STRATEGIC IMPACTS ON AUTOMOTIVE INCUMBENTS IN THE MARKET OF AUTONOMOUS DRIVING

Jessica Porzelt

Dissertation written under the supervision of Peter V. Rajsingh, Ph.D.

Dissertation submitted in partial fulfilment of requirements for the MSc in Management with Specialization in Strategy and Entrepreneurship, at the Universidade Católica Portuguesa, 07.01.2019.

ABSTRACT

Title: Strategic Impacts on Automotive Incumbents in the Market of Autonomous Driving

Author: Jessica Porzelt

Automation and connectivity within the automotive industry are affecting automotive incumbents (AIs) causing significant shifts towards technology and software. These current trends enable the development of autonomous vehicles (AVs) which will become increasingly prevalent over the next decade. The complex technologies necessary to make autonomous driving (AD) a full reality and which are transforming the automotive industry entail high uncertainties and strategic challenges.

The aim of this study is to examine how AD affects AIs' businesses and strategic choices. Secondary data in the current literature about automation, AD and strategic literature concerning disruptive innovation was reviewed to study the topic. Primary data was gathered through interviews with professionals working in the field of AD. The interview analysis is based on the inductive categorization methodology of Mayring (2015) to provide thorough evaluation of the data.

Chiefly, the findings revealed that attempting to seize a first mover advantage is not recommended for AIs in the case of AD. A large challenge is the lack of technological know-how needed to keep up with leading tech-companies in this field. Furthermore, competence in opening up cities and regions for AD should be developed. As disruptive technologies in general and specifically AD lack trust of customers, it is important to develop confidence building strategies. Digital features that are desired by future customers must be determined as well as an attractive business model to compete as an incumbent in the AD market. Overall, the future role of AIs in the AV supply chain is not yet clear.

Keywords: Automation, Autonomous Driving, Automotive Industry, Automotive Incumbent, Disruptive Innovation, Disruptive Technology, Innovator's Dilemma, Strategic Decision-Making, Strategic Failure, Strategic Positioning, Uncertainty

SUMÁRIO

Título: Impactos Estratégicos sobre os Automóveis Incumbentes no Mercado da Condução Autónoma

Autor: Jessica Porzelt

A automação e a conectividade dentro da indústria automotiva estão afetando os corporação automóvel (AIs), causando mudanças significativas em direção à tecnologia e ao software. Estas tendências actuais permitem o desenvolvimento de veículos autónomos (AVs) que se tornarão cada vez mais prevalecentes ao longo da próxima década. As complexas tecnologias necessárias para tornar a condução autónoma (AD) uma realidade plena e que estão a transformar a indústria automóvel implicam grandes incertezas e desafios estratégicos.

O objectivo deste estudo é examinar de que forma os AV afectam os negócios e as escolhas estratégicas dos AIs. Os dados secundários da literatura atual sobre automação, AD e literatura estratégica sobre inovação disruptiva foram revistos. Os dados primários foram recolhidos através de entrevistas com profissionais que trabalham na área da AD. A análise da entrevista é baseada na metodologia de categorização indutiva de Mayring (2015).

Principalmente, os achados revelaram que a tentativa de aproveitar a vantagem de ser o primeiro a mover-se não é recomendada para as AIs. Um grande desafio é a falta de know-how tecnológico necessário para acompanhar as principais empresas de tecnologia. Também, a competência na abertura de cidades para a AD deve ser desenvolvida. Como AD carecem de confiança dos clientes, é importante desenvolver estratégias de criação de confiança. As características digitais que são desejadas pelos futuros clientes devem ser determinadas, bem como um modelo de negócio atractivo para competir no mercado de AD. Geralmente, o futuro papel das AIs na cadeia de fornecimento de AV ainda não está claro.

Palavras-chave: Automação, Condução Autónoma, Indústria Automóvel, Corporação automóvel, Inovação Perturbadora, Tecnologia Perturbadora, Dilema do Inovador, Tomada de decisões estratégicas, Falha estratégica, Posicionamento Estratégico, Incerteza

ACKNOWLEDGEMENTS

First of all, I want to express my gratitude to my supervisor Peter Rajsingh, for his inspiration, guidance in an exciting direction and through the entire process, valuable feedback, constant availability and support to carry out this dissertation.

Another thank you to all my friends that endowed me the best free time besides the dissertation writing and to my fellow students that shared time and experience with me in different libraries and locations to write my dissertation.

A special thanks goes to my boyfriend Chris who always supported me in the way I did my research and the appropriate time I spent for it. Thank you for creating my weekends in Munich to wonderful ones and for endless, supporting phone calls during my dissertation time in Lisbon.

Finally, a big thank you to my parents who accommodated me during my writing time in November and December at my hometown Munich. I was always equipped with a full fridge and lovely evenings when getting home after long days. Furthermore, thank you for the huge support during my entire study career and for enabling this possibility of doing my Masters in Lisbon at Catòlica Lisbon School of Business and Economics.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

GLOSSARY

AD	Autonomous driving (meaning automated level 5)
ADAS	Advanced Driver Assistance System
AGV	Automated guided vehicle
AI	Automotive incumbent
AV	Autonomous vehicle (meaning automated level 5)
CAV	Connected autonomous vehicle
CPS	Cyberphysical systems
DI	Disruptive innovation
DT	Disruptive technology
ICT	Information and communications technology
IoT	Internet of Things
MaaS	Mobility-as-a-Service
ODM	On-demand-mobility
OEM	Original equipment manufacturer
R&D	Research and development
SAE	Society of Automotive Engineers
SI	Sustaining innovation
V-to-C	Vehicle-to-cloud-communication
V-to-I	Vehicle-to-infrastructure-communication
V-to-V	Vehicle-to-vehicle-communication

