'Self-Driving Car Project Monthly Report' of October 2015, Google revealed a large amount of semi-automated vehicle users distracted themselves during car rides, despite being told explicitly to monitor their surrounding as if they were driving themselves (Google, 2015). Even if only for safety reasons, it would be best to skip partial automation and move directly towards fully automated vehicles. Through this, the responsibility of the human driver to pay attention to the road if a system fails would be reduced. However, directly jumping to full automation will not be possible given the current development rate.

Overall, investigating acceptance rates of self-driving cars is becoming increasingly important the closer we get to the deployment of the technology. We must address potential users' concerns not only to recognise acceptance bottlenecks but also to counteract them. Marketing and educational measures on the benefits of self-driving cars, potentially even conducted by governments, should be introduced to address the emotionally driven, current acceptance rate of the future mode of transport. In addition, the development from private ownership to shared service must be monitored to anticipate the purchase quantities and thus prepare the automotive industry accordingly.

1.5.4 Further Related Studies

In 1993, Underwood conducted a study with automotive experts. The experts believed that only 5% of market share between 2040 and 2075 will be taken up by Level 5 automated vehicles. Additionally, Level 5 vehicles will never achieve 50% of market share (Underwood, Chen, & Ervin, 1991). In 2013, Sommer found that of survey participants 67% would find self-driving vehicles useful on long highway journeys, 52% in traffic jams, and 34% in city traffic (Sommer, 2013). A further study conducted by Underwood in 2014 found that the biggest perceived hurdle by the 217 automated vehicle experts was the legal liability and regulation consideration. Contrary to arguments provided in this dissertation, the experts perceived user acceptance to be the smallest challenge to overcome. However, their timeline estimation of the introduction of various automation levels so far does not meet reality. They believed that Level 3 automation, a level they did not expect to be practical, would be readily available in 2018. However, only at the end of 2021 was this feature officially approved. Additionally, they expect Level 4 to be available in 2024 and Level 5 in 2030 (Underwood S. , 2014).

Kyriakidis et al. conducted a study with 5,000 participants from 109 countries. 20% of participants would not be willing to pay for self-driving vehicle capabilities and only 5% would be willing to pay more than US$30,000. Additionally, just like a study conducted by AAA, they found that use of automated cruise control increases the acceptance of Level 5 automation (American Automobile Association, 2016). Lastly, the researchers found that participants of higher income countries were more concerned about data sharing than those of lower income countries. Lower income country participants showed a greater interest in the improved safety benefits self-driving vehicles could provide them (Kyriakidis, Happee, & de Winter, 2015).

A study conducted by German automotive club ADAC in 2016 found that safety concerns and loss of control were Germans biggest concern regarding self-driving vehicles (ADAC, 2016). Hulse et al. conducted a study with 1,000 participants about their perception of self-driving vehicles, focusing on perceived safety and acceptance. The survey found that from the self-driving passenger point of view, participants were more concerned about the technology when taking on the perspective of a pedestrian. As other studies have shown, males had a greater acceptance rate of self-driving vehicles than females. An interesting argument added by the researchers was that given the high accident rate among young male drivers, the adoption of self-driving vehicles by this gender and age group could benefit overall road safety (Hulse, Xie, & Galea, 2018).

In a report published by IDnow in 2019, the wish to use robo-taxi services by future self-driving vehicle users exceeds the wish of owning a self-driving car. This contradicts the findings of paper 3 of this dissertation. However, the survey was conducted pre-pandemic and thus the underlying decision conditions differed from the desire to socially distance during the pandemic (IDnow, 2020).

Garidis et al. found that safety was the strongest self-driving vehicle adoption factor amongst the 470 study participants from Germany. Those who believe that self-driving vehicles have a high level of safety have a greater intention of using the technology than those who do not believe it. Just like previous studies, the loss of control influenced the adoption rate negatively. Loss of driving joy, legal considerations, and environmental benefits showed no influence on the intention to use a self-driving vehicle (Garidis, Rossmann, Ulbricht, & Schmaeh, 2020).

1.6 COVID-19, the Catalyst for Technological Development

A lot of the insights above paint the picture of the mobility world pre-pandemic. However, COVID-19 broke out, halting mobility movement, progress and development. As a result, some of the assumptions mentioned above are no longer valid. While COVID-19 caused a push in the digitalisation of companies in Germany (Erdsiek, 2020), the future outlook may have fundamentally changed the way we handle mobility. The following text provides an insight into the unexpected changes as a result of the pandemic:

On 31st December 2019, the Wuhan Municipal Health Commission reported cases of pneumonia. Exactly one month later, on 31st January 2020, the Virus SARS-CoV-19, also referred to as COVID-19 or Corona Virus was declared as a Public Health Emergency of International Concern (PHEIC) (World Health Organisation, 2020). Through global travel, the virus's short transmission and two-week incubation time, the pandemic swept across the globe rapidly. To mitigate the virus, many countries decided to restrict cross border travel. Further, governments introduced social distancing measures, curfews, and even lockdowns. While 'system-relevant' institutions, such as supermarkets and postal services, remained operational, offices and shops were closed. Where possible, companies told employees to work from home. People were only allowed to leave their homes to go to the supermarket or for doctor visits. As a result, travel behaviour came to a halt.

1.6.1 Movement during the First Wave

Google's COVID-19 Community Mobility Report compares movement data to the baseline, "the median value, for the corresponding day of the week, during the 5-week period Jan 3–Feb 6, 2020." (Google LLC, 2020). The mobility behaviour within nations changed drastically in March compared to January of the same year. Measures across Europe varied, from a full early-stage lockdown in Italy, a late full lockdown in the United Kingdom, social distancing measures in Germany, and business as usual in Sweden.

As the spread of the virus eased during the summer of 2020, Europe decided to lift its travel restrictions. Transit station records reveal that Germans were starting to use public transport again, with only 27% less movement in June than in January. However, as a result of increased local and global travel, infection numbers have risen again dramatically, resulting in a second wave of the virus sweeping across Europe.

Beginning of 2022, Germany has had five COVID-19 waves, with 22.8 million infections having been reported at the start of April 2022 (Robert Koch Institute, 2022).

1.6.2 Automotive Knock-On Effects

A report released by Statista shows an unfavourable outcome for the automotive industry. HIS Markit predicts the American market a total loss of 4.1 million produced vehicles due to shut down production in 2020 alone. While China is expected to experience a decrease of 3.8 million produced cars, the European market is hit the hardest, with 5.2 million vehicles not being built as a result of the pandemic (Wagner, 2020). March 2020 already saw a 39% decrease in sales compared to March 2019, a worse decline than suffered by the industry during the financial crisis in 2008 (JATO Dynamics, 2020).

Several assumptions laid out in this dissertation are based on pre-COVID-19 developments. As the study included in the final paper of this dissertation shows, people are still concerned about being in contact with strangers in September 2020. As a result, the rate of privately-owned vehicles being used instead of public transport has increased. At this point, however, we do not know if this will persist or only reflects a temporary change in behaviour.

If consumers change from public transport to private vehicles in the long run, several assumptions on which future mobility concepts are based may prove to be wrong. Private car ownership may be on the rise again and car-pooling concepts, such as MOIA, may not succeed as hoped, and the predictions made by MIT may not become true. Also, the integration of AI may not be at the centre of companies' development plans. Economic perspectives worsened as a result of COVID-19. Due to factory closures, supply chains are being shaken up. Lower revenues for companies will result in lower tax incomes for governments. Governments will now focus on supporting economies instead of investing large sums in new technology, resulting in large setbacks for the development of AI.

On the other hand, COVID-19 also acted as a catalyst for technology integration (Erdsiek, 2020). As a result, the pandemic may open up new opportunities for autonomous vehicles. As the paper *'Social Distancing, Autonomous Vehicles' Unexpected Supporter – How COVID-19 has Changed Future Mobility Behaviour and Perception in Europe'* shows, Europeans' perspective on self-driving vehicles has improved. But the pandemic's influence towards using private vehicles over public transport can also be seen here. While previous studies have shown that the use of a self-driving vehicle service is receiving greater attention than the ownership of private self-driving vehicles, the pandemic resulted in the opposite. Currently, more potential consumers prefer their own self-driving vehicles rather than just using the MaaS concept. However, we do not yet know the long-term effects on the automotive and technology industry. The recovery of companies, industries, and economies will be the main focus of governments in the years after the COVID-19 pandemic. Depending on the willingness and capability to invest, AI may be the supporting technology helping companies get back on their wheels.

1.7 Dissertation Outline and Summary of Papers

Whether the actual act of movement of self-driving vehicles or the processes and stakeholders involved in the creation and deployment of the new mode of transport, research possibilities into CCAM are almost endless. Economic research into AI is only in its infancy as businesses and industries only just begin considering its integration. So, what are the basic requirements to introduce self-driving cars on our roads as quickly as possible? They are:

- infrastructure;
- a technology-driven automotive industry; and,
- user acceptance.

These three vital economic aspects of self-driving car execution are considered in this dissertation.

1.7.1 First Paper: Obtaining the Required AI Infrastructure in Europe

The first paper of this dissertation, titled ‘Are USA’s and China’s artificial intelligence activities outsmarting Europe? – A critical analysis of AI and Europe’s approach to it’, focuses on the European AI infrastructure. Without the acceptance and striving for AI integration within the automotive industry, the execution of self-driving vehicles will be tough. The idea for this paper stems from the AIP project already mentioned above, of which Prof. Dr. habil. Wolfgang H. Schulz and I were part. As key German automotive companies participated in the project, the focus remained on the German automotive industry. However, to provide AI (and autonomous vehicles) with the best development and integration conditions, Europe must act as one.

Results

The paper starts with an explanation of what AI is, revealing a gap between expected skills and the technology’s real abilities. Also discussed are China’s governmental power and population size, revealing a clear advantage when trying to create a legal framework for AI as well as gathering sufficient data for ideal AI execution. The USA’s cowboy economy mentality allows the economy and industry not to be afraid of potential failures. They are more risk-friendly and learn through a trial-and-error approach. AI requires a greater level of risk-taking than Europe is known for. The somewhat reserved approaches of Europe towards new developments hinder the creation and deployment of AI and thus self-driving vehicles. The paper provides an action plan, recommending a more European rather than single market approach to AI execution, from acting together by pooling financial investments to collecting relevant data for AI application.

1.7.2 Second Paper: AI as Process Optimiser for the Automotive Industry

The second paper is titled: ‘The Knock-On Effect of Introducing AI as a Supply Risk Optimiser - How Implementing AI Can Assist Companies to Endure a Crisis’. For the automotive industry to remain competitive vis-a-vis the technology industry and to allow the automotive industry to grow, manufacturers and suppliers should integrate AI into their day-to-day operations. The most pressing matter in 2020/2021 is to ensure the industry comes out of the pandemic as quickly as possible. To get back on its feet, a clear insight into the supply chain is essential. Integrating AI within the supply chain to minimise potential future supplier risk issues would enable buyers, whether OEMs or suppliers, to have a better overview of their sectors. How does the DACH (German, Austrian and Swiss) automotive industry see supplier risks? How does it handle them? Also, what role does AI play in tackling issues? The second paper discusses these questions through a qualitative study.

Results

Risks associated with the supply chain have increased over previous years due to globalisation and out-sourcing activities. The majority of study participants currently only monitor TIER 1 suppliers, but all of them wish to monitor past TIER 3 suppliers. Integrating AI within the supply chain would enable a better understanding of potential risks, but only a few study participants have either integrated AI in their company or are willing to discuss their level of integration. By revealing their AI efforts, they may raise competitors' attention towards the benefits of the technology. At the same time, by admitting to not using the technology they may admit falling behind other companies' efforts. Overall, to minimise supplier risks, to bring the automotive industry forward as a whole, and to leave the problems brought on by the pandemic behind as quickly and smoothly as possible, the industry must integrate AI.

1.7.3 Third Paper: How the COVID-19 Crisis Drives Self-Driving Vehicle Acceptance

The third paper in this dissertation is titled 'Social Distancing, Autonomous Vehicles' Unexpected Supporter – How COVID-19 has Changed Future Mobility Behaviour and Perception in Europe'. As a result of COVID-19, our mobility world came to a halt. Our desire for and feeling of ease with travelling long and short distances declined, and we started to reconsider when, where, and how we move. Self-driving vehicles would allow us to travel from A to B without driving ourselves, and, provided that these vehicles are for individual use, would lower our potential exposure to carriers of the virus. Theoretically, the acceptance of self-driving vehicles should rise due to the pandemic.

Results

To investigate this thought further, a quantitative study focusing on social distancing as an acceptance driving variable was created. Supposing a potential consumer of a self-driving vehicle values social distancing and actively chooses a mode of transport based on social distancing opportunities, their willingness to use self-driving vehicles should rise. Based on previous studies revealing that more potential users would be willing to use a self-driving vehicle service rather than owning one themselves, the focus of this study was the willingness to use robotaxis (if they existed). Using the Technology Acceptance Model, with an added social distancing variable, an increase in acceptance of robotaxis was revealed. Contradicting previous studies' findings, the number of participants wishing to own a self-driving vehicle exceeds the willingness to use a robotaxi. If this development remains post-pandemic, future mobility assumptions that self-driving vehicles will be shared and owned by mobility service providers rather than individual owners will have to be reassessed.

1.8 Conclusion

1.8.1 The Drive to Pursue this Dissertation

My curiosity about artificial intelligence created my drive to pursue this dissertation. I wrote my master's thesis about the acceptance of autonomous vehicles in 2017, and while this was the initial intention towards this PhD thesis, through the AIP (KI Plattform) project, I learnt about the true complexity of the topic. While this dissertation covers a wide variety of topics related to autonomous vehicles, from infrastructure realisation to how the automotive industry is adjusting to AI, as well as how society perceives and accepts the technology, all essays reflect upon their interdependency and explore how autonomous vehicles can be introduced in the market.

1.8.2 Limitations and Future Research

The meta-level of economic research of AI is still in its early days. One of the difficulties with setting strategic goals is that they require a clear time frame of when these goals should be executed. Because of the unknown scientific development process and unclear introduction point of the more developed AGI, it is difficult to set strategic goals for AI. While the introduction timeframe is not a component this dissertation focuses on, it is important to note this. 20 years ago, the introduction of AGI was estimated to take 15 years. In 2020, we are still told to wait a further 20 years. Thus, the hypothesis and suggestions made by this dissertation are connected with uncertain time elements.

While there are many engineering-related publications, relatively little has been published in scientific papers about the business and economic aspects of AI and autonomous driving. Therefore, finding sufficient scientific sources proved to be difficult. The information gathered was sourced mainly from grey literature sources, such as company websites, company reports, and online newspapers with a long-standing history of new technology knowledge sharing. Through the expansion of the dissertation focus from acceptance to the assessment of several stakeholders relevant for the introduction of self-driving vehicles, a much broader field had to be explored. While this gave me a better insight into the ongoing developments surrounding AI and CAV, it also meant a more complex research undertaking was necessary. Further, the dissertation takes a more practical approach to AI and self-driving vehicle development, with many industry examples provided.

Lastly, the dissertation topic covered only considers a small aspect of mobility developments. In order to get a better understanding of the competition between nations, studies such as in Paper 2 should be repeated in the USA and China to draw a clear comparison between the nations' industries. Especially as a result of the pandemic, more uncertainties arose. Because of this, the study in Paper 3 should be repeated at a later stage to assess which mobility developments, such as the shift from public transport to private vehicle use, persist and which developments were only temporary. Through this, either the pre-pandemic path can be followed again or the foundation of future mobility needs to be adjusted.

1.8.3 Action Recommendations

Porter describes competitive strategy as "taking offensive or defensive actions to create a defendable position in an industry" (Porter, 1980, p. 34). Based on this dissertation, it is time for the German and European automotive industries to take an offensive position and ensure they keep up with their foreign competitors. There are several actions that can and should be taken. These can be split into management recommendations for OEMs and Transport policy/government action recommendations.

1.8.3.1. OEM Management recommendations

As previously mentioned, there are several benefits of AI in the automotive industry. These include improved insights into supply chains, finances, and even customers. Quality control can be improved and error margins reduced; waste can be reduced as well. Looking at strategic, operational, and tactical management, there are several improvement opportunities.

Strategic management of OEMs should focus on unified actions with other automotive companies from the European Union. Through this, the focus is shifted from individual companies or single markets to creating EU-wide functioning AI systems, including self-driving car networks. Through a stronger focus on transfer projects, theoretical undertakings can be turned into reality. An example of this could be the AIP project and turning the theoretical platform into reality. This can help speed up development processes by purchasing already existing data instead of spending time on collect own data.

Looking at tactical management, which focuses on short to mid-term timeframes around 1 to 3 years, OEMs should consider their internal operations and which ones can be improved. First, they should consider in which areas they could do better. Then, they must assess which actions they must take to do so. This may mean the consideration of purchasing/development of physical tools or integration of AI software to assess data. To make an informed decision, it is important that

OEMs know which kind of data they may need for this execution. In the case of introducing supporting software, the company must consider if they have the appropriate data needed for this kind of assessment. If this data does not exist, the company should consider how to gather this information. Using the example of a machine that assesses cut vehicle components in order to introduce quality control machinery and software, the OEM must clearly state which quality parameters are within and out of the norm. This data must then be 'fed' to the software and machine in order for it to make correct decisions on which cut vehicle parts are appropriately cut and which are not. It is no longer about gathering big data, but precise data relevant for setting an AI software clear examples of what is and is not to be achieved.

Lastly, operational management, which centres on day-to-day tasks, should focus on employee handling. It is important that employees understand the benefits AI can bring them instead of fearing it. The greater the disapproval of the software or machinery is, the greater the potential for its mistreatment. Additionally, as Silvain Duranton and Tubari and Cassilli state, humans are essential for the execution of artificial intelligence. This role must be made clear to employees to reduce their fear and concerns and unleash AI's full potential.

1.8.3.2. Transport policy recommendations

In 2019, the German government set aside a total of €3.5bn for the "realisation of the German AI strategy". Some of the goals are fostering a "responsible and orientated towards the common good development and use of AI", including the creation of German a monitoring body and the encouragement for the creation of a European body and a national education strategy surrounding the use of AI. This strategy aims at making Germany one of the world leaders for AI and to secure the future competitiveness of the nation. (Die Bundesregierung, 2018) However, the German newspaper Handelsblatt found that only 10% of the fund was used in 2021. None of the €15m allocated to the German Foreign Ministry have been used yet. Of the €967m budget for the Federal Ministry of Economics, only €144m were used. Also, the planned German-French transnational AI Centre has not been realised. The Federal Ministry of Education and Research argues that only after the funding period is over can a proper assessment of the funds be made. However, looking at these first impressions, a close eye must be kept on these developments. In order to remain competitive, the realisation speed of planned projects needs to improve (Stiens, 2021). The allocation of funds for AI expansion is not sufficient if the projects are too slowly executed, the right personnel cannot be found, or the projects themselves are simply too ambitious. Thus, my first recommendation is to monitor and potentially reevaluate the existing projects benefitting from the AI fund in order to understand why the money has not been used yet, and evaluate how the project realisation can be sped up. Additionally, to reiterate previous comments and referring to Paper 1, we need inter-European actions. The recognition for Europe-wide AI actions is important, but an even greater emphasis should be put on turning them into reality to ensure the EU is not left behind by the competition.

To optimise and maximise institutions' particiation in the development and integration of AI and self-driving cars and to turn theoretical considerations into reality, the institutional role model (IRM) could be applied. The IRM is a model developed by Prof. Dr. habil. Wolfgang H. Schulz and focuses on reducing companies' moral hazard and finding the best insitution for the execution of a task. Additionally, the approach enables non-discriminatory cooperation. The IRM "overcomes the weaknesses of traditional operational and organizational provision concepts" (Schulz, Joisten, & Arnegger, 2019). It can be useful towards turning the large number of theoretical AI projects into real-life integration. Step 1 consists of choosing necessary meta-rolls relevant for the successful execution of a project. Step 2 involves creating a list of institutions that could take on the previously set roles. Step 3 focuses on assessing these chosen institutions for each role. Here, the institutions are asked about their own experience and believed capabilities to take on the various tasks. Furthermore, the other participating project partners are asked about their beliefs and confidence in said institution taking on a particular role. Additionaly, external experts are asked about their perception. Through this, the best perceived institution for taking on a particular role can be found. Step 4 finalises the role allocation, with Step 5 completing the procress with necessary legal considerations (Schulz, Franck, & Smolka, 2021). Through the application of the IRM, cooperation issues can be overcome and projects can be executed, not only in the best possible way, but also with the interest of the greater good in mind. Therefore, I recommend the consideration of the IRM for future transfer projects to the accelerate AI and self-driving vehicle development and integration.

Focusing on the findings of Paper 2, we must proactively expand the AI integration of automotive manufacturers and suppliers. When researching existing projects, two schemes came up: Digital-Jetzt and Go-Digital. Digital-Jetzt provides small and medium enterprises of any industry with funding to expand their digitalisation infrastructure. Based on the company's submitted digitalisation plan, the company may receive funding of up to €50,000, with a maximum of €100,000 if the investment goes towards value chain or network digitalisation improvements (Federal Ministry for Economic Affairs and Climate Action, 2022). In order to accelerate AI integration, a KI-Jetzt (AI-Now) fund should be set up. It should enable going beyond standard digitalisation measures, by focusing on untapped AI opportunities. Additionally, the Go-Digital fund provides small enterprises with consultant and realisation support. If granted, the fund covers 50% of 30 days of the consulting service within a six month period. The service covers five areas, including ‘digitalisation strategy’ and ‘IT-security’. The support was set up to ensure small enterprises to be sustainable and competitive in the ever-increasing digitalisation world (Ministry of Economic Affairs and Climate Actions, 2022). In a similar manner as the proposed AI-Now fund, a potential Go-AI fund could help companies realise their potential. Preparing our streets for future mobility requires more companies than just the automotive manufacturers. Thus, having a fund that focuses on smaller company sizes than automotive manufacturers and their suppliers is crucial. However, the entire automotive industry would benefit if support for all types of company sizes and turnovers is set up. The more companies use AI to improve their products, the more the overall mobility world will benefit.

We must continue to assess future consumer acceptance of self-driving vehicles, as done in Paper 3. If acceptance declines, we must understand the concerns and fears to proactively counteract them. If acceptance increases, we should understand what the driving factors are and further emphasize them. PAVE, Partners for Automated Vehicle Education, was started in 2019 in the United States and is a coalition of partners, including vehicle manufacturers, non-profit organisations, mobility service providers ,and other mobility-related goods and service companies. PAVE aims at informing the public about the benefits of autonomous vehicles to increase acceptance. PAVE Europe is the European counterpart, aiming to be operational in 2022 (www.pavecampaign.org). The potential impact this not-for-profit coalition will have is enormous if they are able to fully understand the concerns and needs of future users. Additionally, one could argue that Germany will be a particularly hard market to convince. To encourage Germans to give up our own vehicles in favour of vehicles that drive for us, which are most likely electric and thus do not provide us with the usual motor sounds, will be more difficult compared to other markets with a lower ‘car-appreciation’ level.

Overall, we need realisable actions instead of imagining new, ideal, moon-shot projects. We must work on a European-wide joint strategy to create an AI infrastructure. Further, we must turn theoretical projects into transfer projects to realise the benefits AI can provide the industry and companies. Finally, we need public education both in the field of AI and self-driving car benefits. In order for Germany and the European Union to remain competitive, we must introduce AI and autonomous vehicles in an accelerated way.

2 Are USA's And China's Artificial Intelligence Activities Outsmarting Europe? – A Critical Analysis of AI and Europe's Approach to It

2.1 Journal Publication Information

This paper, written in co-authorship with Prof. Dr. habil. Wolfgang H. Schulz, was accepted by the European Journal of Management (1555-4015) on 5th December 2020 and published in the European Journal of Management, Volume 20, Number 1, on 30th December 2020.

Full citation: Edye, C. F., & Schulz, W. H. (2020). 'Are USA's And China's Artificial Intelligence Activities Outsmarting Europe?' – A Critical Analysis of AI and Europe's Approach to it. *European Journal of Management*, 85-98. http://dx.doi.org/10.18374/EJM-20-1.8

2.2 Abstract

Artificial Intelligence (AI) is vital for nations and their national industries to remain competitive in the world of digitalization and to ensure growth, employment and overall welfare. AI in the field of transportation would result in benefits for individual drivers, other participants in traffic, as well as process advances for manufacturers and suppliers. Further, a domino effect for society as a whole could be created. This paper explores the European Union's approach to AI, and the road blocks it is currently facing, including analyzing its competitors. AI data does not follow classic economic theories. Here, scarcity is no longer the rule, instead the larger the data sets and information provided, the higher their value. This provides China (large population) and USA (capital resources) with key advantages, due to their ease of generating data, or does it? While the European Commission wants to invest €20 billion to expand AI in the European Union, it has to tackle several issues for AI to be truly effective. One issue is that the union's nations must act together to generate data sets large enough to compete with China and USA. Further, AI built into vehicles will need to be 'smarter' compared to foreign vehicles, to enable handling the complexity of different driving behaviors upon border crossing. While it may take longer to expand AI in Europe, the broader knowledge required could become Europe's advantage for catching up with its competitors.

Keywords: artificial intelligence, competition, development, automotive, AI productivity

2.3 Introduction

Artificial intelligence, or ‘AI’, is the new buzzword of the business world. While the technology industry has been working on and with artificial intelligence for many years, the rest of the economic world is slowly catching up. According to a study conducted by PwC, through the incorporation of AI into businesses and the economy as a whole, China will have increased its GDP by 26% in 2030. Together with the United States of America, who according to the study may enjoy a 14.5% boost in GDP, the two countries will capture 70% of the global economic impact AI will have. (Rao & Verweij, 2017) Europe on the other hand is struggling. Despite its strong economic and technological role, it is becoming increasingly more difficult to compete with other leading technological nations.

The German government lists more efficiency potential for existing business models, as well as creation and enabling of new business models, as a key focus of AI adoption among businesses. AI is applied in the automotive industry, healthcare sector and even administrative areas of governments. Companies such as Amazon and Netflix heavily use AI to improve user/customer experience. Already in 2013, 35% of product purchases at Amazon.com and 75% of movies watched on Netflix were generated through product recommendations, created using AI technology. (MacKenzie, Meyer, & Noble, 2013) From a nation’s perspective, they should use AI not only to compete with other nations, but also to improve their economies, labour markets and society as a whole. (Bundesregierung, 2018)

Individual topics such as autonomous driving is becoming an increasing focus not only of the automotive industry, but also the technology industry, as well as governments. Business landscapes and their actors are changing as a result of expanding AI. The previously saturated automotive market has new players, such as Tesla and BYD. But also the technology industry as a whole is competing with companies such as Google and Uber entering the automotive industry. (Gao, Kaas, Mohr, & Wee, 2016) One indicator for the attention given to AI, is the amount of research conducted in its field. Elsevier publisher released a report on AI research development over the past years. In 2017 alone, over 60,000 publications related to AI were published, a 12.9% annual increase over the past 5 years. Europe is not only researching in the most diverse fields, but also publishing the highest number of AI related publications, followed by the United States. However, China is catching up, though their reach seems to be more local than global. (Elsevier Artificial Intelligence Program, 2018)

Theoretically, this should mean that Europe should be a key player, if not ahead of its competitors in the development and implementation of AI. But why are they not at the front of the competition? The media is increasingly highlighting that Europe is falling behind and the AI battle is being carried out between China and U.S.A. Thus, the race to become the leader in AI and machine learning has begun. Nations must stay focused on AI expansion, in particular those that have national industries responsible for wealth, in form of growth and employment, such as Germany and its automotive industry.

2.3.1 AI and the Transportation Industry

AI is the foundation of future mobility in many aspects:

1. AI enables and improves autonomous driving for many stakeholders. In order for autonomous vehicles to function, the new 'brain' of the car will be based on artificial intelligence. While many scenarios and related driving behaviour will be pre-programmed into the car, there may still be scenarios the car was not 'trained' to react to and must decide itself how to act in a particular situation. This requires the car to make decisions based on the knowledge it has. Through the inclusion of smarter vehicles and vehicles that communicate with each other in real time, traffic processes will change, increasing driving safety for individuals and traffic safety for all driving participants. Overall, this contributes to Vision Zero, an American multi-national road traffic safety project, aimed at completely eliminating fatalities in road traffic accidents (www.visionzeronetwork.org).
2. As describe by Lipson and Kurman, the physical car will become secondary and the AI inside of the car will be the key focus area of car developers (Lipson und Kurman 2016). This in turn opens up many areas for the technology industry to enter the previously saturated automotive industry. Actions such as breaking will no longer be performed by a human being putting their foot on the break and instead occur through a string of software decisions. Thus, AI already today is creating a shift from hardware to software focus. Further, processes can be optimized, from improved purchasing behaviour, to more efficient production steps. In the long run, this will have an influence on the price of vehicles in the future, making cars cheaper and thus improve individual mobility.
3. AI allows for the overall improvement of traffic systems. Through the use of all-inclusive transport management, efficiency is improved. This in turn lowers emission and is an important component of climate change.

2.3.2 Problem Definition

Currently only a small number of hyperscalers exist. These are Amazon, Microsoft, Google and Alibaba, all gathering data about business activities, as well as individual behaviour. Three companies from the United States and one company from China. This provides the U.S.A. with a clear lead in AI activities. From a European point of view, the question now is: What about us? Especially in the transportation industry Europe must remain competitive. The continent has many automotive manufacturers, some even being national industries, making it vital to uphold the industries' position within the nations and thus requiring AI to remain competitive during the changing mobility world. While also giving you an insight into the basics of AI, this paper provides a critical insight into AI expansion in Europe and considers why Europe should act as a whole continent, instead of leaving individual countries to attempt to compete with key players in the AI world. Further, advantages of Europe's competitors are considered and compared to Europe's actions, as well as considering possible future actions to ensure AI expansion. This is done using the transportation field to highlight AI need.

2.4 The Basics of AI

Artificial Intelligence (AI) is defined as "the ability of digital computer or computer-controlled robot [...] to solve problems that are normally associated with the higher intellectual processing capabilities of humans" (Encyclopaedia Britannica, 2019) AI dates back to the 1950s, when John McCarthy used this term for a workshop draft at Dartmouth College. (Russel & Norvig, 2009) But it is a slow process to get AI 'up to speed' with human actions and interactions. Elaine Rich defined AI as "the study of how to make computers do things which, at the moment, people do better" (Rich, Knight, & Nair, 1991). 35 years later, these definitions still apply (Faggella, 2018). Computers are already able to take on mathematical problems and calculate these at a faster rate than humans. However, even though emotion detection is already possible, the emotional and empathetic interaction of humans is still a challenging aspect for AI. (Chui, Manyika, & Miremadi, 2018) After all, these two aspects are key components in 'higher intellectual processing capabilities'.

According to a study conducted by PwC, up to $15.7 trillion can potentially be contributed to the global economy in the next 11 years through the incorporation of AI alone. Further, an increase of up to 26% could be generated of local economies' GDPs. (Rao & Verweij, 2017) But it is crucial for economies to take full advantage of AI for this prediction to become reality.

2.4.1 AI Crash Course

"AI makes it possible for machines to learn from experience, adjust to new inputs and perform human-like tasks. [...] AI works by combining large amounts of data with fast, iterative processing and intelligent algorithms, allowing the software to learn automatically from patterns or features in the data." (SAS, 2019) There are three different types of AI: Narrow, General and Super AI. (Jajal, 2018) Key to all types is that AI has "access to objects, categories, properties and relations between all of them to implement knowledge engineering" (Techopedia, 2019)

Artificial Narrow Intelligence (ANI) is able to carry out a single task. Its actions are based on "a specific data-set" and do not go beyond the known scope of activities it may perform. It is the type of AI already integrated into our world today, such as Siri, functioning through a combination of speech recognition, in charge of turning spoken language into text, and natural language processing, where computers are able to "understand human speech as it is spoken". (Diaz-Santana, 2017) Large datasets are assessed to allow the variety of accents and speech patterns to be recognized (Nellis, 2017). The easier the task provided to Siri, the more accurate (and satisfying) is the answer we receive. (Jajal, 2018) To put it in Tim Urban's words: ANI is "a super powered human... at that one thing." (The Artificial Intelligence Channel, 2017)

The next classification of AI is AGI, Artificial General Intelligence. AGI is in theory "a machine that can perform any intellectual task that a human being can" (Urban, 2015), but it does not exist yet. Among complex skills AGI will be able (once fully developed) to solve problems and reason, something that ANI is not able to do. This behaviour is based on emotions and self-awareness. (Jajal, 2018) Raymond Kurzweil predicts that this will be reached in 2029 (Kurzweil, 2014). The next step towards ensuring the creation of AGI is sufficient computational power. (Urban, 2015) But the steps after this are not yet clear. AGI is a far more complex system than ANI, and some argue that ANI cannot be seen as "steppingstones to developing an AGI". (Heath, 2018)

The highest and most complex level of AI is ASI. Oxford Philosopher Nick Bostrom describes ASI as "an intellect that is much smarter than the best human brain in practically every field, including scientific creativity, general wisdom and social skills." Once we have reached AGI, "there will be a positive feedback loop" (Bostrom, 2006) that will enable the creation of artificial super intelligence (ASI) in a very short amount of time. Bostrom argues, that in order to truly enable ASI, a computer with high enough processor speed and large enough memory will be required. Once we have the hardware and software required for ASI to perform well, it will learn through human interaction and interaction with its environment. Further, the system would have to be fed with information, such as through an attached video camera providing real-life data, and also manual entry of data. But ASI should be treated with caution. Strict regulations for the use of ASI must be set. If not, ASI may swerve out of control, with some arguing that it can eventually control us, instead of the other way around. Elon Musk argues that "AI is far more dangerous than nukes" (Robinson, 2018), referring to the most intelligent type of AI. Urban believes that "superintelligence of that magnitude is not something we can remotely grasp" (Urban, 2015).

Machine Learning (ML) is often used as a synonym for AI. However, ML is a part of AI and is responsible for "conferring upon machines the ability to "learn"" (De Jesus, 2017), thus actually implementing AI. Through the use of algorithms, patterns are detected, and information is extracted, in order to allow decision-making and even make predictions. ML "uses methods from neural networks, statistics, operations research and physics to find hidden insights in data without explicitly being programmed for where to look or what to conclude" (SAS, 2019). In particular important for AGI and ASI, ML goes further than pattern recognition and enables machines to learn and develop. ML is seen as the "key [...] for modern AI technology" (Döbel, 2018) In recent years Deep Learning (DL) has allowed for "super-human accuracy for image classification and object detection" (Marr, 2018) DL works by using "huge neural networks with many layers of processing units, taking advantage of advances in computing power and improved training techniques to learn complex patterns in large amounts of data." (SAS, 2019) Overall ML and DL will be key for the implementation of AI.

2.4.2 Economics of AI & Data

The larger the dataset, the more information can be extracted. The more information can be used for understanding the task to be measured (whether it is understanding customer data or purchasing behaviour, process optimization or knowing which data to measure in the first place), the higher the value creation as a result. Overall, this increases the value of the dataset itself. Thus, the more data, the higher the value. Through the importance of data, also old data becomes important. Old and new data should be combined and shared. This forces cooperation and questions current European competition law. It is contrary to classic economic theories of scarcity, further highlighting how disruptive AI can be, as it does not even follow a theory that is at the core of economic knowledge. This strongly suggests that as much data as possible should be generated, either through pool size or investments made into data gathering, whether real or synthetic data (further discussed below).

However, some believe that data itself is of no value, or at least not to the extent companies first believed it to be (Hammond, 2013). Rana Satzendra, CTO of diwo, a decision-making platform, argues that data is only of value when it is "an object of exchange in an economic activity" (Rana, 2018). He continues writing that data is only of value when it is sold. "Data has to be paired with other data and intelligence for value" (Rana, 2018) causing value to be derived from data, rather than data providing value in itself.