1 INTRODUCTION

Autonomous Driving (AD) will be the means of conveyance of the future and demonstrates significant potential for solving infrastructural challenges faced by most big cities and countries. It is widely seen as one of the most disruptive innovations (DIs) nowadays to transform mobility and cities (Faisal, Yigitcanlar, Kamruzzaman, & Currie, 2019). Currently, the question is not if but when AVs will be market-ready (Mosquet et al., 2015). Compared to other innovations, vehicle innovations usually take longer as more regulatory issues are entailed than for other innovations (Litman, 2019). Experts and original equipment manufacturers (OEMs) say AVs will hit the road in the 2020s/2030s. The estimation ranges between 2040 and 2050 until AVs will be commonly affordable.

Effects such as congestion reduction or increased safety might be the first observed. Further positive impacts are expected, such as independent mobility for non-drivers, the very young, elderly or low-income people, pollution reduction and enhanced parking situations (Fagnant & Kockelman, 2015; Litman, 2019). Different studies from the U.S., Brazil or China reveal a general interest of people in AD (Herrmann, Brenner, & Stadler, 2018). According to a German statistic, only 18% would willing to use an AV whereas 29% would not and 53% are not yet sure (Aral, 2019). The main stigmas to acceptance are fear of manipulation (E.g., hacker attacks), lack of trust in the technology, or the concerns that it will not be affordable (DHBW Ravensburg, 2019). Moreover, robotization of automobiles illustrates a threat of loss control (Maurer, Gerdes, Lenz, & Winner, 2016). Many moral and ethical question, as well as safety and security questions arise in the context of AD. Hence, this technology evokes considerable skepticism alongside the advantages it produces.

Nevertheless, many car manufacturers and companies from different areas, like Tesla, Uber or Google, are engaging in R&D in the field of AD (Lipson & Kurman, 2016). At the same time, acquisitions, investments and partnerships increased rapidly in this sector (Fagnant & Kockelman, 2015). Companies need to decide how to add value in the AD market: software, hardware, data, content or a combination of some of these? It is necessary to acquire know-how and capabilities which explains the increasing acquisitions, investments and partnerships in the sector. For car manufacturers in particularly, meaning AIs, it is important to engage in innovation and acquire new knowledge to keep up with technology and software companies (Herrmann et al., 2018).

AD implicates competition not only between companies but also between countries. This is especially the case since governments, regulators and cities must be highly engaged in the field. At the moment, the United States is at the forefront of AD – both technologically and legally. The U.S. have the most self-driving cars on the road with many pilot projects from different companies in process. But the European Union is catching up. A legislation to allow AD on EU streets coupled with a legal framework for safety, cyber security and data treatment is in development. Furthermore, first test paths are being prepared with proper infrastructure. For instance, the highway between Nuremberg and Munich in Germany has already been equipped with the appropriate infrastructure. Technological and infrastructural progress is as also taking place in Asia, particularly in China. Numerous Chinese companies are being supported by the government in China's race to become the preeminent nation in AD (Herrmann et al., 2018).

With so many parties actively involved in the development of AD – from skeptical customers, to competing and transformative companies, countries and governments – the complexity of the AD landscape is apparent.

1.1 Topic Relevance and Problem Statement

This dissertation addresses a highly contemporary topic - the changing automotive industry due to the emergence of AD. The industry, primarily made up of big corporations and AIs, particularly OEMs, faces huge strategic challenges. Market boundaries are starting to blur which allow players from different markets to enter the automotive industry. The current literature does not discuss in any substantive manner the specific strategic challenges OEMs are confronting in the context of emerging AD technology. Based on Christensen's Theory of the *Innovator's Dilemma,* it is well known that incumbents are threatened when confronted by disruptive technologies (DTs). Consequently, it is important to recognize when strategic challenges occur, and to formulate decisions accordingly. This is especially true for the emerging disruption being brought about by AD.

This dissertation aims to answer the following research question:

How does Autonomous Driving affect automotive incumbent's businesses and strategies?

2 LITERATURE REVIEW

The first section is an overview of how automation has transformed the industry and people's lives. In the second section, the current state of autonomous driving research is discussed. The last section examines DT and strategic failures building upon Christensen's theory of the Innovator's Dilemma (1997) and applying insights to AD.

2.1 Automation

The technology of automation, sometimes known as the Third Industrial Revolution, replaces humans with machines in different areas of activity (Guarnieri, 2010; Hitomi, 1994; M. Wollschlaeger, Sauter, & Jasperneite, 2017). Automation has transformed the working environment in most industries (Autor, 2015; Leung, Paolacci, & Puntoni, 2018). This phenomenon harks back to the nineteenth century when automation displaced jobs for the first time. Back then, the threat was primarily for people with manual occupations. Today, the effects are more widespread. Technical professions being replaced, and a wide array of activities are now being performed by robots and AIs (Baldwin, 2019; Blanas, Gancia, & Yoon, 2019). Automation creates efficiencies for complex tasks and also for smaller activities in our daily lives, such as with the use of food processors for cooking or vacuum cleaner robots (Leung et al., 2018; Royakkers & van Est, 2015).

The first industrial communication networks appeared in the 1980s and generated new opportunities. Within the scope of information and communications technology (ICT), several more technologies have arisen that automate procedures and activities like the Internet of Things (IoT), the cyberphysical system (CPS) or the tactile internet (M. Wollschlaeger et al., 2017). These technologies enable networks and devices and allow for greater exchange of information between machines, in particular between controllers, sensors and actuators, and between humans and machines. The CPS, in particular, facilitates further technological developments such as autonomous driving or next-generation space vehicles and airplanes (Baheti & Gill, 2011). Automation systems have also evolved towards information processing using cloud-based technologies. Our new era of automation, coupled with communication technologies, is known as *Industry 4.0* or *the Fourth Industrial Revolution* (Fraunhofer Institute for Production Technology IPT, 2019).

The manufacturing industry has been transformed by mobile robots called automated guided vehicles (AGVs). These fully automated vehicles are able to navigate internal and external areas around factories, automatically guided along fixed pathways by a centrally controlled computer. AGVs illustrate the effectiveness of guided vehicles but are limited to warehouses and manufacturing plants and presently do not function well on openly trafficked roads (Baldwin, 2019; Wallace, 2010).

2.1.1 Automation and Connectivity in the Automotive Industry

The interconnectivity mentioned above profoundly affects the automotive industry as well. The industry is experiencing significant innovations as automated and connected vehicle technologies gain importance and traction. This is transforming the traditional role of car makers as manufacturers are orienting the industry more towards solving technological challenges (Bailo et al., 2018; Ferràs-Hernández, Tarratas-Pons, & Arimany-Serrat, 2017). It also forces AIs to collaborate with new technological entrants, in particular tech start-ups and software companies (Bailo et al., 2018; Ferràs-Hernández et al., 2017). Previously, the industry was based mostly on engineering proficiency only (Wollschlaeger, Foden, Cave, & Stent, 2015).

Today's automated systems, such as the Advanced Driver Assistant System (ADAS), provide convenience and support for drivers. The system does not presently create a fully automated ride, but further developments of the system will eventually lead to this (Royakkers & van Est, 2015). Based on new information technologies, ADAS allows vehicles to communicate with the inside and outside environments. The IoT and the collection, aggregation and analysis of real time data enhances the communication and connectivity of cars (Coppola & Morisio, 2016; Lu, Cheng, Zhang, Shen, & Mark, 2014). Other new services include Mobility-as-a-Service (MaaS), commonly known as carsharing (e.g. DriveNow), ridesharing (e.g. Uber) and carpooling (e.g. BlaBlaCar). This sector will gain more importance in the future and by 2030 the market could have been grown to $2 trillion. Sharing rides is attractive in the AD sector as well due to significantly reduced transportation costs for the user. Environmental consciousness is growing in people's minds and the car is increasingly losing its function as a status symbol. In addition, congested roads and lack of parking spaces in cities creates disincentives for owning a private car and promotes using sharing services. So-called robo-cars or robo-taxis describe the combination of AD and sharing concepts (Herrmann et al., 2018). Another example

of car connectivity is vehicle-to-cloud-communication (V-to-C) which equips vehicles with the latest weather and traffic information. More advanced systems allow even more information, such as V-to-I, connecting vehicles with infrastructure (E.g., traffic signs) or V-to-V, which connects vehicles with other vehicles (Herrmann et al., 2018). These technologies are first steps to fully autonomous driving vehicles on public streets.

2.2 Autonomous Driving

Although this dissertation focuses on automobiles, AVs can also be ships, drones, trucks, trains or airplanes (Yigitcanlar, Wilson, & Kamruzzaman, 2019). According to Baldwin (2019), automated systems presently still require human interaction. But as technology progresses, human interaction should be completely eliminated. The Society of Automotive Engineers (SAE, 2018), speaks of six levels of automation from level 0 where there is no driving automation to level 5 which represents full driving automation. In level 1 the driver controls most of the functions. In level 2 the driver is supported by at least one driving assistance system and in level 3 the vehicle is able to take over safety-critical functions. In level 4 the vehicle is already fully autonomous but the driver is able to interact for specific scenarios, and in level 5 the vehicle is able to drive fully autonomously in every situation without human interaction (Faisal et al., 2019; Herrmann et al., 2018; Martínez-Díaz & Soriguera, 2018; Maurer et al., 2016).

Pilot projects by pioneers like Uber or Waymo have reached levels 3 to 4, but on public roads only level 2 vehicles are in use (Bailo et al., 2018). AUDI is an AI who already offers a level 3 vehicle. And currently, most of the AIs are working on level 3 and 4 models (Martínez-Díaz & Soriguera, 2018). Eight of the big car manufacturers (Tesla, Audi, BMW, Daimler, Nissan, Volvo, Toyota and Ford) expect to have a level 4 or 5 vehicle in production by 2021, with some even announcing public road readiness as well (Business Insider, 2016).

2.2.1 Technology

AVs use the same technology described in section 2.1.1. The key factor of AD technology is vehicular communications with the external and internal environment, known as the V2X communications. In particular, vehicles must be responsive to the entire infrastructure of their environments, to other vehicles, to pedestrians, and they must communicate with the cloud and

with other personal devices to become a connected autonomous vehicle (CAV). Crucial components are the GPS function and sensing system, consisting of a mixture of sensors (e.g., Lidar), radars and cameras, that detect and collect all the data around the vehicle. These data are processed by a central computing system that extracts the relevant perception data and then makes real-time decisions to guide the vehicle safely through its environment (Bagloee, Tavana, Asadi, & Oliver, 2016; Liu, Tang, Zhang, & Gaudiot, 2017; Martínez-Díaz & Soriguera, 2018).