In summary, the above observed development in economic theory for data applies when a dataset is being sold and is of actual value to a company, while datasets already belonging to a company only create value when the right "value creation mechanisms are triggered" (Rana, 2018).

2.4.2.1 Positive Aspects of AI

Lauterbach and Bonime-Blanc (Lauterbach & Bonime-Blanc, 2018) highlight key applications of AI helping economies and companies grow:
A central fear towards AI is an increase in unemployment. However, thus far AI would not have been possible without human actions. Humans still choose when and where to apply AI and if these two factors are combined, a true optimization process can occur. The insurance company Lemonade (www.lemonade.com) has already included an AI software to accept insurance claims. If a claim is approved, the insurance money is paid almost instantly. Only when a mistake on a form was made, or the case is more complicated than the software is programmed to be able to handle, is the claim sent to a human employee. Through this, processes can be sped up and human labor can be used more efficiently. Ajay Agrawal argues that AI can also result in cost optimization across entire supply chain. While the obvious thought direction would be the adoption of new measures for sourcing products, or finding new ways to save time, and thus money, integrating AI can also result in improved predictions, such as upcoming sales and thus allows a nation, industry or company to act according to the improved forecasting. (Agrawal, 2018)

But in order to make the most out of collected data, the right data must be collected. AI can help companies in the backend to obtain these. Greg Hanson, CTO and VP of Informatica, believes that "we need to make sure that we've got artificial intelligence [...] to ensure we've got well-curated data going into our analytics engines". (Ismail, 2018; Agrawal, 2018) Thus, AI essential for converting data into useful information, but we must also collect the correct data to achieve our targets.

2.4.2.2 *Negative Aspects of AI*

But AI is not purely beneficial. There are two possible ways AI could become dangerous. (Tegmark, 2019) Either it is purposefully used to cause damage, or ASI takes a turn for the worse and develops into a destructive machine, such as displayed in the film I, Robot. Many nations are continuing to invest in military robotics and AI, such as China. By 2030 China's President Xi Jinping wants to invest $150 billion to ensure China becomes the world's leading AI country. As part of this goal, the government wants to improve its unmanned weapon system to "combine dozens, even hundreds, of unmanned drones into a single devastating wave" (Herman, 2018) But also the U.S.' military is planning on investing $2 billion over the next 5 years into AI. (Stober, 2018) An open letter signed by Elon Musk, as well as Stephen Hawking, calls for the ban of weapons "beyond human control" (Future of Life Institute, 2015) While on one hand the threshold of going to war will be lowered, due to the lack of human casualties, fear is growing that through the combination of ASI and machines, fights may spiral out of control.

2.5 Opponents in the Battle of AI

Europe's main competitors in the fight for AI come from North America and Asia-Pacific. The leadership roles the American and Asian technology companies have been able to obtain in the fight for AI and ML leadership, can be led back to large financial means, as well as access to large data pools, computing power and cloud-based development platforms. (Lucas & Waters, 2018) Further, strong relationships between companies and universities allow for the optimal education basis of future employees. (Elsevier Artificial Intelligence Program, 2018) Investment behaviour across the leading AI nations have varied immensely in 2017. The United States focused on short- and long-term investments, diversifying its AI interest across several fields. China on the other hand has very strict goals set by its government, resulting in new AI technology being created by several industries. (ABIresearch, 2018)

2.5.1 China

A decade ago, China's economy was growing rapidly due to its low-cost manufacturing possibilities. In recent years, China has put an increasing focus on technological advances, such as building semiconductors. (Zinn, 2018) China is planning on becoming the world's leading AI nation, which is another step towards ensuring further advancements and growth in power. Former Google CEO Eric Schmidt said in relation to Chinese AI advancements that "they are going to use this technology for both commercial as well as military objective with all sorts of implications." (Shead, 2017).

As previously mentioned, the Chinese government is heavily involved in the expansion of AI. After academia, the government publishes the most research papers in China (Shoham, 2018). Governmental influence in AI development and investment, can also be seen in investment efforts into AI start-ups. US$4,9 billion were raised by AI start-ups in China in 2017, and only through a small number of investments (ABIresearch, 2018).

Through strict policy guidelines, China is ensuring it will meet its 2030 goal of becoming the strongest AI power. 'A Next Generation Artificial Intelligence Development Plan' sets out the Chinese AI Adoption strategy for the next 10 years. By 2020, China wants to be on the same level as its competitors, if not exceed them by having "established initial AI Technology standards" ((Chinese) State Council, 2017). By 2025, China wants to have achieved "major breakthrough" in AI to get ahead and ensure its "industrial upgrading and economic transformation". Finally, by 2030, China wants to be "the world's primary AI innovation centre". ((Chinese) State Council, 2017) According to Graham Webster et al., the Plan's "specific and nonspecific goals, its bureaucratic positioning, and its long time-horizon make it an important reference point for a wide variety of policy, business, and security developments in coming years." (Webster, Creemers, Triolo, & Kania, 2017). By 2030, a high-level industrial AI park will have been built (through an investment of $2.1 billion) with 400 enterprises operating there. These companies are predicted to generate an output of $7.7 billion annually (Galeon, 2018). But while clear goals are set out, Webster et al. criticise the plan's lack of 'how' to turn these goals into reality. (Webster, Creemers, Triolo, & Kania, 2017)

Another key advantage China has is its population size. Through its large bureaucratic system, China is able to gather data from across the country. But Jacob L. Shapiro argues that if the country relies on bureaucracy to be efficient, it has a problem. The government's dependency increases on a well-functioning system. (Shapiro, 2018) So, is this involvement after all beneficial? In a country with 1.4 billion people (Worldometers, 2019) data collection must function well to truly gather representative data of the whole nation. Furthermore, many argue that China's success rate is stagnating, underlined by slower rate of economic expansion. (Wei, 2018)

Nonetheless, China has a large population, allowing for the gathering of a large volume of data. While data collection alone is not sufficient for AI expansion, it is still a key component of AI advancements. As previously mentioned, the more data available the more information can be collected and extracted for improvement, and thus China has a strong advantage over the United States and Europe.

2.5.2 United States of America

According to Bjørke and Ahmed, Cowboy Economics occurs when "you have depleted and devastated the current place and you simply break up and go west, for the next place to deplete" (Bjørke & Ahmed, 2011) In his article 'The End Of The Cowboy Economy' Stephen B. Shepard argues that the United States were reaching the end of this attitude. Further, according to Kenneth Boulding, the United States had "a frontier ethic of limitless resources" (Shepard, 1973). Limitless resources are often not paid much attention to and taken for granted. But modern developments suggest that the era of the cowboy economy is not over. It seems to have just transformed, at least from a European point of view. Shepard refers to the high use of raw materials such as gas and oil at low prices. Back in 1973, Shepard suggested stronger regulations, to ensure conservation of oil and to make other modes of transport more competitive.

Today, the new focus of the cowboy economy seems to be its financial means. Many private investors investing large sums of money and the display of little risk averse behavior has led to many technology developments. (The Economist, 2008) But not only large investments into the technology industry characterizes this type of economy. Also, the 'seeing how it goes' attitude of technology deployment is part of it. While discoverers, such as John Cabot and Christopher Columbus, previously invaded the USA without considering native Americans and their rights, the modern way of conquering is the deployment of new technologies in society without having done enough due diligence. (Maier, 2014) One example for this is Uber and its strong influence on the taxi industry. Germany for example banned Uber, as people wishing to drive people in exchange for money require a 'passenger transport license'. Uber did not consider this when entering Germany, allowing its drivers to 'chauffeur' without this license. As a result, they had to leave the German market back in 2014. But the company itself believes that these laws are outdated. (Maier, 2014) This kind of response suggests that the cowboy economy is very much still alive.

'The National Artificial Intelligence Research and Development Strategic Plan' is the American plan proposed for AI expansion. There are several objectives: The government desires long term investments in order to drive discovery and insights in AI. Furthermore, the United States do not intend to replace humans with machines or AI. Instead they desire an "effective method for human-AI collaboration". In 2017, Pew Research found that 70% of survey participants were worried about a "future where robots and computer can do many human jobs" (Anderson, 2017). It is imaginable that this point in the plan, was a strategic move to ensure wider acceptance of AI among the population. Replacement through machines is a wide concern of employees and could potentially hinder the adoption of AI within companies. Only recently the ethics behind AI has started to be a focus of AI research. The United States aims at “understanding and addressing ethical, legal and societal implications of AI” (National Science and Technology Council, 2016), as well as ensuring safety and security, so that AI can be “accountable, fair and transparent” (Cath, 2018). Just like the Chinese Plan proposes, the United States also wants to create an environment for AI training and testing, as well as being able to share public datasets. Further, they wish to create standards and benchmarks, just like China ((Chinese) State Council, 2017). This shows that in the end, there are key milestones that have to be achieved, in order to fully integrate AI in the economy. Lastly, the United States wishes to understand its AI related work force better. However, recent US immigration policy is putting a strain on talent sourcing. The H-1B visa required by foreign tech talent to work in the US is becoming increasingly more difficult to obtain. As a result, Canada is observing an increasing in highly skilled tech workers (Envoy Global, 2019). Overall, low risk aversion, strong financial means and the cowboy economic attitude mean that the United States is thriving when it comes to future technology development, especially AI. Or is it?

2.5.3 Europe

Europe on the other hand is struggling with its AI expansion. The strongly fragmented European research industry, as well as the new European Data protection laws, make the interaction between actors relevant for the development of AI increasingly difficult. As a result, the access to relevant AI components (data, tools and computing power) is yet another issue facing the German economy. Through the high costs associated with the deployment of AI in a business, the joint-work between providers is key (Döbel, 2018) (Chui, Manyika, & Miremadi, 2018).

European companies seem to act risk averse. They are afraid of carrying the risk of investing in a product where they could potentially fail, with market failure at the centre of their concern. (The Economist, 2008) Here also the lack of wealthy investors (such as in the United States) becomes apparent. However, in order to assure that Europe is not left behind, the following actions can be taken: First, it is important that European nations act together. Counting all Europeans, a size of almost 743 million inhabitants can be counted. (Worldometers, 2019) This has a big impact on data collection possibilities, can easily compete with the United States, and gets closer to China’s population size.

The second approach comes from Walter Eucken, who suggests then a mixed policy is critical for countries advancements. The central focus lies on splitting time, money and effort put into development, between two groups that are dependent on each other. Here, government and private companies act together to create the necessary environment to build up AI technology. Eucken stresses that the government should refrain from leading actual product development and operations. One of the reasons for a mixed policy is that the government may not know which direction a technology will go into (this would be the opposite approach of the Chinese). As a result, he proposes the corporation between public and private actors. The government becomes responsible for funding the infrastructure. Companies on the other hand should then invest their money into actually operating and advancing with the product. An example of this would be that the government providing the right environment for autonomous cars to drive on the road, while companies such as BMW or Volkswagen should invest their time and money into autonomous vehicle development. This way development is supported, without directly influencing future development, such as in China. Here again, the importance of a united Europe is important to provide sufficient financial means, as well as the right attitude so that Europe can improve its AI position. In the end, without infrastructure, operations may not be possible, while without operations infrastructure investments may not be desirable. Additionally, this approach can help reduce Europe's risk averse behaviour. (Eucken, 2004)

A key issue facing Europe and its AI development, is the new EU General Data Protection Regulation (GDPR), which came into force on 25th May 2018. It was put in place to protect individuals and give them more control over own data. The law requires explicit consent to process data of an individual. (European Union, 2019; EU GDPR.ORG, 2019; Burgess, 2019) As a result, AI concerning projects require extensive knowledge of the new law to enable proper AI expansion. While one could argue that this is beneficial to those the data and information belongs to, from the point of view of research and development it is standing in the way of economic expansion. Castro and McLaughlin highlight that it costs businesses a lot of money, due to new technology requirements, creation of new data handling policies, as well as hiring additional staff (some companies even have to create the position of a Data Protection Officer) (Burgess, 2019). A survey conducted by PwC found that 68% of the 200 US companies that took part, planned on spending $1 to $10 million to comply with European GDPR changes (Maiello, 2017). While the above-mentioned points impact technology advances as a whole, certain aspects of the regulation specifically target AI. Article 22 requires companies to have "humans review certain algorithmic decisions. This restriction significantly raises labour costs and thus creates a strong disincentive from using AI" (Wallace & Castro, 2018). This directly impacts Europe's ability to accelerate expansion plans, putting Europe further behind its competitors, making it more difficult to catch up with the government-controlled activities (China) or the more liberal attitude towards data collection (USA). Several questions are naturally being raised: Will these laws change again? Will there be exceptions? However, industry experts, such as Stephan Scholz of Volkswagen, do not consider this as an issue and instead just see it as a “small hurdle” (S. Scholz, personal communication, December 7, 2018) that can be overcome. Thus, we should not be concerned about how the new regulations are preventing us from collecting relevant data and slowing down AI expansion and instead focus on finding solutions to overcome this hick-up.

2.6 Future Outlook

Following David Ricardo’s theory of comparative advantage, trade should be conducted if a difference in unit labour requirement (how many hours of production are required to produce one unit of product) exists. (Krugman, Obstfeld, & Melitz, 2009, S. 26) If country A can product X at a lower cost advantage than Country B, but country B can produce product Y at a lower cost than Country A, the two nations should trade products X and Y, each producing the good or service they have an advantage in. (Suranovic, 2010, S. 67-68) Even if another nation does not have this labor advantage, but it still specializes in another good or service the more advantaged nation needs, it can still grow their economy, as “total world output of both products could rise” (Suranovic, 2010, p. 68), creating a comparative advantage for both and providing a key incentive for trade. When applying this theory to the current AI activities across the globe, financial or population ‘disadvantages’ in the form of lower capital or labor availability, as is the case in the European Union compared to China and the United States, thus does not automatically mean Europe is actually at a disadvantage, but that the countries within the European Union should come to an agreement of how to use their resources more efficiently to build a stronger AI network.

It becomes clear that the European Nation can only take the lead in AI development and expansion, if we run more data through algorithms at a lower cost. Instead of focusing on an individual country’s success, cooperation between nations should be supported. One example of this is the announced cooperation between key automotive players BMW, Volkswagen and Daimler. While until now they have insisted on strengthening the individual companies, companies are starting to work together to bring out future technologies’ full potentials. This new cooperation between competitors is starting to influence EU competition policies and placing governments in front of new issues. The next step for Europe will be to create large enough computing power centres, containing sufficient GPUs to run complex algorithms vital for AI activities.

Especially for businesses, PwC provides several suggestions for an improved and more efficient AI adoption. Key for the right choice of AI technology is to know the business and its industry. Foreseeing upcoming challenges, as well as opportunities will lay the foundation for the correct technology choice. This in turn requires knowledge of current and upcoming AI technologies in the market. Further, decision whether the company just wants to improve its business or be an innovator in its field is also critical but may also imply taking risks. Key is to collect the right data and knowing how to use it. Rao and Verweij highlight that consumer demand will be driven by an increase in product quality and product personalisation. Both will be achieved through proper AI adaption. To allow personalisation, companies must know their customers, achieved by collecting and successfully analysing data. (Rao & Verweij, 2017)

While it is possible to see Europe's large number of nations as a disadvantage for autonomous driving development, it can provide a strong strategic advantage. China and the United States each have different regions, yet overall have laws applying to the entire country. Europe on the other side is split into several countries, some of them with very different laws. This applies especially in the mobility world, such as the no-speed limit Germany vs. the very strict speed-limit enforcing Switzerland. When it comes to the use of autonomous vehicles, this will be especially critical. When a car crosses the border, it will have to adopt to local laws. In order to comply with different transport laws, a more complex artificial intelligence system will be required that not only has knowledge of local laws and driving behaviours, but also knows when to switch between them. One could argue that the system has to be smarter than those used in the United States or China. If the technology works on this entire continent, it should also work in individual countries, and should be seen as the product's unique selling point. Europe should use this as its advantage to gain back a leading role in the development of AI, especially underlining its strong reputation in the transport industry.

Lastly, linking back to the previous mentioned negative direction AI could go into, proper governance and control will be critical. (Rao & Verweij, 2017) If AI does not work properly and cause issues, media will pick up on it. A popular example already today are Tesla accidents over the past years. While car accidents tend to appear in local news, if at all, autonomous vehicles have made headlines across the world. And this is only at an ANI to AGI level. Once we reach ASI level and the technology creates biases or purposefully acts malicious, the danger and negative headlines increases, and reputations of companies and the technology (whether used for passenger vehicles, large public transportation networks or for machinery in logistics) will be severely damaged.

Overall, there is a lot of 'talk' on AI across governments, academia and the business world. As highlighted by the AI reports of Europe, China and the United States, each have their own goals and implementation plans, although they do overlap. For Europe, it will be critical for governments to work together, as well as key companies across the continent to offer support or at least focus on the inner-company integration of AI strategies.

Transparency will help future consumers to lower their scepticism of AI and start trusting the technology. Ellen Engel highlights that trust consists of two parts: trusting the technology and trusting the company itself. This trust can be gained through performance of AI as presented, that we understand the technology itself and that we believe that the technology is well intended. Further, Engel writes that only in conjunction with trust in the firm itself, future end-consumers will adopt the technology. (Enkel, 2017) Nations, as well as companies, aiming to use AI should however, clearly set a focus on what they are trying to achieve. Only with clear goals, a roadmap for AI inclusion can be set. It should also be recognized that quality of data is relative. In the case of automated vehicles, thousands of small scenarios must be assessed. Knowing which algorithms and data sets will be useful for a particular task will help in solving particular problems and increase the rate of AI adoption.