2.2.2 Challenges

DTs, such as AD that involve uncertainty about the future, always confront various challenges (Shaheen, Totte, & Stocker, 2018). This section is divided into six challenge areas pertaining to autonomous driving: (1) Technological Challenges, (2) Safety and Cybersecurity Challenges, (3) Ethical and Moral Challenges, (4) Infrastructural Challenges, (5) Legal and Regulatory Challenges, and (6) Business and Managerial Challenges.

Technological Challenges

From a technological point of view, the main challenge is to create a communications network that is reliable, safe and powerful enough to transfer an enormous amount of high-speed data under various weather and traffic conditions and across borders. The system must be secure and robust to withstand hacker attacks and be free of errors that might lead to system failures. A major challenge is that the sensing apparatus that needs to perceive every obstacle of its environment, yet sensor technology still has performance flaws (Kaur & Rampersad, 2018; Martínez-Díaz & Soriguera, 2018).

Safety and Cybersecurity Challenges

Although AVs are supposed to eliminate human failure, accidents and increased road safety, safety challenges are the most significant reasons limiting the introduction of AVs (Bagloee et al., 2016; Fagnant & Kockelman, 2015). The Uber self-driving test car crashed in March 2018 killing a pedestrian. This shook people's faith in autonomous car driving technology (The New York Times, 2018).

Another safety aspect is electronic security in the overall context of IoT. Even though the vehicle disallows human interaction, the system can be susceptible to hackers or terrorists (Fagnant & Kockelman, 2015; D. Wollschlaeger et al., 2015). This means that safety does not only pertain to technological error, but also implicates the security of the systems itself.

Market acceptance will play a critical role in the future of AV. Trusting the system plays a key role for adopting this new technology. *"Automation is only useful if the operators trust the technical system and thus also use it"* (Maurer et al., 2016, p.106). Creating this trust is a crucial challenge for AIs (Kaur & Rampersad, 2018).

Ethical and Moral Challenges

AVs raise various ethical questions which R&D departments must take into account (Maurer et al., 2016). Even though cars have sensors to avoid collisions and the overall infrastructure seeks to obviate negative events, there remains a probability of accidents occurring. In extreme situations a control algorithm needs to make moral decisions such as whether to protect passengers over pedestrians. How to decide in these situation presents an ethical dilemma (Bonnefon, Shariff, & Rahwan, 2016; Maurer et al., 2016). The question of who bears responsibility for negative situations also has yet to be determined. According to Li, Zhao et al., (2016), people place the responsibility more upon car manufacturers and the government rather than blaming the AV itself as an autonomous moral agent.

Another concern is that individuals resist losing control when they are merely passengers and have no responsibilities for driving. In fully autonomous vehicles, the driver is completely replaced as an active physical decision-maker. Mental models, meaning important behavioral patterns developed during driving experiences, may disappear over time when human reactions are no longer required for critical safety situations. Instead, new skills of understanding and monitoring driving systems must be learned (Maurer et al., 2016).

Infrastructural Challenges

Most cities and metropolitan areas face major problems with traffic congestion. This should be reduced through AVs. City infrastructure needs to be created in conjunction with AVs, most notably expansion of V-to-I communication (Fagnant & Kockelman, 2015). Functional V-to-I

communication requires complete and clear signs and well-constructed technology-enabled roads set up throughout an entire city area (Martínez-Díaz & Soriguera, 2018).

Legal and Regulatory Challenges

Legal issues present challenges as well. As already stated, regulations will need to stipulate who takes responsibility and is liable for accidents. If the AV shows an error which causes an accident, more parties could be accountable. These include "the vehicle manufacturer, the manufacturer of a component used in the autonomous system, the software engineer who programmed the code for the autonomous operation of the vehicle, and the road designer in the case of an intelligent road system that helps control the vehicle" (Marchant & Lindor, 2012, p. 1328) (Hevelke & Nida-Rümelin, 2015; Marchant & Lindor, 2012). It is necessary to introduce certifications and regulations around vehicle safety, tort liability and data protection. For instance, EU commission is already working on a coherent legal framework (European Commission, 2018).

Business and Managerial Challenges

For AIs developing AVs means working together with different parties such as tech startups and policymakers. New entrants specializing in AD software are playing an increasingly significant role as the industry develops by providing essential technologies. Collaborations with tech startups and other service provider companies is indispensable for car manufacturers (Bailo et al., 2018; Yigitcanlar et al., 2019). Technological progress and rising competition are forcing AIs to acquire new capabilities which leads to organizational and process transformations (Herrmann et al., 2018). E.g. Volkswagen and Ford invested in Argo AI, a software developer startup, to expedite developing AVs (Volkswagen Newsroom, 2019).

Bailo et al. (2018) show different partnerships and collaborations in the mobility sector with the following illustration:

Figure 1: *Illustration of car manufacturer's partnerships in the market of connected vehicles, automated vehicles, and mobility services*

Source: Bailo et al. (2018), Center for Automotive Research

AIs are collaborating with tech companies and also with policymakers and urban planners for the development of AVs (Litman, 2019). Even though the car manufacturers believe the technology will be commercialized in the next few years, the complexities present substantial uncertainty, especially regarding timing of when it will be available and how it will vary across geographies (Maurer et al., 2016).

2.3 Strategy in the Context of Innovation and Uncertainty

When it comes to DTs, the terms DI and strategic failure are extensively discussed in management theory. The literature on these topics will be covered widely in this thesis, especially literature on innovation strategy. A pioneer in the field is Clayton M. Christensen with his seminal work *The Innovator's Dilemma* (Christensen, 1997). These and other works will be drawn upon to discuss strategy and strategic failure, uncertainty, DI, DT, strategic opportunities, existing industries and new entrants. All these concepts bear upon important strategic challenges and uncertainties pertaining to AD.

2.3.1 Disruptive Innovation and Strategic Failure

The term of DI or DT was defined and shaped by Christensen in various works. Understanding DTs is the basis of most innovation, especially technological phenomena like AVs.

Unlike sustaining innovation (SI) or technologies, which simply improve the performance of an existing product or service, in the short-term DI may result in worse product performance. "Products based on disruptive technologies are typically cheaper, simpler, smaller, and, frequently, more convenient to use" (Christensen, 1997, p. 11). Not all these factors are crucial for every DT depending on the industry (Danneels, 2004; Govindarajan & Kopalle, 2006a). A key to understanding DT entails looking at customers. They typically do not want and cannot use DTs in the near-term. First movers adopting DTs are a niche cohort and, for the firm, disruption is the least profitable activity generating lower margins. The paradox associated with DT for mature organizations is that by concentrating on their large customer base they improve existing products and generate higher margins, but this does not allow them to focus on a DT.

Furthermore, DTs are usually initially useless in mainstream markets and are introduced in insignificant or emerging markets. Since DTs in some way seek to provide customers with a product they don't need or can't use, organizations also tend to "overshoot" vis-à-vis their customers, meaning the product offers customers more than they are willing to pay for and actually demand. Richard Rumelt proposes that every innovation is a form of value denial - products or services that do not exist in the market but are actually desired and viable (Lovallo & Mendonca, 2007). A disruptive product will not be competitive at the time of its inception, but its competitive advantage takes hold over time. When more investment is made in R&D, then the product is more likely to satisfy consumer requirements in mainstream markets rather than being confined to niche markets. Consequently, DTs have the potential to displace what already exists. Nevertheless, Christensen's main finding implies that incumbents tend to fail or falter when trying to develop DTs. Incumbents handle SIs well due to their established processes and resource deployments, but these processes and resources tend to not support disruption. With respect to R&D, incumbent firms struggle to keep up with the R&D associated with startups that are singularly focused on DTs. Thus, DTs cause incumbents to be replaced by competing entrants (Christensen, 1997; Christensen, Anthony, & Roth, 2004; Moy, 2004).

Organizational structure is a strategic challenge when it comes to DTs. Since DTs usually necessitate novel processes or resources, a creation of separate and autonomous business units facilitates development of DTs (Christensen et al., 2004; Govindarajan & Kopalle, 2006).

Furthermore, a company should concentrate on being a learning organization when it comes to product innovation. Henderson & Clark (1990) introduced the framework of architectural innovation which depends on organizational learning. Organizational learning is an important factor in the context of innovation, a concept shaped by Peter Senge and his work *The Fifth Discipline* (Senge, 1997). For innovative products, it's also crucial to learn about component changes meaning fully understanding the product's architecture. When it comes to product innovation, organizations demand different skills of different people and entities. With respect to organizational learning, Christensen (1997) also states that managers facing a DT in a developing market should define strategic plans relating to execution in terms of discovery and learning.

2.3.2 Uncertainty in Strategic Decisions

Uncertainty in a managerial and strategic context refers to unpredictable variables pertaining to environmental and organizational factors that affect an organization's performance (Miller, 1993). According to Christensen (1997) it is not possible to analyze markets that do not exist yet nor how market applications of the future will actually perform. The full implications of DTs are unknowable at the stage when those technologies are under development. This is also aligned with Raynor's view (2007) that extrapolating into the future entails unpredictable uncertainties.

Raynor (2007) further states that the ideal strategy is one that best aligns with tomorrow's circumstances. Committing to a strategy means deploying capabilities which can't be adapted afterwards even if the predictions prove to be wrong (Raynor, 2007). Nevertheless, Rumelt maintains that strategic thinking helps position a company for uncertain conditions (Lovallo & Mendonca, 2007). Ambiguity and uncertainty are inescapable but to achieve some semblance of certainty, organizations can wait for the others to stake positions in the market and see what happens. This implies that one of the challenges of a competitive strategy in the face of uncertainty entails monitoring competitors who take positions and then acting early to leapfrog over them. Christensen et al. (2004) also recommend this flexibility and nimbleness and advocate following an emergent strategy. An emergent strategy means collecting feedback and information about emerging market conditions to observe what works and what fails. Unlike Lovallo & Mendonca (2007) and Christensen et al. (2004), Wernerfelt & Karnani (1987) state that the best competitive strategy in the face of uncertainty is to focus on being a first mover

instead of waiting for a competitor's action. Incentives to invest early in R&D are strongest when more competitors exist, meaning the higher the competition, the greater the need for an earlier commitment to action (Wernerfelt & Karnani, 1987).

3 METHODOLOGY

This section covers a detailed description of the methodology used to examine the stated research question.

3.1 Research Approach and Design

The underlying methodology incorporates both secondary and primary research. Secondary data in terms of current literature was reviewed to study the topic and enhance knowledge. After assembling secondary research data, it was possible to prepare qualitative research in the form of primary data conduction. The primary data consisted of conducting three semi-structured interviews with professionals working in the field of AD AIs. The interviews were intended to obtain insights and perceptions of experts in the automotive industry dealing with AD.

Due to the complex topic and the uncertainty of the market, this qualitative approach was determined to be the most appropriate course of action. Furthermore, it was chosen to enable deeper understanding of the investigated problem and to provide qualitative information that pertains to various dimensions of the field (Queirós, Faria, & Almeida, 2017). The secondary research method relies on the reviewed literature that serves as the basis for the literature findings of section 2.1, 2.2. and strategic theories of section 2.3 discussing the primary research findings.