2.6.1 Managerial Implications

AI is disrupting economic foundations. Not only a continent- or nation-wide change must happen, but also companies and managers should prepare for the imminent technological change. An adjustment of managerial behaviour will be essential. First, companies' national competitiveness levels need to be opened up to a more European approach. To compete with its international competitors, doing business alone will no longer be sufficient to obtain 'critical mass' of potential data access and financial means. Instead of seeing other European companies, or nations, as a threat, they should be considered as allies and companies' strategies must be adapted accordingly. Further, leading by example, higher management must also reflect upon these orientation changes within their day-to-day work to create a trickle-down effect to lower ranked workers. Additionally, the introduction of new technologies often causes concern among employees. Whether being unsure how to use a particular new software, or even worrying about job security, a lack of acceptance within a company can hinder the success of newly introduced measures. In order to ensure that AI has its intended effect, managers must prepare their teams. Explaining AI's intended use and teaching how to use it, while also accepting and counteracting people's concern, can help employees to feel more at ease about the changes. Overall, change management across all levels of a company, will be key. But these changes should not be seen as threats, but instead seen as an opportunity to grow.

2.6.2 Limitations and Future Research

China, USA and Europe are seen as the strongest AI developers in the world. However, the competitor list is longer than just these three nations and other nations should be considered in the race to the AI front. Especially within Asia, the competitor list is long. South Korea and Japan both released research and development strategies for AI in 2018. Both nations are also known for their technological drive and competitiveness and are thus also strong competitors for Europe. But through the population size of China, as well as the governmental influence within China, the Chinese nation can establish itself as a single competitor to Europe. Even if Europe pools together its population it is not able to reach the same data pooling opportunities. Therefore, this paper focused only on China rather than Asia as a whole.

Given the European Union – Japan Partnership agreement, which is the world's largest open economic area, and the Free Trade Agreement between the EU and South Korea, instead of seeing Japan and South Korea as further threats, Europe could consider them as potential European allies. The next research steps should include a substantive assessment of whether it would be of benefit to pursue European – Asian AI alliances and together compete against China's growing AI power.

2.6.3 Final Thoughts

Artificial intelligence is key to thriving in the transportation industry and the future business world. While we are currently at an ANI level companies, industries and whole nations are working tirelessly at creating at least an AI system that competes with humans, and eventually can excel us. While this brings many benefits, we should also be cautious. Regardless of concerns, is not an option to not take part in the race to become a key player in AI across the world. Europe should look at the assets it can create through the development of a more intelligent AI system compared to China and the United States. Through this, it may be able to compensate its lack of financial means, as well as population size of its competitors. The European commission released its "White Paper on Artificial Intelligence – a European approach to excellence and trust" at the beginning of February 2020, arguing that Europe has to act as one instead of focusing on the single markets (European Commission 2020). This recognition will be key in driving Europe forward to ensure it stays just as smart as China and the USA.

3 The Knock-On Effect of Introducing AI as a Supply Risk Optimiser - How Implementing AI Can Assist Companies to Endure a Crisis

3.1 Journal Publication Information

This paper, written in co-authorship with Prof. Dr. habil. Wolfgang H. Schulz, was accepted by the International Journal of Business Strategy (1553-9563) on 21st December 2020 and published in the International Journal of Business Strategy, Volume 20, Number 1, on 30th December 2020.

Full citation: Edye, C. F., & Schulz, W. H. (2020). Time to Return to the Driver's Seat – Implement AI as a Supply Risk Optimiser to Manoeuvre out of the Crisis. *International Journal of Business Strategy*, 53-64. http://dx.doi.org/10.18374/IJBS-20-1.5

3.2 Abstract

2020 has been the year of unexpected changes. While the COVID-19 pandemic caused businesses and entire economies to struggle, it also acted as a catalyst for digitalisation and a rethinking of strategies. This paper focuses on supplier risks, such as the pandemic, within the automotive industry, and how Artificial Intelligence (AI) can help struggling companies get back on their feet post pandemic. A total of 25 companies within the automotive supply chain, from OEMs to TIER 3, were asked about their impression of supplier risk developments in a qualitative study. After breaking down the companies' focuses on various supplier issues, the integration of AI within the business was considered. It is clear that despite positive attitudes and perceptions of AI, companies are hesitant to share AI-related information. With supplier risks having increased over the previous years, and an increasing belief that it will further increase over the upcoming years, AI will become a key player ("game-changer" as quoted by a TIER 2) in supporting business activities to smooth out potential issues. However, to the outside high costs and low willingness to integrate AI can be blamed, but through deeper questioning the silence surrounding AI should be seen as a strategic decision to get an advantage over competitors rather than a pure lack of knowledge and integration. With COVID-19 having changed the mobility world drastically, now is the time to act. Despite AI requiring large investments, the payoff, in the long run, will help companies get back on their feet by improving their supplier risk management through information gathering and evaluating, as well as enabling an early warning system to prepare for problems before they arise.

Key words: Supplier risks, Pandemic, Artificial intelligence, change

3.3 Introduction

2020 has been the year of many unexpected changes. As the SAR-CoV-2, also known as COVID-19 or CoronaVirus, swept across the globe, the mobility world came to a halt. People stopped short- and long-distance traveling, whether by plane or public transport, and started working from home. As a result, mobility companies across the various sectors within have struggled. Entire productions of vehicles were halted, such as Volkswagen suspending production across plants worldwide in March 2020. Some plants remained closed for up to 10 weeks, and when production returned only continued at a 60% to 70% capacity rate (Volkswagen AG 2020). Automotive manufacturers such as Ford raised money from debt investors in order to have sufficient liquidity to overcome the crisis (White 2020). The production suspension caused manufacturers and OEMs to suffer. While a national lockdown may not have been avoidable, there is a measure companies can take to prepare themselves for a crisis: incorporating Artificial Intelligence (AI) within their companies can support various departments and thus the company as a whole to pre-emptively and reactively help the companies to overcome difficult times.

The COVID-19 pandemic may have resulted in companies struggling with the production of their vehicles, as well as to have sufficient financial means to ensure payment of workers and other critical components relevant to the production and sales of their vehicles. Instead of being worried, manufacturers and suppliers should take this as an opportunity to rethink their strategies and integrate new innovations to help them thrive. The companies which already have AI integrated now benefit from the control mechanisms it provides them, such as assessing their costs and losses better than others. They now have the first-mover advantage, come out of the crisis (financially) stronger and can focus on expanding AI and thus set themselves further apart from their competitors. While companies may want to save money now, this could be a critical time to invest in technology that will save them money in the long run. AI investments require large initial upfront payments but may provide companies with improved insight into their business and processes.

AI can support companies in various ways, from the integration of automated machinery to software helping with processes within departments. An example of this would be an AI that can help them assess the production and movement of parts necessary for the manufacturing within the company and from their suppliers. Further, AI could gather and evaluate information from suppliers. Through this, companies are provided with supplier risk information, allowing the company to act accordingly and minimize the possible threat and damage. Through globalization and the trend of outsourcing, companies become increasingly international and dependent on each other. This can create greater supplier risks, making a greater overview of suppliers and economic and environmental influencing factors essential. If companies integrated AI within the supply chain department, this insight would allow them greater information influx, evaluation, and ultimately control. But how are supplier risks actually perceived? Are companies prepared to counteract them? And lastly, to what extent has the automotive industry already integrated AI to help them? Using a qualitative study, this paper will assess the German, Swiss, and Austrian industries' approach to supplier risks and AI readiness, as well as argue why the integration of AI will be a vital investment that will pay off in the long-run.

3.4 Literature Review

3.4.1 COVID-19

COVID-19 drastically changed the mobility world as we know it. While planes allowed us to travel to the other side of the world within 24 hours, it also allowed the pandemic to spread like a wildfire. From standing shoulder to shoulder in packed underground trains or busses, we are now afraid of leaving our houses, even seeing our closest friends and families as potential carriers of the virus. As a result, local and global travel decreased drastically. Airlines across the world had to drastically reduce their operating rates, some were even down to single percentage capacities, such as Cathay Dragon that operated at 3% in 2020 (Lei 2020). As a result, several airlines went bankrupt, including German LGW or Virgin Australia (Begley Bloom 2020) (Reuters Staff 2020). Further, transport companies, such as Transport for London (TfL) reported a 95% decrease in journeys (Transport for London 2020). E-Scooter companies such as Bird and Lime temporarily discontinued their service. German company TIER however continued their service and even provided 'system relevant' workers, such as nurses and police officers, free rides (Tier 2020).

Despite pre-pandemic government efforts to encourage people to travel using public transport, a clear move back to private passenger vehicles could be observed during the pandemic. During the German summer holidays, a reduction of only 3% fewer cars traveling to their destination could be observed. While many decided to stay home, those that would normally have travelled internationally or flown to their destination were now using their car to travel to their national and European destinations. As a result, the traffic data recorded during the 2020 Summer holidays only experienced a small decrease (ADAC 2020). The mobility world is now moving from a renaissance from public transport and bike to the renaissance of private vehicles. While it is unclear if this is a temporary development, it is possible that the pandemic will influence us to start using our private vehicles more in the long-run. As a result, our assumptions for the future mobility world, where self-driving cars will be shared and owned by companies rather than individuals will not be met.

Instead, the automotive industry may have to focus on a higher number of automated vehicles being sold to private owners.

3.4.2 AI

The COVID-19 pandemic resulted in a digitalization move within the German economy (Erdsiek 2020). While this may have been forced as a result of an increase in home-office work, the effect is highly beneficial in the potential AI adoption in the long run. According to a study by the World Economic Forum conducted in 2020, 85.7% of companies that participated are looking to speed up the digitalization of work processes. Further, 77.1% want to offer more home-office opportunities. The Digital Quality of Life Index puts Germany's digitalization efforts only at 16th place. Lead by Denmark, Sweden, and Canada, the index measures aspects such as the available digital infrastructure and cost of the internet (Surfshark 2020). If the foundation for digitalization and thus AI are already falling behind, the actual integration of AI in the long-run can become difficult. But the pay-off of digitalization can already be seen in the nation. Already before the pandemic, 44% of German companies were able to increase their revenue due to digitalization (Käufer 2017). This should encourage companies across the country to consider improving their own digital infrastructure, and ultimately foster the integration of AI.

While this benefits the economy's digital infrastructure, more home office opportunities may mean less mobility movement, which will negatively affect the mobility industry. However, very promising is the wish to integrate AI within the industry by 2025 by 76% of participating automotive companies. Further, 60% of automotive companies wish to integrate robots, such as industrial automation, further showing a recognition of the potential integration and influence AI may have on the industry. But barriers to adoption have already been identified, putting a "skills gap" of the local labour market and the organizations' leadership, as well as "inability to attract specialized talent" at the forefront of making AI integration more difficult. However, as these difficulties are already on the companies' radars, they are able to focus on these to make sure AI will be integrated smoothly. (World Economic Forum 2020)

But what actually is AI? AI can be split into three categories: Artificial Narrow Intelligence, Artificial General Intelligence, and Artificial Super Intelligence. While AGI is set to mimic human intelligence, such as being able to conduct deductive reasoning, ASI is more intelligent than humans. But AGI and ASI are still years away from being developed and integrated. ANI however is already used today and can be found in smartphones through virtual assistance, such as Siri and Alexa, or robots, such as the transport robots of travel retailer Gebr. Heinemann at Oslo Airport that move goods from the storage facility closer to the sales area. ANI follows the rules it was programmed with, capable of only one task at a time, such as checking the travel distance of a journey or gathering information and filtering the important aspects. Integrating AI into a company requires knowing exactly what the goals of the integration are. KPIs can be assessed, information selected, and machinery processes improved. In order to get the full potential out of the technology, the more specific a company is with its intentions, the better.

From process optimization, such as a more efficient way of filling out forms, to better marketplace analysis or even the introduction of machinery, both software and hardware can be optimized, making the usage areas vast. With AI being a new area of knowledge, knowledgeable workers are scarce. Further, including AI within a company requires large financial sums. The acquisition and maintenance of the computing power is important, and the more algorithms are required to run simultaneously, the greater the need for more GPUs, making the investment costly. Further, the creation of the algorithms used for goal execution have to be created and the code written, requiring AI experts to create the right concepts and computer scientists to write the code. Lastly, data is critical. While traditional demand and supply rules suggest that the scarcer something is, the greater the value, data for AI follows the opposite. The more data a company has, the more precise the outcome will be, thus the larger a set of data, the more valuable it will be. While the 2000s followed the trend of mass data, in order to fully integrate and successfully execute AI, knowing and collecting the right data will be key.

3.4.3 Supplier Risks, AI and COVID-19

In recent years, the established automotive industry started changing. Through the introduction of electric cars and an increasing focus on fully automated cars, a shift from purely hardware to hardware and software components can be observed. This opens up the market to new players, such as Tesla, which do not have a long-standing history of automotive knowledge. Through this market entry barriers were lowered, further disrupting the market. The change in connection with a greater sourcing pool, made possible through globalization, increases companies' concerns regarding their future. Through long production chains and thus dependencies, a smooth production process is at risk. In the automotive manufacturing world of the 20th century, vehicles have not only become more technology-heavy, but also rely on a large number of suppliers. As globalization and outsourcing increased, the dependency of companies on each other grew. As a result, having a clear overview of the various component suppliers is key in order to avoid supplier risks, such as potential bottlenecks or even production stops.

Supplier Risk is one of six internal company risks (operating risks, sales risks, financing risks, personnel risks, research, and development risks). In recent years, supplier risk has risen drastically. While this is also due to environmental influencing factors, geopolitical uncertainties, as well as the interconnectedness of economies and businesses, are all to blame for companies' vulnerabilities (Alicke und Strigel 2020). Advantages of scale no longer exist which means that even large companies cannot fully compensate for the impact caused by supplier risks. The reliable and trustworthy prediction and forecasting of supplier risk will become increasingly critical. With Artificial Intelligence (AI) a new technology exists which enables new possibilities to reduce substantial risks. Supplier risks become increasingly critical in the future and with AI, forecasting can be improved, and that the intensity of supplier risk issues can be reduced or even avoided. However, firm restrictions exist hindering the practical usage of AI. We assume that on one hand the automotive companies have an increasing supplier risk in the future. On the other hand, AI may be the solution to this problem. But companies do not have the skills and abilities to use AI in the most appropriate manner, whether strategically or technologically.

The pandemic pressured companies into re-thinking their current strategy and consider their long-term strategic options. At this point, we cannot say whether COVID-19 resulted only in temporary developments, or a long-term change. But no matter the outcome, the automotive industry has to prepare to get back on its feet past the pandemic. Integrating AI as a supporting system in any automotive company, whether OEM or TIER3 supplier, will help the automotive industry as a whole. Especially in supply chain management, AI has a large potential to improve risk assessment, as large volumes of information can be processed and interpreted in a shorter amount of time. For those companies investing in AI at an early stage, this can provide the company with a strong strategic advantage. Having information about a steady flow of the supply chain will be critical in not only getting cars on the road as the economy recovers from COVID-19 but also allowing a stable supply stream for the future.

3.5 Methodology

In order to assess the perception of supplier risks, supplier risk minimizing activities and integration of AI within the automotive industry of the DACH region, a questionnaire for a qualitative study was constructed.

3.5.1 Questions

A vast array of questions were asked to create an insight into the companies' perspectives on supplier risks and AI. "How do you assess the significance of Supplier Risks for your company in 2019/20?" And "How do you assess the significance of Supplier Risks for the automotive industry in 2019/20?" assessed the perception of the industry as a whole versus the influence on the own company. Further, "How have the Supplier Risks changed over the past 5 years?" and "How will Supplier Risks change over the next 5 years?" provided an insight into anticipated supplier risk changes.

"How do you currently handle Supplier Risks?", "How strong is the impact of the following Supplier Risks for your supply chain? : Supply chain disruptions because of unstable logistics ("bottlenecks" time/quantity) / quality/insolvency or bankruptcy/fraud/hostile takeover?" and "How much do you focus on the following Supplier Risks:: Quality & Production Performance / financial stability/logistics risks (pandemic, force majeure, etc.) / market risks (e.g.: Brexit, economic downturn) / compliance & reputation?" focused on the possible supplier risks facing a company and their impact.

To assess the insights into the company's suppliers, "How far is your visibility of your suppliers' network?" and "How deep should the visibility of your suppliers' network be, if possible?" were asked. They allow a comparison between reality and ideal. "How many levels of your suppliers' network are you currently monitoring?", "Do you have an early-warning system, alerting you of a potential suppliers' Risks? (e.g., monitoring tools, employee(s) assessing potential suppliers' risks, etc.)" and "What is the depth of your financial stability monitoring of your supplier?" established an outline of the company's supplier focus.

"Who is responsible for the Supplier Risk monitoring?", "On what information are you basing your evaluation of your suppliers' financial situation?", "Do you have a dedicated Crisis Team in place, which acts when a Supplier threatens to become a risk for your continuous production objective?", "Are your employees trained to handle supply chain crises caused by your suppliers?", "How do you help struggling suppliers?", "Which measures could be part of your support for struggling suppliers?", "How would you rate your success at maintaining a seamless production rate?" and "What is your success rate at avoiding adjustments to your production programmed due to an emerged Supplier Risk issue?" all assessed how the companies handle issues that arise. "Do you use dedicated tools for monitoring suppliers' risks and if yes, which tools are in use?" not only revealed specific tools used for assessment but also set the ground for AI-related questions.

After assessing the companies' supplier risks attitude and behaviour, AI-specific questions were asked. "Are you familiar with the use of Artificial Intelligence (AI) in the business context?" and "According to your opinion, how significant will the impact of AI become?" were asked to all participants, to see the general understanding and perception of AI by participating companies. However, all questions after "Are you currently using AI in any of your departments?" were only inquired about to companies that already had AI integrated in their company were asked.

"If yes, in which department?" and "Do you use Artificial Intelligence tools to minimize Supply Risks?" were key goals to assess how AI is integrated into companies. "Are you satisfied with the AI tools you use?", "What is the purpose of your applied AI tools?" were specific questions towards companies that not only integrated AI but also used it within the Supply Chain Department. The company that did not use their existing AI system for supply chain issues was asked "Would you like to use AI tools for Supplier Risk minimization in the future if available?" and "Why have you not yet adopted AI tools for Supplier Risk minimization?" to get a deeper understanding of why the technology has not yet been adopted despite already being used within the businesses.

"In what area(s) is or will AI be a significant technological progress in the field of supplier risk monitoring and prevention?" was the final question asked to all participants. Possible answers included "Information gathering about suppliers", "interpret relevance of information gathered", "create a risk prognosis for suppliers" and "create risk assessment regarding markets". Also, additional answers could have been provided. Through these participants' opinions towards supplier risk management and AI could be evaluated.

3.5.2 Key Study Assumptions

All questions were asked to confirm or reject the assumptions of the development of supplier risks within the automotive industry:

- Supplier risks have increased over recent years.
- Supplier risks will increase in the upcoming years.
- This will be affecting individual companies more and more and thus become a greater focus area for companies.
- Companies handle supplier risk issues reactively.
- There is limited visibility towards suppliers.
- There is a greater wish for visibility and transparency between buyer and supplier
- The majority of companies do not have an early-warning system for supplier risks
- The majority of companies do not have employees focusing only on supplier risks

- The ability of companies to react to supplier risks has the potential to increase.
- AI activities can create a strategic advantage
- AI is not integrated into business activities / strategic management processes
- Companies will invest in AI in the upcoming years

Some questions asked were part of the general survey and thus evaluation was simpler, and answers could be compared to each other more easily. However, throughout the interviews, additional comments were made that were taken into consideration in the discussion section to reflect further upon the answers given to the general questions.

3.6 Results

A total of 25 high ranked employees and managers of German, Austrian and Swiss companies along the automotive supply chain were interviewed, of which two (8%) are OEMs, 11 (44%) are TIER1 and 12 (48%) are TIER2 suppliers. 60% of companies have a revenue volume of at least 3 billion Euros. 60% of participants had a revenue of over at least 3.000.000.0001 Euros.

16% of participants assessed supplier risks to be of low significance for their own company, 52% as medium, and 32% as high to very high. However, 48% believe the influence of supplier risks to be of medium significance for the entire automotive industry in 2019/2020. 52% even assessed it as high or very high significance. No participant perceived it as low or very low significance. Almost all participants, 92%, observed an increase of supplier risks over the past 5 years, and 100% of participants state that supplier risks will increase or strongly increase over the upcoming 5 years.

The quality impact would have a medium impact on 60% of the participants, 28% high, and 4% very high impact. Insolvency would affect 60% of participants with medium strength, and 20% with high or very high strength. Also, fraud would result in a medium impact on 56% of participants, and 24% in a high to very high impact. Hostile take-overs would have a higher impact than the other potential supplier risks, with 48% perceiving it as medium impact, but 28% as high and 8% as highly impactful on the business. However, unstable logistics is the main concern of participants. 20% perceive them as medium impact, 36% as high impact, and 44% as a very high impact. Supply chain disruptions because of unstable logistics are the companies' biggest concern.

44% of participants have an early warning system alerting them of potential supplier's risks. Out of the 11 companies using monitoring systems, between 4 to 20 employees are engaged in the Supplier Risk Management of the company. One interviewee could not "share the number". 56%

do not have an early-warning system alerting companies of potential risks occurring. 32% have dedicated employees responsible solely for supplier risk issues. 20% have employees that also work on supplier risks and other supply chain-related tasks. A further 20% see supplier risk management as part of their supply chain department without having dedicated employees. Lastly, 28% have no dedicated employee, department for Supplier Risk monitoring or management. 12% handle supplier risks issues pre-emptively, 76% reactively and 36% handle issues before and after they have occurred. Overall, 40% of participating companies monitor TIER 1 suppliers. TIER 2 is monitored by 44% and a further 16% monitor TIER 3. When being asked about their preference towards visibility, 68% would like to monitor at least as far as their TIER 3.

Supplier risks monitoring includes observing quality and production performance (32% focus on this a lot, 64% see it as a key focus area), financial stability (12% focus on this a little, 60% neither a little nor a lot, and 24% a lot), logistic risks, such as a pandemic (12% neither a little nor a lot, 46% a lot and 52% see it as a key area), market risks, such as Brexit or economic turn down (4% not at all, 36% neither a lot nor a little, 52% a lot and 8% key focus area) and lastly compliance and reputation (4% not at all, 32% neither a lot nor a little, 56% a lot and 8% key focus area). Further, regarding the suppliers' financial stability, 20% monitor the financial stability of all Tier 1 suppliers and selected suppliers beyond TIER 1 that are critical to the company's supply chain, 28% monitor main suppliers and 52% do not monitor any of its suppliers' financial stability. Included in the financial stabilities monitored, 56% assess balance sheets and publicly available information, 12% assess the information provided by credit agents, 20% look at the management accounts of suppliers, and 52% have further checks. Further, 60% of participants do not use any monitoring tool as support. While 28% use the software Riskmethods, 12% of participants stated using Google as a dedicated tool for supplier risk monitoring. 20% stated using other monitoring tools but chose not to provide details about which software they use.

36% of participants have a crisis team in place that will act when a supplier threatens to become a risk for the company's continuous production projective. 72% trained their employees to handle supply chain crises by their suppliers. 24% will offer on-site support, 36% will help remotely, while 56% do not support struggling suppliers. This help may include technical/management support, short-term liquidity protection, and long-term financial support optimization/continuation, such as purchasing of a supplier or mergers & acquisitions. Overall, participants stated their success rate at avoiding adjustments of their production programme, due to an emerged supplier risk issue, has highly successful. Only 12% stated to having a medium success rate, while 52% of companies rated their success as high and 32% of companies as very high.

3.6.1 AI

36% of participants were somewhat familiar with AI in the business context. 40% were moderately familiar while 20% were extremely familiar. Only one company was only slightly familiar. The significance AI will have is seen as a medium by 8%, high by 56%, and very high by 36% of participants. Currently, 44% have incorporated AI in any of their departments. AI is integrated into Marketing, Quality Management, Customer Service Supply Chain, and further departments not specified. 12% use AI in the Supply Chain department to minimize Supply Risks. Out of these three companies, two are satisfied with the tool. In two companies, AI is applied for information gathering about suppliers, interpreting the relevance of information, and gathering for risk assessment. All three companies are using AI to create a risk prognosis for their suppliers. The company that uses AI in the supply chain department but not to minimize supply chain risks would like to do so in the future. The reason mentioned for not having AI integrated yet is that they do not have enough knowledge of available AI tools and also experience low acceptance of the company towards integrating AI.

Participants see AI as useful tools to gather information about suppliers, interpret the relevance of information gathered for risk assessment, create a risk prognosis for suppliers, and create risk assessments regarding markets.

3.7 Discussion

This paper assessed how supplier risks are perceived within the automotive industry, how companies within the automotive industry are handling them, and the perception and integration of AI within the participating companies as support to their current activities. As the frequency of remote work increases in 2020, and most likely will remain for the near future in many sectors, AI could be of immense assistance. Through the speed at which AI can process information, anomalies within data can be found quicker, as well as development pictures of a supplier or the industry as a whole being spotted as soon as possible.

3.7.1 Supplier Risks Perception and Concerns

Overall, Supplier Risk assessment has shifted over the years. While the significance of participants' companies was assumed to be between low to high significance, the overall assessment for the automotive industry as a whole reveals a more intense picture. The data shows that companies consider supplier risks to be of lesser significance for them compared to their allies and rivals, and the industry as a whole.

Participants were asked about different factors impacting supplier risks for their supply chain. A total of 80% believe that unstable logistics are the key issue for their supply chains. While quality concerns are also raised, the more interesting answer seems to be regarding the concern of hostile take-overs occurring. This result may reflect the worry of automotive players and hints towards a shake-up within the industry. Regarding focus areas of concern, 64% critically assess quality and production performance, and 52% focus on logistic risks. The majority answering with 'neither a little nor a lot' towards the question of financial stability being a focus of supplier risk for the country, suggests that this is a constant point they measure, which should not be forgotten about but does not receive particular attention either. This falls in line with previously made statements of which factors are considered to strongly influence potential supplier risks. Lastly, with the changing political landscape across the globe market risks (such as Brexit), and compliance and reputation, are focus areas for over half of the participants, however, are not a key area.

Companies would like to have a better understanding of their suppliers and be able to see as far as Tier 3. This suggests a desire for greater transparency in their supply network. When broken down to which level of supplier they actually monitor, 60% only go as far as TIER 1. AI would enable a better flow of information between the TIERs and OEMs. Financial stability is a good indicator of a company's success and overall health. Yet, 52% of participants do not monitor their suppliers' financial stability. The other half focus on their main suppliers, as well as 20% even going further than TIER 1 to ensure their production runs smoothly. 56% of participants base their evaluation on publicly accessible data. AI would allow the companies to analyse data better, and immediately raise areas of concern.

Further, one-third of companies have a crisis team available as further support. Through this, the company can ensure that production is seamless, reducing supplier risks when they occur. While not all have a team available, more than two-thirds of participating companies however have at least an employee able to handle crisis situations. With the strong dependencies of buyers and suppliers, support seems to be a key issue to overcome supplier risks. But support among companies varies greatly. Apart from the 56% of interviewees that do not help their suppliers at all, 20% of participants help their struggling suppliers remotely from their office, 8% purely on-site support, and 16% on-site and remotely. Various support measures are taken. This includes technical and management support, short-term liquidity protection, as well as longer-term financial support. But looking at the circumstances the industry is faced with in 2020, and travel being discouraged or no longer an option at all, the crisis team has to handle all issues remotely. Having a stable digital infrastructure will have helped automotive companies to have a softer fall during the pandemic, as the requirements for working from home would have already existed. Companies without this infrastructure will have struggled severely trying to set up the home office foundation as quickly as possible.

3.7.2 AI – The Technology That Shall Not Be Named

During the survey period, one OEM had a significant problem because two suppliers went bankrupt and were unable to provide the OEM with important components. There was no sign of this failure. The planned processes to estimate risks had not provided any indications. When asked about steps to solve the issue, the OEM said: "We continue to produce without the parts being installed. We have delivery difficulties and have to store the cars temporarily. What do we do? We always form ad hoc crisis teams, but the focus is to seek replacements for the supplier instead of helping them." Further, one of the TIER 1s also suffered from the insolvency of two suppliers: "Unfortunately, we have only a weak early detection method. We are not prepared to help actively. The first solution is installing crisis teams." It is possible that if both had integrated AI earlier, they may have been able to detect these supply issues before it became a knock-on effect for them.

Several interviewees pointed out that providing answers to the AI-related questions was not possible. Many interviewees hesitated when asked if AI is used within their company. A TIER 1 manager said that "if I told you that we already use AI, I might start an avalanche and we lose our competitive advantage". The fear of providing too much information that could be useful for the competitors leads to 84% of the respondents not wanting to answer the question of whether they use AI to minimize supplier risks. Accordingly, it is clear that 88% of the questions related to AI were not answered. Furthermore, 96% were unwilling to share whether they want to use AI tools at all.

When answering this question, interviewees often came up with the answer that they already know the relevant suppliers of AI tools, but there is a great fear that they will tie in too early. They want to avoid a lock-in effect. The bigger the firm size, the more likely it is to buy AI tools. However, mainly TIER 1s fear lock-in effects, occurring through the decision of choosing one AI tool, and related hard- and software, over the other. Therefore, they want to avoid a decision that is made too early. However, the longer they wait, the lower the competitive advantage they can gain using AI. To lower the fear of choosing the wrong AI tool, the willingness to pay for external consultancy is growing. Overall, this strategy might lead to higher costs but avoids a prolonging of losses. Trust is a key issue when choosing providers of AI. Many TIER 2 and TIER 3 are concerned about recent developments regarding HUAWEI, as they are taking a lead role in 5G network expansion in Germany. Concerns focus in particular on server locations and handling of data. Further, some suppliers do not like that Volkswagen has such a close relationship with the American company Amazon, as they would prefer at least a European player.

A strong tendency of suppliers to improve the company's overall IT system, including digital knowledge and application, before considering the integration of AI tools, was evident. On top of that, it is important to know what 'problem' should be solved using AI before purchasing an AI tool. A particular TIER 2 decided to train its employees, improving their AI skills. Reference was made to the example of SAP, which set up a digital academy for its employees. Often, employees fear that AI will take away their job. But workforce acceptance of AI is key, to ensure that its full potential is unfolded. The knowledge gap, such as awareness of benefits AI may provide for the worker, can be closed by introducing such digital academies for education purposes. Due to the large investments required to purchase AI, purchasing decisions are done by the key decision-makers. Their decision however is often based on information provided by different departments within the company. By training employees, ideal decisions of what is needed can be made. This again leads back to having a knowledgeable workforce, further strengthening the need for spreading knowledge about Al.

If one interprets the answer behaviour economically it is evident that individual decision-makers do not have knowledge of the probability distribution of the outcomes of using AI tools. Due to the uncertainty of the outcome, the risk preference of the decision-maker is influenced. Although using AI has the highest expected profit, it becomes certain that because of the missing knowledge of the outcomes they will not invest in AI. It is apparent that enabling AI investments requires knowledge on AI which is practically difficult to obtain. Firm size and financial resources play a key role in the integration of AI within a business.

3.7.3 AI: OEM vs. TIER 1

The following text reflects participants that provided AI-related information.

The purpose of those including AI in their company is to gather information about their suppliers. This in turn supports the desire of being able to get a better overview over their suppliers and to actively reduce supplier risks. The spread of AI integration is balanced among OEMs and TIER 1s. This shows that AI is not limited to a specific value chain and instead already today can be applied to various areas of a supply chain. However, as expected at this early stage of AI integration, all companies actively using AI have the financial capacity of being able to include and operate these technologies. All companies have revenue above 5 billion Euros. The companies are investing in

AI, despite having different perceptions of supplier risk change. This suggests that despite experiencing and observing supplier risk not only over the previous 5 years but also the expectations for the upcoming 5 years with different intensities, it does neither encourage nor prevent AI from being included within the business.

AI allows companies to act pre-emptively, especially compared to the 64% of participants that act reactively to supplier risks occurring. This suggests that AI may reduce the intensity and potentially even prevent supplier risks from disrupting a supply chain. All AI using companies have early warning systems installed. Already today their visibility of their suppliers goes at least as far as their TIER 2, however all wish to be able to get an insight into further TIERs. At least 20 employees are engaged in supplier risk management, but some were reluctant to share exact employee numbers due to concerns regarding information sharing with competitors. Further, the importance of supplier risk monitoring is underlined by having employees specifically employed for supplier risk monitoring. As a result, all have dedicated crisis teams, as well as trained employees to act when supplier issues occur. While the OEM handles issues from its own office and may also provide long-term financial support, the TIER 1 also offers on-site support, as well as short term financial and technical/management support.

Despite sharing many similarities, each company revealed different areas of supplier risk focuses. In particular logistic risks were of concern for the OEM. This may be due to the majority of OEMs assembling vehicles, instead of producing particular parts themselves. This increases the dependency on their suppliers, making logistical issues a threat to their success. For TIER 1s however, quality and production performance are of greatest concern. OEMs may put pressure on TIER 1s to produce and provide only the highest quality goods. Thus, TIER 1s put a greater focus on the goods they receive from their own suppliers. Further, in particular, the OEM using AI is concerned about a hostile take-over occurring. While this on one hand can disrupt its own supply chain, it can also lead to losing important technological know-how. Further, it may also enable competitors acquiring said supplier to gain a greater advantage over them. The gain of power of the acquiring company weakens the bargaining power of the OEM and influences its profit margin.

As a result of incorporating AI into their business, all companies are very confident about being able to maintain a seamless production rate, as well as being able to adjust their production programme. This may be due to being able to observe and address potential supplier risks early. This in turn allows them to react accordingly, and with enough time. When going into details regarding its supplier risk monitoring tool, all companies did not reveal the exact name. This again highlights the secrecy surrounding the topic. This shows that companies consider AI as a competitive advantage. The companies have not reduced the use of AI to the supply chain department, but also use it for quality management, marketing, and customer service. The tools are being used for information gathering about suppliers, interpret the relevance of information gathered for risk assessment and creating a risk prognosis for suppliers.

3.7.4 Managerial Implications

AI integration within the automotive industry must be communicated openly instead of making decisions behind closed doors. From OEMs to TIER 3 suppliers, all levels could support each other by integrating process optimisation tools such as the supplier risk minimisation measures touched upon in this study. But in order to ensure companies across whole automotive industries are supporting each other, the fear within individual companies towards the new technology possibilities must be taken. Workers are concerned about being replaced, which threatens the proper integration of AI. But right now, AI integration would not be possible without humans and thus they must learn to accept them (Duranton 2020).

Further, in order for the German, Austrian and Swiss automotive industry to progress and to keep up with competitors from international automotive industries, European nations should not focus on single market strategies, but use their European interconnectedness to drive AI integration forward. Through measures such as joint computer processing centres, financial investments necessary for AI infrastructure creation can be pooled. However, this is only possible if countries recognise that they need to pull on the same strategic strings instead of seeing each other as competition.

3.7.5 Study Limitations and Future Research

This study reflects on the AI integration within the German, Austrian and Swiss automotive industry. But how developed is the integration of AI within other strong automotive industries? While the USA is known for its risk-taking attitude and entrepreneurial strive, China is very open with its AI plans for the future. Both nations are key nations in the field of AI development. Are their automotive industries also trying to minimise the attention given to AI to gain a strategic advantage, or have they got a more open approach towards integrating AI for process optimisation, such as in the supply risk area? This study should be repeated in additional regions to draw a comparison between strong automotive industries' use of AI.

3.7.6 Final Thoughts

Overall, supplier risks have grown and will grow over the upcoming years. Whether OEMs, TIER-1 or TIER-2, AI will play a key role in reducing supplier risks in the future. Even though the exact number of companies already using AI tools is unclear, there are more businesses already using the technology than they lead to believe. Actively not answering an AI question, suggests that there is a strong likelihood that they have integrated AI already, but do not want to share their competitive advantage with their rivals. At the same time, this may also be done to hide AI inactivity, to not show any signs of weakness to their competitors.