3.2 Expert Interviews

The three interviews with the AIs were conducted in German and lasted about 30 - 45 minutes. They were recorded for further and deeper analysis. The educational and professional backgrounds as well the current occupations of the interviewees allowed them to be classified as experts in the field of AD, qualified to comment upon current changes in the automotive industry. Given that strategic insights about the development of an emerging and completely new technology implicates sensitive information, the interviewees were assured anonymity.

Table 1: *List of interviewees and their position at the automotive incumbent*

Position	Organization	Interview
Strategy Project Lead for Autonomous Driving and PhD in Adoption of Disruptive Technologies of incumbents	Automotive incumbent	1
Development and Strategy for Digitalization and Autonomous Driving	Automotive incumbent	2
Business Development, Partnering and Strategy in the Development of Autonomous Driving	Automotive incumbent	3

3.2.1 Interview analysis based on Mayring's (2015) scheme

The analysis of interviews is based on the inductive categorization methodology of Mayring (2015). Qualitative content analysis is divided into sections based on different categories using Mayring's method of summarizing. This is appropriate for analyzing interview data in a structured manner and guarantees a realistic and unbiased representation of the material. Categories are derived directly from the material without previous assumptions or definitions. This methodology helps structure the interview findings for section *4. Findings* of the dissertation. Content within the different categories overlaps in places.

The single steps of the procedure are illustrated in Figure 2 and Figure 3 shows the method directly applied to the interviews.

Table 2 represents the single encoded categories, meaning the frequency at which interviewee's phrases fit into each category.

Figure 2: *Inductive category building in accordance with Mayring (2015)*

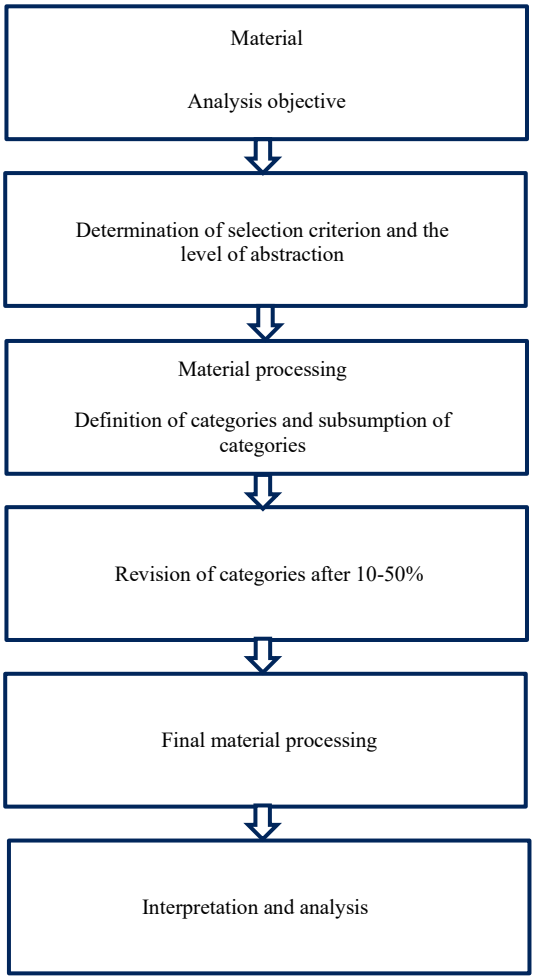

Figure 3: *Inductive category building in accordance with Mayring (2015) applied to the interviews of this study*

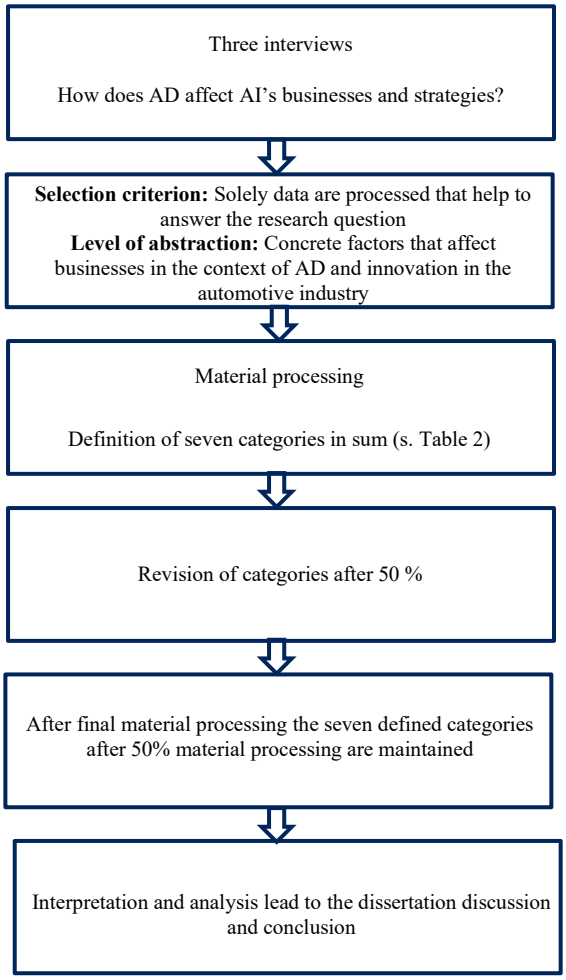

Table 2: *Category definition based on the three interviews*

	Defined Category	Codes (Phrases)
1	Competitive Environment in the AD Market	8
2	Innovation Type of Autonomous Driving	7
3	Technological Challenge	8
4	Corporate Strategic Positioning in the AD Market	14
5	Changes in Automotive Incubent's Competitive Advantage, Structures, Resources and Processes	30
6	Appropriate Business Model	5
7	Changing Customer and Trustbuilding	15

4 Findings

The interview findings were categorized in seven sections that display a strategic view of the current automotive industry and its incumbents. AD opens up many opportunities for AIs but at the same time implicates potential threats. Therefore, a well-calibrated strategy is required to deal with uncertainties associated with the future (Interview 1, 2019).