It is clear that the companies that already invested in AI before the COVID-19 crisis will have a better overview of the current threats facing the supply chain and the company. It will ultimately have improved the company's readiness for supplier risks and enable them to get on their feet quicker as the pandemic passes. One could even argue that companies that had a good strategic management team already invested in AI 5 years ago and thus subconsciously prepared for the strategic long run, as well as crisis times. However, as we cannot turn back time, we must look into the future and prepare the automotive industry to anticipate and survive crises better. While the financial burden may be large, and employees may need to be convinced of AI's use, especially during times where companies are struggling to keep afloat, the long-term investment of integrating AI into the business will provide substantial help to the entire company.

4 Social Distancing, Autonomous Vehicles' Unexpected Supporter – How COVID-19 Has Changed Future Mobility Behaviour And Perception In Europe

4.1 Journal Publication Information

This single-authorship paper was accepted by the Journal of Academy of Business and Economics (1542-8710) on 5th December 2020 and published in the Journal of Academy of Business and Economics, Volume 20, Number 4, on 30th December 2020.

Full citation: Edye, C. F. (2020). Social Distancing, Autonomous Vehicles' Unexpected Supporter – How COVID-19 has Changed Future Mobility Behaviour and Perception in Europe. *Journal of Academy of Business and Economics,* 46-61. http://dx.doi.org/10.18374/JABE-20-4.4

4.2 Abstract

The future concept of autonomous vehicles is based on assumptions, that the mobility world moves further towards sharing economies, such as car-sharing business and car-pooling opportunities, and away from private vehicle ownership. But the pandemic resulted in the opposite. People are avoiding strangers through social distancing, using fewer public transport options and instead an increasing number of private vehicles. If fully autonomous vehicles are for individual use only, and correct hygiene measures are put into place, the technology could provide a good transport alternative to current options. On the assumption, that theoretically the acceptance of self-driving cars should rise due to social distancing possibilities, this study was created. Focusing on perceived ease of use, perceived usefulness and social distancing attitude, the hypothetical use of robo-taxis during this pandemic is assessed. Pre COVID-19, previous studies revealed that acceptance of the technology was declining. With a changing mobility attitude and perception, could this be the time to market autonomous vehicles as a useful alternative to public transport and grow its acceptance? Using the Technology Acceptance Model, this paper asses the opinion of 1593 Europeans towards robo-taxis, self-driving cars as a whole, and the changing mobility behaviour as a result of COVID-19. The results show that 47.5% of participants, an increase of 5.3% compared to pre-pandemic times, would use robo-taxis during the pandemic and 48.6% would like to own a self-driving vehicle if they were available. While the pandemic has resulted in a decline of mobility movement across the world, it opened up the opportunity of rethinking the future mobility world.

Keywords: Autonomous vehicles, pandemic, acceptance, mobility behaviour, change

4.3 Introduction

In 1939, General Motors introduced the first concept of an autonomous vehicle to the world. Visitors of the Futurama were fascinated by a new electric vehicle that would run on electromagnetic roads, but they did not imagine it would ever be built (Lipson, 2016). This concept was the predecessor of self-driving cars as we imagine them today. Over the following 80 years, the world has seen many technological advances, from the introduction of the internet, to laptops, to smart phones or even smart glasses. But not every introduction was a success. What makes a technology succeed, is certainly not its existence, but the execution of a good product with the combination of user acceptance.

In recent years, the automotive industry was already changing. Through an increasing demand for electric vehicles, the previously saturated market was gaining new competitors. Not only electric vehicle companies, such as Tesla or Rivian, were taking market shares from established automotive manufacturers, but also the technology industry as a whole, including Apple and Google, ventured into the automotive industry. Through the changing competitor landscape and customer demands, the automotive industry was experiencing a shift from petrol and diesel fuelled private transport, to electric shared mobility alternatives, such as car-pooling concept MOIA and car-sharing companies like ShareNow. But not only automotive companies are challenging the established vehicle manufactures, also other mobility modes were becoming more attractive to drivers. Governments were heavily investing in the expansion of public transport, as well as fostering the use of bikes. Through the expansion of bike and bus lanes, at the cost of car lanes, the inner-city use of cars became increasingly inconvenient. But recognizing the wishes for a more environmentally friendly and easy transport experiences, both of individuals and goods, and to keep up with technological developments and competitors' activities, the automotive industry increasingly focused on self-driving technologies.

The movement away from private vehicles as we know them, have resulted in large managerial implications for European automakers and have resulted in a wake-up call that companies' reputations are no longer enough to sell vehicles. Seeing a window of opportunity to regain attention, established car manufacturers, such as BMW, Mercedes, Audi and Volkswagen are creating their own vehicles and vision of the future. In order to not be left behind in the race to self-driving cars by younger companies, the manufacturers have decided to move to the front of research and development, often being part of government funded projects, recognizing, designing, building and testing not only vehicle but also infrastructure related aspects. An example of this is project PEGASUS ("project for the establishment of generally accepted quality criteria, tools and methods as well as scenarios and situations for the release of highly-automated driving functions" (PEGASUS, 2020)), focusing on creating standards for automated vehicles, which is supported by the four German vehicle manufacturers. BMW and Daimler even started a joint development cooperation, putting behind its competitor days and acting together in the interest of the technology, and to ultimately not be left behind by international competitors.

An increasing number of manufacturers across the world are working on the new transport mode, in the hope to be the first company to have produced a mass-market ready vehicle. Self-driving vehicles include passenger cars, for private use or as robo-taxis, busses and lorries. Swedish vehicle manufacturer Volvo even saw their chance in the designing and testing of autonomous garbage collection trucks. By entering the previously unconsidered niche market, Volvo is highlighting automated driving opportunities beyond the typical passenger or logistics vehicles. Test tracks are being built to test the self-driving vehicles under various conditions from highway tracks to busy city traffic, such as in the USA (Detroit and San Francisco), or the tri-border region connecting Germany, France and Luxembourg. Technological advances and political frameworks are being created to bring self-driving technology on our roads. However, the technology is not receiving sufficient future user attention and acceptance. Instead of reporting about the technology's benefits, newspaper headlines have scared people away from the technology. The annual autonomous vehicle acceptance study, started in 2016 by the American Automobile Association (AAA), has shown a decline in American consumer acceptance (American Automobile Association, 2019). But in January 2020, the world was hit with a global pandemic, reflecting on the population's vulnerability, making stable economies struggle, and overall changing society as a whole. And one of the most affected industries is the mobility industry.

As a result of the now ten-month ongoing pandemic, the mobility industry changed drastically. Previous assumptions for the foundation of autonomous vehicle introduction and expansion are being contradicted and mobility behaviour is moving in the opposite direction as pre COVID-19. People no longer travel the world for business and pleasure and for many home office opportunities were introduced. Buses and trams are almost empty, and the population actively tries to avoid potential sources of infection, whether strangers, friends or family members. Traffic data shows an increase in vehicles being driven, while transport methods that previously required closer contact with others are staying empty. But the pre-pandemic developments, sharing transport methods and not using private vehicles, were the foundation for the development of self-driving mobility of the future. Theoretically, during a pandemic, we need transport modes that allow us to travel from A to B with as little human interaction as possible. While we can attempt to avoid public transport, those needing to travel even short distances without a private vehicle may not have any alternatives. We can walk and ride a bike, but alternative transport modes without human interaction, such as small self-driving vehicles, do not exist yet. One could argue that exactly this upcoming technology would be a good transport mode to help reduce transmission of the disease, as well as providing a greater ease about travelling in general. A survey by the AAA found that experience heavily influences the acceptance of self-driving cars (American Automobile Association, 2016). Robo-taxis, taxis without a human driver, would allow short and long-distance travellers to travel without driving themselves, as well as providing the opportunity of no human interaction with potential transmitters, and thus would be a useful and important transport mode. Especially through the increasing awareness and attention towards reduced human interaction as a result of the pandemic, the concept of robo-taxis should find a greater following. Thus, this paper focuses on a few key questions: To what extend has our travel behaviour changed due to COVID-19? Do we think that robo-taxis would be a good addition in our transport network in the pandemic era? And is social distancing the unexpected supporter driving autonomous vehicle acceptance?

4.4 Literature Review

The mobility world before COVID-19 was moving into a very different direction than the world during COVID-19. However, whether this is a temporary development or will establish itself as the new norm, is uncertain at this point. In order to analyse the developments, the mobility industry before and during the pandemic must be considered. Further, the technology acceptance model (TAM) will be explained and considered. TAM has become a widely used theory to assess the acceptance of this future technology. Through the addition of a social distancing variable, the desire to adopt the technology may receive a more rational component, since people weigh up their transport options based on their ability to avoid others, and ultimately could play a key role for an increase in acceptance of the technology.

4.4.1 Mobility pre COVID-19

As a result of engineering skills, technological advances and globalisation, travel had never been easier. Airplanes enabled travelling the world without week-long travel times. Within 24 hours one can travel from London, UK, to Wellington, New Zealand, or from Seoul, South Korea, to Buenos Aires, Argentina. Retrospectively, the pre COVID-19 mobility world was a carefree transport era. A clear shift towards shared transport means could be observed. Pre-COVID, in order to change the user behaviour of car owners and users, public transport had to be "accessible and must appear attractive" (Eriksson, 2011). With an expanding public transport network, long traffic jams and expensive parking, and an increasing awareness for environmentally friendlier behaviour by sharing transport means, people were increasingly encouraged to switch from private cars to busses and undergrounds. To ensure the shift away from private vehicles to more environmentally friendly measures, governments offered financial incentives to the purchase of electric vehicles. 26 of 27 European nations offer financial stimuli, ranging from money towards the purchase of a new vehicle to tax benefits (European Automobile Manufacturer Asssociation, 2020). But also bike purchases have been subsidised by governments (Haubold, 2020). Further, existing car lanes were replaced with bigger bike and bus lanes. For example, Hamburg's Green Party declared the intention of building 100km of new bike lanes a year (Grüne Hamburg, 2020). Through the combination of support from the government, a reduction in private car ownership, and the move towards more environmentally friendly transport alternatives, the bike and public transport industries experienced a renaissance.

Further, governments were even ensuring to look into the future when designing new city boroughs. An example of this is Hamburg's HafenCity. A new district to bring together different social classes, as well as building a mobility network that focuses on sharing. Only a reduced number of parking spaces were built, another measure to drive people towards public transport and away from their vehicles (Freie und Hansestadt Hamburg, 2015). Through the high costs of vehicle ownership, and the introduction of sharing economy businesses, companies such as Car2Go and DriveNow (recently merged into ShareNow), allowed those with driving licenses to drive cars, without owning them. Another sharing concept by company MOIA, which uses electric minibuses and artificial intelligence to bring consumers together that want to drive into the same direction, was also growing. The transport mode allows a closer pick up and drop off point than public transport, while also providing a smaller shared space, similar to that of private vehicles (www.Moia.io). The CEO of MOIA, Ole Harms, aimed at "freeing European Cities from one million private passenger cars by 2025" (Volkswagen AG, 2017). In less than two years of operating, MOIA had already recorded 1.8 million rides in Hamburg (MOIA, 2020). In 2019, electric scooters were introduced in many European markets. The most represented e-scooter companies were Bird, Lime and Tier. March 2020, just as COVID-19 was heavily spreading across Europe, Tier became Europe's most represented e-scooter company, with scooters in 54 European cities (Mobility Foresights, 2020). The idea of a smooth transition between transport options, through the use of multi-modal ticketing systems, which does not involve individual cars, played a critical role in moving drivers from their private cars to public transport. Overall, through the introduction of a variety of transport options, the mobility world was moving towards a shared environment.

4.4.2 Mobility during COVID-19

But the mobility world pre-COVID also allowed viruses to sweep across the globe. Ebola and swine flu were two of the few pandemics that travelled across the world in the 21st century, but none of them were as influential and easily transmittable as the COVID-19 virus. From travelling the world to staying at home, some forced by their governments, others by choice, our mobility behaviour has drastically changed. The grounding and low passenger rate of the operating flights have resulted in several airlines going bankrupt. While Forbes reported 14 insolvent airlines (Begley Bloom, 2020), such as British Flybe or Australia's second biggest airline Virgin Australia, the full list is longer and includes airlines such as German LGW (Reuters Staff, 2020) and Asia's Cathay Dragon, a subsidiary of Cathay Pacific which operated at only 3% capacity in April of 2020 (Lei, 2020). As the virus spread continued, busses and trains were emptying out. In May 2020, Transport for London (TfL) reported a 95% decrease in tube journeys and 85% decrease in bus journeys (Transport for London, 2020). While the decrease meant a reduction of contact to potential carriers of the virus, it meant financial problems for TfL and other transport companies across the world. Due to decreased demand, MOIA disabled its car-pooling service from 20th March until 25th May 2020, and operated like a normal taxi service (MOIA, 2020). Further, many e-scooter service providers decided to temporarily discontinue their service. Only Tier, the German e-scooter company, decided to continue its service. Through intensive hygiene measures, as well as free rides for system-relevant employees, such as hospital workers or police officers travelling to their place of work, the company gained attention (Tier, 2020).

As a result of avoiding shared transport means, whether public transport, car sharing or car-pooling services, the use of private vehicles increased compared to pre-COVID across. In Europe, USA, China and Japan, travellers are choosing their own car over planes and trains (Furcher, et al., 2020). While German traffic data shows fewer and shorter traffic jams than the previous year, the overall number and lengths that were counted were high. Over the 12 weekends of the German summer holidays, a reduction of only 3% of the number of traffic jams from 2020 compared to 2019 could be observed, despite many previous travellers deciding to avoid going on holiday at all this summer (ADAC, 2020). As a result of COVID-19, governments learnt to be more creative and adapt to an unforeseen pandemic. In order to ensure that also bike riders could practice enough social distancing, 'pop-up bike lanes' were introduced in Germany.

Overall, COVID-19 resulted in a reassessment of the way we travel. While the use of public transport declined, the use of private vehicles increased. However, the biggest question still remains: will this be a temporary change, or will the concern about contracting a virus from others result in the manifestation of the movement away from public transport means to privately owned vehicles?

4.4.3 Autonomous Vehicles

Self-driving cars, once fully developed and tested, should be safer than human driven vehicles. 94% of accidents in the USA are caused by human error (National Highway Traffic Safety Administration, 2017). If the human driver is taken out of the accident equation, fewer road accidents should happen. Further, autonomous vehicles would allow for more people, especially those too young or unable to drive, to use cars to travel, making it a more inclusive transport mode than standard private passenger cars. Further, autonomous vehicles would allow commuters to use the driving time more effectively.

But the development of the vehicles is complicated. Not only the automotive manufacturers, but also technology companies, as well as governments, and lastly society as a whole, are needed to bring the technology on the road. Governments must take care of the necessary infrastructure, such as information transmitting traffic lights, or the legal framework for autonomous vehicles to operate. Further, vehicle concepts among manufacturers vary, no mass-market ready product is available and ideas and opinions of future allies and opposers are thus only based on hypothetical scenarios. If potential future users are not interested in the technology, the high hopes and expectations of autonomous vehicles changing our mobility landscape, will not be met.

As previously mentioned, the long-term study by the American Automobile Association (AAA) has revealed a low acceptance rate between 2016 and 2019, with a fluctuating number of 70% of participants being afraid of self-driving cars (AAA Automotive, 2019). One could argue that the decline is caused by negative newspaper headline. Further, loss of control and uncertainty regarding technology safety (ADAC, 2016), as well as little knowledge about the technology have created a negative perception. Since the first concept of self-driving cars was introduced 85 years ago, society has had a long time of being able to imagine a hypothetical mobility world. Without addressing the benefits and sharing the positive potentials of the execution of self-driving cars, it will be difficult to change the perception we have of a technology that will take control away from us. It is important to act now, assess how society feels about the technology, and put measures into place to take away fears and educate us about the future transport mode. But as development assumptions on which we base our future mobility concepts are being contradicted by recent mobility consumer behaviour as a result of the pandemic, the influence of the pandemic on the acceptance rate becomes uncertain and must be assessed.

Through a study by AAA, we know that ADAS features have a positive influence on the acceptance of autonomous vehicles (American Automobile Association, 2016). The integration of ADAS in vehicles is ever increasing and should thus result in an increase of potential future users of autonomous vehicles. The more potential consumers exist at the introduction of the technology, the greater the initial use, and thus the faster the technology will be accepted by others. Overall, we must know current acceptance rates, concerns and wishes from potential consumers in order to market and improve the image of the upcoming transport mode to ensure its best possible introduction to roads from the start.

4.4.4 Technology Acceptance Model

The Technology Acceptance Model is a theory that was created by Fred D. Davis in 1989 (Davis, 1989). TAM is a practical approach to acceptance assessment of a technology. Focus of the TAM are the perceived ease of use (PEOU) and perceived usefulness (PU) of a technology. PEOU is "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989 S. 320) and PU focuses on "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989 S. 320). Davis' original TAM uses 12 key questions.

While the theory has been widely applied to intangible products such as e-commerce (Pavlou, 2014) or the use of e-mails (Gefen, et al., 1997), it has been increasingly used for the assessment of autonomous vehicle acceptance (Cho, et al., 2017) (Koul, et al., 2018) (Müller, 2019) (Koul, et al., 2018). TAM study findings range from people being less worried about self-driving cars as pedestrians than as passengers (Hulse, et al., 2018) to users anticipating no change in their annual distances travelled as a result of self-driving vehicle ownership (Zmud, et al., 2016).

Under the assumption, that autonomous vehicles are technologically safe and only transport a low number of passengers, rationally they should be better to avoid the spreading of a virus compared to shared transport, such as car-pooling or public transport. The influence of Social Distancing and character on the willingness to use robo-taxis can be determined through the application of the TAM. Through the addition of the Social Distancing variable, the influence of our own level of importance to socially distance and the willingness to choose transport mediums based on that, is considered.

4.5 Methodology

This paper focuses on a questionnaire-based study, assessing the acceptance of robo-taxis, as well as the changing mobility behaviour of Europeans during the COVID-19 pandemic. The questionnaire consists of establishing participant profiles, followed by an assessment of travel behaviour, and lastly TAM related questions. While a reduction in movement can already be explained due to government-imposed lockdowns, and a high number of home office adaptations, the shift in transport modes used is based on individual preferences and will thus be assessed too. The in-depth travel behaviour questions may provide further insights into the changing behaviour.

4.5.1 Questionnaire Design

The first part of the study focuses on background information of the participants. The assessed traits are gender, age, level of education, monthly household income, years of driving experience and car ownership. They are assessed in order to identify possible different opinions and acceptance groups among the participants and establish certain behaviour patterns. These in turn are vital to later market robo-taxis, and self-driving cars, to various potential user groups. Further, participants are asked if they are part of a COVID-19 risk group.

The second part of the study aims at understanding actual travel behaviour during the pandemic. Participants are asked if their use of public transport, private vehicles, riding a bike or walking changed for work, pleasure / leisure activities and for necessities (such as supermarket runs). The possible answers are: 'Significantly decreased (25% or less)', 'Decreased (10% less)', 'Stayed the same', 'Increased (10% more)', 'Significantly increased (25% or more)'. Next, the opinions on sharing transport pre- and during pandemic is considered with the statements "Before COVID-19, I was comfortable sharing public transport with strangers." And "during COVID-19, I feel comfortable sharing transport with strangers.". "Robo-taxis would be useful vehicles during a pandemic to avoid strangers.", and "I would prefer using self-driving cars instead of public transport" allow a more specific insight into the opinion of self-driving cars. Lastly, "If self-driving cars existed, I would like to own one." Enables the comparison between technology use and ownership.

The final part of the survey focuses on the TAM, with the Behavioural Intention (BI) concentrating on the hypothetical use of robo-taxis during the pandemic. All TAM related questions in the questionnaire are statements that are assessed on a 1 to 5 Likert Scale. The structure mimics the original TAM assessment. Only the questions relevant for this technology were adapted and partially rephrased to fit this study. Perceived Ease of Use and Perceived Usefulness each contain four statements. “Learning to operate a self-driving car would be easy for me.”, “I would find it easy to get a self-driving car to do what I want it to do.”, “It would be easy for me to become skilful at using a self-driving car.’ And “I would find a self-driving car easy to use.” Are applied to the PEOU statement group. “Using a self-driving car would make it easier for me to drive.”, “Using a self-driving car would improve my driving performance.”, “Using a self-driving car would allow me to concentrate on other things while driving.” And “Self-driving cars would be good for reducing the number of accidents.” Were included to assess PU. “Social distancing is important to me.” And “I choose my transport mode based on social distancing possibilities” form the Social Distancing variable used to assess BI. Lastly, in order to assess the current level of acceptance and willingness to use a hypothetical self-driving car, the behavioural intention was stated as “If robo-taxis existed, I would use them now.”.

Using a confidence level of 99%, a confidence interval of 5 and a population of 743 million (United Nations, Department of Economic and Social Affairs, Population Division, 2019), a sample size of 666 is necessary to carry out a representative study of Europe. The questionnaire is distributed through various channels, ranging from E-Mails to LinkedIn posts, as well as the survey distribution platform ClickWorker. By using the service, a quality control of the survey, as well as ensuring a high number of surveys were completed during the same time span.

4.5.2 Hypotheses

Together, all hypotheses asses a changed attitude towards self-driving vehicles as a result of COVID-19. The hypotheses are: Perceived Ease of Use has a positive influence on the willingness to use Robo-taxis (H1), Perceived Usefulness has a positive influence on the willingness to use Robo-taxis (H2) and Social Distancing has a positive influence on the willingness to use Robo-taxis (H3). Further, “gender affects the willingness to use robo-taxis (H4)”, “age affects the willingness to use Robo-taxis (H5)”, “level of education affects the willingness to use robo-taxis (H6)”, “income affects the willingness to use robo-taxis (H7)”, “years of driving experience affect the willingness to use robo-taxis (H8)” and lastly, “type of car owned affect the willingness to use robo-taxis (H9)”. Figure 5 shows the complete Social Distancing TAM.

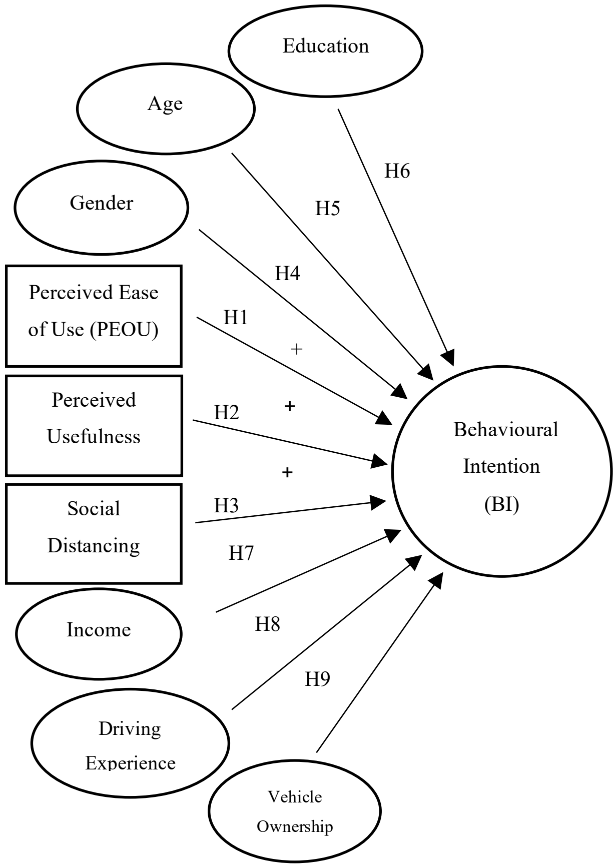

Figure 5 Social Distancing TAM

4.5.3 Data Analysis

In order to understand the participants' demographics, frequencies of gender, age, level of education, years of driving experience, car ownership are assessed. TAM related questions are evaluated based on frequency and then will be computed into single variables for the regression model. In order to further understand the travel behaviour of recent months, correlations between individual questions regarding movement frequency and transport modes used, will be conducted. Through this a stronger behavioural pattern will emerge, and travel behaviour can be analysed further. Finally, regression models are created in order to assess the technology acceptance model and the acceptance of robo-taxis.

4.6 Results

The survey was conducted from 9th September until 17th September 2020. A total of 1616 participants completed the study. Out of these, 3 are from Canada and 12 from the United States. As the study focuses on the opinion of Europeans, these 15 surveys were not considered, leaving a participant size of 1601 Europeans that completed the survey. Further, the eight non-binary participants were omitted from the results, as the participant size is too small to be representative and thus statistically influential, making the final participation number 1593. Habitants of the following nations, but not limited to this list, took part: Ireland, Switzerland, Netherlands, France, Germany, Austria, United Kingdom, Belgium, Czech Republic, Poland, Romania and Hungary, Italy, Greece, Spain and Portugal, Finland, Norway, Denmark and Sweden.

Frequency – Participant profiles, travel frequencies, types of transport and additional questions

All frequencies of the 1593 participants can be found in 6.2 in the Annex. While 52.2% of participants were women and 47.8% were men, the most represented age group were the 25- to 34-year olds (35.2%) followed by the 35- to 44-year olds (23.2%). 67.6% of participants originated from Western Europe. Over a third of participants, with 37,4%, have at least a bachelor's degree and a further 28.7% have a master's or Doctorate / PhD degree. While 32.2% earn between 1000€ and 2000€, 19.7% earn 2000€ to 3000€ and 18.9% between 3000€ and 5000€ a month. 47.9% have had their license for over 10 years, with 55.3% owning a manual vehicle, 16.4% an automatic vehicle and 28.3% no vehicle at all. Out of the 1593 participants, 11.7% belong to COVID-19 risk groups.

As a result of COVID-19, 64% of participants travel less for leisure activities, 42.6% less for work and 39.5% less for necessities, such as grocery shopping. Further, the use of public transport declined for 59.8% of participants, as well as 24.9% using their car less. However, at the same time 29.7% use their cars more, as well as 25.4% using their bikes more. Walking saw the greatest increase with 48% of participants walking more than before. While pre-COVID, 57.1% felt comfortable taking public transport with strangers, only 15.2% were comfortable doing so since the outbreak of the pandemic. Overall, 57.4% of participants had an attitude change towards everyday travel.

When asked about the usage intentions pre-COVID, 42.3% agreed that they would have used robo-taxis if they existed. This number rose to 47.5% when asked about using robo-taxis during a pandemic. An even higher number, of 48.6% of participants, agreed that they would like to own an autonomous vehicle. While 58.3% of participants would prefer using a self-driving vehicle over public transport, 60.6% of partakers agreed that robo-taxis would be a useful transport medium during a pandemic.

Correlations

The data revealed a negative correlation between the use of public transport and own car (r= -0.77, p=0.002) and walking (r= -0.059, p=0.018). Confirming a switch from public transport to private vehicles or walking. Further, there is a negative correlation between the Social Distancing attitude and the use of public transport (r= -0.274, p=0.000), suggesting that participants avoid public transport due to the lack of perceived social distancing opportunities. The Social Distancing and use of cars (r=.067, p=.008) correlation and social distancing and walking correlation (r=.096, p=.000) are both positive. Therefore, walking and private vehicles are perceived as the better transport option based on social distancing opportunities. There is no correlation between using public transport or social distancing perception and the use of bikes.

Regression I

To test the strength of the focal variables on the dependent variable BI, first the model only including the focal variables was tested. Here, the influence of PEOU, PU and SD on BI were assessed. The result is a model with all independent variables being statistically significant [F(3,1589)=203.622, p=0.000],with and R^2 of 0.278. The model thus predicts 27.8% of the user behaviour of robo-taxis.

The relationship between PEOU and BI is positive (ß=0.167) and based on the t-value (t=6.904) and the p-value (p=0.000), there is a significant influence of PEOU on BI. Therefore, the hypothesis H1 is accepted. The relationship between PU and BI is also positive (ß=0.401). Based on the t-value (t=16.513) and the p-value (p=0.000), there is a significant influence of PU on BI. Therefore, the hypothesis H2 is accepted. Finally, the relationship between SD and BI is positive (ß=0.061). Based on the t-value (t=4.765) and the p-value (p=0.000), there is a significant influence of PEOU on BI. Therefore, the hypothesis H3 is accepted.

Regression II

Regression II includes the character traits, to assess if differences among participants influence on the willingness to use robo-taxis. Also this regression was statistically significant [F(9,1583)=71.113, p=0.000], with and R^2 of 0.288. The model thus predicts 28.8% of the user behaviour of robo-taxis and is thus a better fit than Model I. However, the constant, as well as PEOU, PU and SD unstandardized Beta values have changed due to the addition of further variables in the regression equation. The new constant is ß=0.611, PEOU's unstandardized beta is ß=0.055, PU's unstandardised beta is ß=0.125 and SD's unstandardised beta is ß=0.063.

The relationship between age and the wanting to use robo-taxis is statistically significant with a p-value of p=0.023 and t value of t=-2.280. The negative relationship shows that the younger the survey participant, the greater their interest in using the robo-taxi service. Therefore, the hypothesis H5 is accepted. There is also a statistically significant relationship between the level of education and the willingness to use robo-taxis, with a p-value of p=0.025 and a t-value of t=2.251. This result indicates that the higher the level of education, the grater the willingness to use robo-taxis right now. Therefore, hypothesis H6 is accepted. H4 (Gender; p=0.052), H7 (Income; p=0.613), H8 (years of license ownership; p=0.088) and H9 (type of car owned; p=0.761) are all not statistically significant and therefore do not affect the willingness to use robo-taxis among participants. The model of Regression II can be seen in Figure 6:

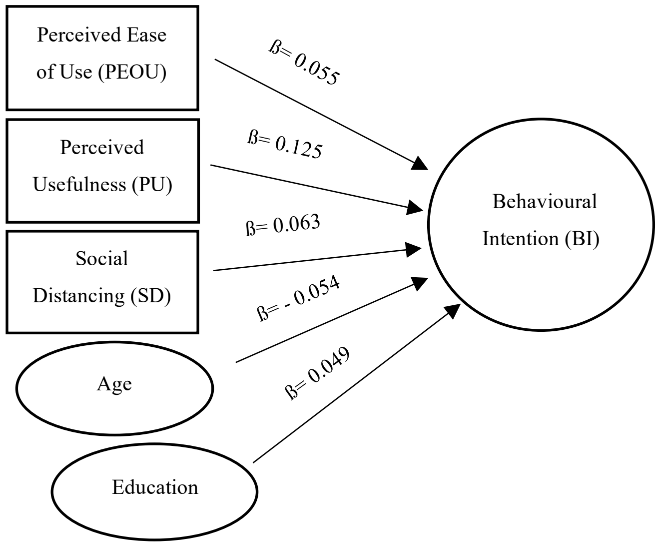

Figure 6 Social Distancing TAM Final Regression

4.7 Discussion

As the virus spread across the world, new safety measures to reduce the rate of infection were introduced. Self-driving cars would allow the users of self-driving vehicles to travel from A to B without having to drive I or being in contact with a driver. As the importance of social distancing to humans and the following of these measures increases, autonomous vehicles now have the opportunity of a gaining a greater potential customer base. Under the condition that self-driving vehicles transported only a small number of riders, infection rates could be reduced while still allowing short and long-distance journeys. Since previous studies have shown a greater willingness in using the technology, but not owning it, robo-taxis would be a possible solution, as they are not owned by the users but still provide the benefits. With increased social distancing measures, robo-taxis should theoretically gain greater support and increased willingness by potential consumers to use the service. The aim of the study was to assess how social distancing might have influenced the acceptance of autonomous vehicles in Europe. 1593 participants from across Europe were asked about their attitude towards travel, their trave behaviour over recent months and their opinion on self-driving cars and robo-taxis. While the survey confirmed some acceptance expectations, it also revealed new developments.

The perception towards every-day travel changed for 57,5% of participants. While this can be interpreted in several ways, such as being more concerned about which transport medium to use, or using transport in general, the data shows that people have become more aware and conscious of their mobility choices. Overall, 42.6% of participants travelled less for work, 64% less for leisure activities and 39.5% less for necessity trips. While movement declined, for the trips that remained transport modes were changed. As observed and felt by mobility companies, the study underlines the decline in the use of public transport and increase in the use of private vehicles and walking. 59.8% of participants use public transport less. Also 24.9% of participants use their private vehicles less. At the same time, 29.7% use their cars more than before. As the correlation showed, there is direct link between fewer public transport trips and an increase in private vehicle use. Travellers are concerned about being in contact with others, resulting in an increase of traffic due to more private vehicles on the roads, and leaving public transport companies, such as TfL, struggling. While only 12.9% of participants walk less, 48% walk more than before. The correlation revealed a connection between less public transport and more walking. On one hand this suggests that travellers decided to walk to their destination, on the other hand the increase could also be explained by walks being one of the few leisure activities still allowed under lockdown rules in some European nations. However, there is no statistically significant correlation between public transport and the use of bikes. As COVID-19 was first spreading during spring and summer, it is possible that the increase of bike usage is the result of the natural, seasonal use of this transport medium. Further, the correlations show that the higher the wish for social distancing, the lower the use of public transport. At the same time there is a positive correlation between social distancing and the use of private cars and walking. Overall, there is a clear link between the lack of social distancing opportunities and lower use of public transport, making participants move further towards their private vehicles and walking, as they are able to shield themselves better from others.

Currently robo-taxis are only a hypothetical scenario. However, the study has confirmed an increase in acceptance of autonomous vehicles as a result of the pandemic. The regression shows that PEOU, PU, SD, Age and Education are all statistically significant in influencing BI. The higher the perceived ease of use, perceived usefulness and perceived social distancing possibilities, as well as the higher the level of education and the younger the participant, the greater their willingness to use robo-taxis.

With 42.3% of participants pre and 47.5% during pandemic agreeing to use robo-taxis, the acceptance of the technology clearly rose. This development is important for the overall acceptance rate, as well as giving an insight into robo-taxi future. Other studies have shown that through experience, acceptance increases. The 47.5% will be crucial in bringing further potential users on board, as pioneer users and owners of autonomous vehicles will show sceptics that and how the technology works and may even convince them to use the transport mode themselves, further increasing its acceptance.

Further, the study revealed that social distancing heavily influences the transport choices we make. As the regression model reveals, the perceived ease of social distancing in robo-taxis increases the willingness to use them. As robo-taxis allow the use of taxis without being in contact with a driver, it provides the ideal shielding measures while providing a transport mode that does not have to be drive by oneself. The younger the participant, the greater the interest in the transport mode. Already previous life influencing transport mode introductions, such as the steam engine, were met with scepticism. But in combination of a lower experience of manually driven vehicles, as well as having grown up with more technological gadgets, they may trust the new, technology heavy vehicle more easily than older generations. At the same time, the higher the level of education, the greater the interest in using the technology. One could argue that those with a higher level of education may work in offices and could use their travel time to work instead. Therefore, they may have a higher interest in the transport mode. A young, higher educated user, valuing and following social distancing measures, that sees autonomous vehicles and easy to use and useful would thus have the greatest willingness to use a robo-taxi if they existed.