4.1 Competitive Environment in the Autonomous Driving Market

The competitive environment in the AD market is causing strategic change within organizations in the traditional automotive sector, especially AIs. In fact, there are four groups of companies participating in the AD market: traditional OEMs, meaning AIs in this study (e.g. Daimler, BMW, VW), tech-companies (e.g. Google, Intel, Nvidia), tech-startups (e.g. ARGO AI) and ride hailing or ride sharing companies (e.g. Uber, Lyft, Didi). The mixture of these players in the market demonstrates how boundaries are starting to blur. Companies and startups that never operated in the sector or did not exist ten years ago have entered the automotive industry (Interview 1, 2019). Waymo, a subsidiary of Alphabet, is currently leading in AD (Interview 1, 2019; Interview 2, 2019). Waymo was founded to develop a self-driving car, in particular an AD system, to be integrated into models from Jaguar or Volvo (Eichsteller, 2018). The fact that a tech-company and not an OEM is currently pioneering points to the emergence of new competitors for OEMs. Companies like Alphabet are using a core competence – software development – to enter the automotive market which is in the midst of a secular transformation from car manufacturing to software development (Interview 1, 2019). Ford and VW acquired the tech-startup ARGO AI and are seen as market leaders in AD as well. Although Ford and VW are large car manufacturers, they did not possess requisite technology expertise and consequently acquired a startup with software capabilities (Interview 2, 2019). Similarly, General Motors acquired the self-driving car company, Cruise (Interview 1, 2019). Thus, OEMs are being forced to collaborate with tech-companies to acquire the complex technological know-how needed to develop autonomous driving systems. Daimler and BMW partnered to co-develop and share investment costs for AD (Daimler, 2019; Interview 1, 2019; Interview 2, 2019).

The ride sharing market in the US is mainly dominated by Uber and Lyft. To provide some numbers, in Las Vegas there are 3,000 taxis, but 20,000 Lyft and Uber cars. Uber has already tested self-driving cars for the ride sharing market (Herrmann et al., 2018). AD is consequently

no longer a technology that only concerns the traditional automotive industry. It has become a race between AIs, tech-companies, startups, ride hailing companies, representing acquisitions, partnerships and huge R&D investment.

4.2 Innovation Type of Autonomous Driving

For players in the AD market, it is important to figure out which type of innovation they are confronting. The question to clarify is whether to assess AD as a DI or merely as a SI. In a theoretical sense, AD may be posited as a DI or DT. Without theoretical substantiation it is not possible ex-ante to define an innovation as a DT (Adner, 2002). But based on Christensen's theory (1997) it is viable to clarify the role of AD in terms of DI. DTs are uncompetitive in mainstream markets but can displace the mainstream technology of their markets in the future.

A further characteristic is that the DT might appear useless to customers at present, but it has the potential satisfy their needs in the future (Christensen, 1997). This characteristic is clearly applicable to AD. AVs are currently not viable in the present automobile market, notwithstanding the fact that AVs of the automated maximum level 5 are not deployed yet. A different approach to make ex ante predictions would be to rely on historical data. However, in the case of new technologies and emerging markets this is difficult (Danneels, 2004).

Nevertheless, there is a somewhat comparable case that was investigated by Christensen in his work, *Innovator's Dilemma* (1997). The use case deals with electric vehicles (EVs) and is related to AD on a technological level. EVs were first lacking a breakthrough in battery technology and had not gained any traction in the market for a long period of time. But based the evident characteristics of the technology they were classified as a DT, even they initially did not perform better than gasoline vehicles. This case is analogous to AD technology, considering that level 5 has not yet been achieved technologically and in its current stage of development AD cannot compete with actual cars. However, this theoretical approach and use case analogy is not sufficient to evaluate and determine whether AD is in fact a disruptive technology.

The interviews also provided no definitive unequivocal answer to this question. On one hand AD is clearly disruptive when looking at the big picture and if the following three conditions are fulfilled: 1) the AV is able to act like a human 2) the AV is affordable 3) the AV does not require human interaction. Mobility itself changes through elimination of the driver, which is

probably the biggest disruption in the automotive industry since its inception. Likewise, mobility behavior will change because people will be able to use time in vehicles for activities other than driving (Interview 1, 2019; Interview 3, 2019). Secondly, market dynamics change due to the shift of business competencies from car manufacturing to software development and computing. Thirdly, market boundaries start to blur as a result of companies entering the market that were never competing in the automotive or mobility sector. Fourthly, instead of a good working engine, data and communication are the most important elements of AD (Interview 1, 2019). On the other hand, it may be disputed that AD will be a disruptive innovation and it may be described instead as an evolution or incremental SI. There is no rapid introduction of this technology but rather it entails step by step increasing automation of cars. AVs will definitely have disruptive effects on certain players, causing some OEMs or other companies to fail, but previous car models will not become useless and obsolete from one day to the next (Interview 1, 2019; Interview 2, 2019).