The possibility exists that the willingness to use self-driving vehicles in general is even greater than the willingness to use robo-taxis, given that robo-taxis are just one part of the self-driving vehicle family. Despite other studies having suggested that people would rather use the service than own a self-driving vehicle themselves (Geiger, 2020) and the assumption that self-driving vehicles will be shared with others (Kuhnert, et al., 2018), there will still be a large group of future users wishing to buy their own self-driving car. After all, 48.6% of participants would like to own an autonomous vehicle. Reasons for owning a vehicle may be because users would feel uneasy about sharing this transport mode with strangers, they may want to ensure being able to use the car wherever and whenever they wish or simply to own their own vehicle. But assuming that self-driving vehicles will be very expensive, not many may be able to afford this luxury. The data showing a greater number of participants wishing for ownership than the number wanting to use the robo-taxi service, could be driven by the COVID-19 pandemic. But it may only be a temporary development. As the acceptance of the technology is rising, this development is crucial in driving the final adoption and ownership of the technology once it is deployed on roads. The difference between using robo-taxis and owning own fully autonomous vehicles in this study may be small, but the findings compared to older studies is crucial. The assumption, that autonomous vehicles will become a shared technology rather than individuals owning their own vehicle is also contradicted by this. This in turn can provide private vehicle manufacturers with more potential buyers than previously anticipated. As a result, BMW, Daimler and other competitors should prepare for the possibility of more self-driving private vehicles having to be produced in the future for individual buyers, rather than selling large numbers of self-driving sharable vehicles to mobility service providers.

AAA's Greg Brannon, director of Automotive Engineering and Industry Relations, argues that the developing of the transport mode is "evolving on a very public stage and, as a result, it is affecting how consumers feel about it." (AAA Automotive, 2019). While the process to getting self-driving vehicles ready for the mass market is still long, it is crucial that we advertise the benefits of the technology, such as its benefits during a pandemic, to increase its rate of acceptance. Through technology acceptance models and studies assessing concerns and interests of future users, marketing campaigns tailored to increased acceptance can be created. Based on this study younger participants, with higher levels of education, that value social distancing, would be the user of a robo-taxi during a pandemic.

4.7.1 Limitations & Future Research

60.6% of participants agreed that robo-taxis would be a useful transport mode during a pandemic, but only 47.5% said they would use the transport mode if they were available. This reveals a group of people convinced of its use, but not willing to try the vehicle themselves. While the reasons are not known, these participants may have concerns about the technology's safety or hygiene measures. Further, 58.3% of participants would prefer using a self-driving vehicle over public transport during the pandemic. The data reveals that the European interest in a hypothetical scenario outperforms that of an existing transport mode. While according to the AAA studies 70% of

Americans are afraid of using the technology, Europeans either have a higher confidence in the technology than Americans, or it may mean that they are still afraid of the technology, but under current circumstances would prefer using self-driving cars over a transport mode that forces them to share a small space with potential carriers of the disease. A repeat of the study in the United States would enable a clear comparison between Americans and Europeans.

The research was conducted at the start of the second COVID-19 wave. As the number of infections rise again, we may see another decline in transport. The perception after the second wave may move further towards the desire for a further reduction of contact to the outside world and allow autonomous cars, under the condition that they are set up for a small number of passengers, to gain a higher following. Further, the alternative of walking and riding bikes instead of public transport becomes increasingly uncomfortable as we move towards winter. With the colder season approaching, we may see a further increase in private vehicle usage by those that own private cars. However, those without private vehicles will either have to face the cold or be forced to use public transport. This may result in an increased desired to work from home instead of facing a mobility environment that may result in them contracting COVID-19. The next six months will play a key role in shaping the future of our mobility world. Will we see a continued reduction in public transport usage and a continuing increase in private vehicle usage? Is the use of bikes really only due to the seasonal change, or will it be a transport medium that we will see the whole year round?

Overall, the consequences of COVID-19 were devastating for society and the economy. But it leaves the opportunity to re-think important aspects of our lives, such as future mobility. While autonomous vehicle perception has varied over the last few years, this study has revealed that in Europe acceptance is close to 50%. Through initiatives such as pop-up bike lanes, governments have shown that they are capable of acting quickly and adapting to these new circumstances. Through social distancing measures and the manifestation of the measure in our brains, we are rethinking the way we travel, reducing out scepticism in already existing concepts and opening up possibilities for new concepts. We should now focus on moving them from concept to reality.

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6 Appendices

6.1 Appendix I for 'Time to Return to the Driver's Seat – Implement AI as a Supply Risk Optimiser to Manoeuvre out of the Crisis'

Supplier Risk issues within the automotive industry in 2019

Fields marked with * are mandatory.

Dear participant,

This survey is part of a study looking into potential risks to the supply chain caused by ailing, struggling or problematic suppliers in the automotive industry in 2019.

If you have any questions or wish to get in contact with us, please e-mail: c.edye@zeppelin-university.net or wolfgang.schulz@zu.de

Thank you in advance and kind regards,
Prof. Dr. habil. Wolfgang H. Schulz and Christina Edye

* What is your company's position in the supply chain of the automotive industry?

- OEM
- Tier 1 Supplier
- Tier 2 Supplier

* What has been your company's revenue in the last fiscal year?

- <100.000.000 Euro
- 100.000.001 Euro - 300.000.000 Euro
- 300.000.001 Euro - 500.000.000 Euro
- 500.000.001 Euro - 1.000.000.000 Euro
- 1.000.000.001 Euro - 3.000.000.000 Euro
- 3.000.000.001 Euro - 5.000.000.000 Euro
- > 5.000.000.001 Euro

According to your opinion:

	Very Low	Low	Medium	High	Very High
* How do you assess the significance of Supplier Risks for your company in 2019/20?	○	○	○	○	○
* How do you assess the significance of Supplier Risks for the automotive industry in 2019/20?	○	○	○	○	○

* How have the Supplier Risks changed over the past 5 years?

- Strongly decreased
- Decreased

- No change at all
- Increased
- Strongly increased

* How will Supplier Risks change over the next 5 years?

- Strongly decrease
- Decrease
- No change at all
- Increase
- Strongly increase

How strong is the impact of the following Supplier Risks for your supply chain?

	No impact	Low	Medium	High	Very High
* Supply chain disruptions because of unstable logistics ("bottlenecks" time / quantity)	○	○	○	○	○
* Quality	○	○	○	○	○
* Insolvency/bankruptcy	○	○	○	○	○
* Fraud	○	○	○	○	○
* Hostile take-over	○	○	○	○	○

* How do you currently handle Supplier Risks?

- ☐ Preemptive (before Supplier Risks occur)
- ☐ Reactive (after Supplier Risks have occurred)
- ☐ Both

* How far is your visibility of your suppliers' network?

- Tier 1
- Tier 2
- Tier 3
- Beyond Tier 3

* How deep should the visibility of your suppliers' network be, if possible?

- Tier 1
- Tier 2
- Tier 3
- Beyond Tier 3

* How many levels of your suppliers' network are you currently monitoring?

- Tier 1
- Tier 2
- Tier 3
- Beyond Tier 3

* Do you have an early-warning system, alerting you of a potential Suppliers' Risks? (e.g. monitoring tools, employee(s) assessing potential suppliers' risks, etc.)

- Yes
- No

* What is the total number of employees engaged in Supplier Risk Management in your company?

* Who is responsible for the Supplier Risk monitoring?

- [ ] Dedicated Supplier Risk department
- [ ] Part of the purchasing / procurement / supply chain department
- [ ] Dedicated employee(s) solely only responsible for Supplier Risk related tasks
- [ ] Dedicated employee(s) responsible for Supplier Risk related tasks while also focusing on other Supply Chain tasks
- [ ] There is no dedicated employee/department for Supplier Risk monitoring/management

Any further comments on this?

How much do you focus on the following Supplier Risks:

	Not at all	A Little	Neither a little, nor a lot	A lot	Key focus area
* Quality & Production Performance	○	○	○	○	○
* Financial Stablity	○	○	○	○	○
* Logistic risks (Pandemic, force majeur etc.)	○	○	○	○	○
* Market risks (e.g: Brexit, economic downturn)	○	○	○	○	○
* Compliance & Reputation	○	○	○	○	○

* What is the depth of your financial stability monitoring of your supplier?

- ○ We monitor all tier 1 suppliers and selected suppliers beyond tier 1, who are critical to our supply chain
- ○ We monitor all tier 1 suppliers
- ○ We monitor our main suppliers, who are critical to our supply chain
- ○ We do not monitor the financial stability of our suppliers

* On what information are you basing your evaluation of your suppliers' financial situation? (Several answers possible)

- [ ] Balance sheets and publicly available information
- [ ] Information provided by credit agents
- [ ] Management accounts of suppliers
- [ ] Other

* Do you have a dedicated Crisis Team in place, which acts when a Supplier threatens to become a risk for your continuous production objective?

- ○ Yes
- ○ No

Any further comments?

* Are your employees trained to handle supply chain crises caused by your suppliers?

- ○ Yes
- ○ No

Any further comments?

* How do you help struggling suppliers?

- [ ] On-site support (minimum of 2 days)
- [ ] Remotely (from our offices)
- [ ] Our company does not support struggling suppliers

* Which measures could be part of your support for struggling suppliers?

- [ ] We do not help at all
- [ ] Technical/management support
- [ ] Short-term liquidity protection
- [ ] Long-term financial support optimisation / continuation (e.g: purchasing of supplier, M&A)
- [ ] Other (please specify below)

How do you ensure that working with your suppliers, especially with respect to intercultural differences (e.g: language issues or local laws), runs smoothly in a crisis?

* How would you rate your success at maintaining a seamless production rate?

- ○ Not applicable
- ○ Low
- ○ Middle
- ○ High
- ○ Very High

What is your success rate at avoiding adjustments to your production programmedue to an emerged Supplier Risk issue?

- ○ Not applicable
- ○ Low
- ○ Middle
- ○ High
- ○ Very High

* Do you use dedicated tools for monitoring suppliers' risks and if yes, which tools are in use?

- [ ] Google
- [ ] Riskmethods
- [ ] Other (Please specify in next box)
- [ ] We do not monitor Supplier Risks with dedicated tools

* Please specify your Supplier Risk monitoring tools

* Are you familiar with the use of Artificial Intelligence (AI) in the business context?

- ○ Not at all familiar
- ○ Slightly familiar
- ○ Somewhat familiar
- ○ Moderately familiar
- ○ Extremely familiar

* According to your opinion, how significant will the impact of AI become?

- ○ No impact
- ○ Low
- ○ Medium
- ○ High
- ○ Very High

Any comments on AI?

* Are you currently using AI in any of your departments?
  - ○ Yes
  - ○ No

* If yes, in which department?
  - ☐ Marketing
  - ☐ Finance
  - ☐ Quality Management
  - ☐ Customer Service
  - ☐ Supply Chain
  - ☐ Other

* Do you use Artificial Intelligence tools to minimise Supply Risks?
  - ○ Yes
  - ○ No

* Are you satisfied with the AI tools you use?
  - ○ Yes
  - ○ No

* What is the purpose of your applied AI tools?
  - ☐ Information gathering about suppliers
  - ☐ Interpret relevance of information gathered for risk assessment
  - ☐ Create a risk prognosis for suppliers
  - ☐ Create risk assessments regarding markets
  - ☐ None of the above

* Would you like to use AI tools for Supplier Risk minimisation in the future if available?
  - ○ Yes
  - ○ No

* Why have you not yet adopted AI tools for Supplier Risk minimisation?
  - ☐ Financial reasons (e.g: poor cost-value ratio, not budgeted)
  - ☐ Infrastructure to include AI tool does not exist
  - ☐ Not enough knowledge of possible AI tools
  - ☐ Lack of qualified personnel
  - ☐ Low acceptance of company towards integrating AI
  - ☐ Lack of acceptance among employees towards integrating AI
  - ☐ Until today, we consider AI tools not beneficiary for supplier risk minimisation

* In what area(s) is or will AI be a significant technological progress in the field of supplier risk monitoring and prevention?
  - ☐ Information gathering about suppliers
  - ☐ Interpret relevance of information gathered for risk assessment
  - ☐ Create a risk prognosis for suppliers
  - ☐ Create risk assessments regarding markets
  - ☐ None of the above
  - ☐ Others, please specify below

Additional remarks on current or future supplier risk management:

6.2 Appendix II for ‘Social Distancing, Autonomous Vehicles’ Unexpected Supporter – How Covid-19 Has Changed Future Mobility Behaviour and Perception in Europe’

Questionnaire for participants:

2020 Survey assessing future end-consumers' acceptance of autonomous cars

Fields marked with * are mandatory.

Introduction

Dear participant,

This survey focuses on the future world with autonomous (self-driving) cars. Please answer the following questions about yourself. The survey outcomes will form part of Christina Edye's doctorate thesis about the acceptance of Cooperative, Connected and Automated Mobility. Your data will be anonymous. If you have any questions please send an e-mail to: c.edye@zeppelin-university.net .

Thank you for participating.

Kind regards,
Christina Edye and Prof. Dr. habil. Wolfgang H. Schulz (Zeppelin University, Friedrichshafen, Germany)

Definition of self-driving cars for this scenario: Level 5 Full Driving Automation: "Sustained and unconditional performance by an automated driving system of the entire dynamic driving task (DDT), or “all the real-time operational and tactile functions required to operate a vehicle in on-road traffic" without any expectation that a user will respond to a request to intervene." - SAE Levels of Driving Automation (American National Standards Institute)

* Gender
- Male
- Female
- Other (e.g: non-binary)

* Age Group
- 18-24 years old
- 25-34 years old
- 35-44 years old
- 45-54 years old
- 55-64 years old
- Older than 65 years

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* Origin

- Western Europe
- Eastern Europe
- Southern Europe
- Scandinavian Europe
- United States of America
- Canada

* Level of Education

- No schooling completed
- High School graduate
- Apprenticeship
- College (Bachelor's) degree
- Master's degree
- Doctorate degree

* Monthly household income (Reminder: Information provided is anonymous!)

- Less than € 300
- Between € 300 and € 500
- Between € 500 and € 1000
- Between € 1000 and € 1500
- Between € 1500 and € 2000
- Between € 2000 and € 3000
- Between € 3000 and € 5000
- Between € 5000 and € 7500
- More than € 7500

* Years of driving license ownership

- I do not own a driving license
- Less than 1 year
- 1 to 5 years
- 5 to 10 years
- More than 10 years

* Car ownership status

- I own a car
- I do not own a car

* Type of car owned

- Manual
- Automatic

Perceived Ease of Use

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
* Learning to operate a self-driving car would be easy for me	○	○	○	○	○
* I would find it easy to get a self-driving car to do what I want it to do	○	○	○	○	○
* It would be easy for me to become skilful at using a self-driving car	○	○	○	○	○
* I would find a self-driving car easy to use	○	○	○	○	○

Perceived Usefulness

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
* Using a self-driving car would make it easier for me to drive	○	○	○	○	○
* Using a self-driving car would improve my driving performance	○	○	○	○	○
* Using a self-driving car would allow me to concentrate on other things while driving	○	○	○	○	○
* Self-driving cars would be good for reducing the number of accidents	○	○	○	○	○

COVID-19

* Are you in a COVID-19 high risk group (e.g.: above 60 years old or have Asthma or Diabetes / other medical conditions that may increase your likelihood of being infected with the virus?)

○ Yes
○ No

Attitude

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
* COVID-19 has changed my attitude towards everyday travel.	○	○	○	○	○

My everyday travel for...

	Significantly Decreased (25% or less)	Decreased (10% less)	Stayed the same	Increased (10% increase)	Significantly Increased (25% or more)
* Work...	○	○	○	○	○
* Pleasure / Leisure...	○	○	○	○	○
* Necessities (e. g: supermarket)...	○	○	○	○	○

Travel Frequency

	Significantly Less (at least 25%-)	Less (10% less)	Stayed the same	More (10% increase)	Significantly more (at least 25%+)
* I use public transport	○	○	○	○	○
* I use my car	○	○	○	○	○
* I use my bike	○	○	○	○	○
* I walk	○	○	○	○	○

Robo-taxis are taxis without a driver and are not owned by you. They are part of the family of self-driving cars.

Public Transport & Robo-taxis

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
* Before COVID-19, I was comfortable sharing public transport with strangers.	○	○	○	○	○
* During COVID-19, I feel comfortable sharing transport with strangers.	○	○	○	○	○
* Before COVID-19, if robo-taxis had existed, I would have used them.	○	○	○	○	○
* Robo-taxis would be useful vehicles during a pandemic to avoid strangers.	○	○	○	○	○
* If robo-taxis existed, I would use them now.	○	○	○	○	○
* If self-driving cars existed, I would like to own one.	○	○	○	○	○
* I would prefer using self-driving cars instead of public transport.	○	○	○	○	○
* Social Distancing is important to me.	○	○	○	○	○
* I choose my transport mode based on Social Distancing possibilities.	○	○	○	○	○

Final question...

	Negatively	Unchanged	Positively
* COVID-19 has changed my opinion on self-driving cars.	○	○	○

Additional thoughts I would like to share about self-driving vehicles (and Covid-19).

The end!

Thank you very much for participating. If you have any questions, please do not hesitate to contact me.

Christina Edye
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Table 2 shows the break-down of participants from the study included in the paper publication:

Table 2 Participant Traits

Trait	**Group**	**Frequency**	**Percentage**
Gender	Male	762	47.8%
	Female	831	52.5%
Age	18-24 years	348	21.8%
	25-34 years	561	35.2%
	35-44 years	370	23.3%
	45-54 years	200	12.6%
	55 years and older	114	7.2%
Origin	Western Europe	1077	67.6%
	Scandinavian Europe	55	3.5%
	Eastern Europe	207	13%
	Southern Europe	254	15.9%
Level of Education	High School graduate or less	373	23.4%
	Apprenticeship	168	10.5%
	College (Bachelor's) degree	595	37.4%
	Master's degree or higher	457	28.7%
Monthly household income	Less than 1000€	339	21.3%
	Between 1000€ and 1550€	257	16.1%
	Between 1500 and 2000€	256	16.1%
	Between 2000€ and 3000€	314	19.7%
	Between 3000€ and 5000€	301	18.9%
	More than 5000€	126	7.9%
Years of license ownership	I do not own a license	183	11.5%
	Less than a year	100	6.3%
	1-5 years	286	18%
	5-10 years	261	16.4%
	More than 10 years	763	47.9%
Type of Car owned	I do not own a car	451	28.3%
	Manual Car	881	55.3%
	Automatic Car	261	16.4%
COVID-19 risk group	No	1406	88.3%
	Yes	187	11.7%

Source: Own Table