4.3 Technological Challenge

It is obvious, that there's an urgent need for OEMs to acquire new technological knowledge. Besides gathering know-how, there remains the challenge of how to reach a technological stage of maturation for the AV industry. In general, it must be decided whether to develop software in-house or to outsource it. For instance, Ford and VW consign the technological development to ARGO AI whereas General Motors and Honda partnered and develop tech in-house (Interview 3, 2019). Companies like Waymo previously announced that they were ready to deploy AD technology ready, but it turned out they were not able to meet their own deadlines. The technology required is more complex than originally envisaged.

As mentioned in section 2.2.1, one problem is a flaw in the workings of sensors and cameras (Interview 1, 2019). A ca. 90% - 95% safety level of the vehicle can already be achieved, perhaps even a 99%. But it is extremely tough to get to a 100% or at least 99,999% safety level (Interview 2, 2019; Interview 3, 2019). One main challenge is with the data processing of sensor and camera data. Firstly, a proper quality of data must be supplied, meaning the data must be identified correctly by the technology. As an example, a Tesla crashed because it confused a truck with a cloud (Interview 2, 2019; Yadron & Tynan, 2016). Secondly, it must be decided where to process the data, as the amount of data to be processed is enormous. It is possible either to process data in the vehicle itself which leads to a bigger hardware challenge than there

already is. Or it is possible to process data offboard, which means processing in a central data center. This implicates high-speed data transfer in real-time between the vehicle and the data center. The infrastructure is not ready to enable such data processing and transfers, especially because of the lack of large data networks and presence of several dead zones in rural areas (Interview 2, 2019).

One of the most critical aspects is to make the technology affordable. The component prices (computer and sensor systems) are not at appropriate price levels. For instance, when autonomous ride sharing begins with AVs, prices must match the price of taxis and competing ride sharing provider levels. In the beginning robo taxis might not perform better than human taxi drivers (Interview 3, 2019). All of the three interviewees agreed that the technological challenges are still the biggest hurdles for bringing AVs to the market.

4.4 Corporate Strategic Positioning in the Autonomous Driving Market

One main corporate decision which needs to be made is whether to aim for being the first mover of introducing AVs or waiting to let competitors position themselves first to observe what happens. The latter is what Richard Rumelt and Christensen advocate vis-à-vis innovations in general, and particularly with respect to DIs in emerging markets (Christensen, 1997; Lovallo & Mendonca, 2007). Since AD is a technology that is associated with high uncertainty and complexity, the strategic literature recommends waiting to let competitors take a position first to achieve some sort of certainty instead of being a first mover.

The interview findings mostly accord with what appears in the literature on this point, specifically speaking for AIs. Firstly, it depends on the type of company and if it's a fruitful endeavor, before an OEM should push to be the first mover. A key question concerns the nature of the competition itself. Due to the risky and complex innovation needed for AD, one must weigh if it is even possible to be a first mover in the competitive environment of AD. Speaking for a premium level OEM for whom safety is a paramount priority, it's questionable whether one ought to be a pioneer with a technology that has low customer trust and a potential risk of accidents. Safety is a critical matter for car manufacturers, and this is inextricably woven into the value proposition. The risk of accidents is just too high in the beginning and an AI would not want to be associated with this level of failure (Interview 1, 2019).

Regarding autonomous ride hailing or ride sharing services, the market will already be saturated due to the current market leaders (e.g. Uber, Lyft) in this sector. Thus, there will likely be no room to enter the market later with these two companies dominating the market. Furthermore, premium OEMs, for instance, will have a hard time competing on price since it is difficult to bear costs on their own. But from another perspective, it makes some sense to aim to enter the market as a first mover here because of the danger of entering a completely saturated market by waiting too long (Interview 1, 2019). Thus, no matter which approach is chosen concerning entering the autonomous ride hailing market or not, there is a dilemma for OEMs. Either they can protect their reputations for safety by not being a pioneer or they can risk their reputations by becoming pioneers.

However, there are numerous open issues that hinder OEMs from introducing AVs regardless. Still being determined or yet to be introduced are regulatory and infrastructural standards, data communication protocols, and sensor reliability under difficult conditions. Regulatory and infrastructural standards in particular have not been elaborated and no country allows AD on public roads. Before regulations are introduced it is not advantageous to be a first mover. But if an OEM pioneer has the possibility to define standards with regulators on the one hand, this is more reason to move forward (Interview 2, 2019). On the other hand, if one is not a pioneer and decides to wait, this would mean entering a mature market where laws and standards have already been shaped. Technology, as well the go-to-market strategy, can be adapted for these conditions (Interview 3, 2019). Overall, all three interviewees agreed upon the corporate positioning strategy to wait and observe competitors and circumstances.

4.5 Changes in Automotive Incumbent's Competitive Advantage, Structures, Resources and Processes

As already stated, according to the literature incumbent firms struggle to keep up with the R&D lead of startups that are intensively focused on DI. This phenomenon causes incumbents to be replaced by entrants (Christensen, 1997; Christensen et al., 2004; Moy, 2004). Although the distribution of roles in the supply chain of AD is yet not clear, the threat for incumbents of being replaced or overtaken by tech-startups or tech-companies is high (Herrmann et al., 2018). SIs are well handled by incumbents due to their established processes and resources, but in the case of new DIs incumbents risk failing in their R&D efforts (Christensen, 1997). Core competencies in automotive industries are shifting from hardware and car manufacturing

towards software expertise. This forces traditional OEMs to acquire software capabilities. The shift affects OEM's structures, resources and processes, as well as their competitive advantage (Herrmann et al., 2018; Interview 1, 2019; Interview 2, 2019; Interview 3, 2019). According to Henderson & Clark (1990, p. 28) "[…] learning about new architectures require a different kind of organization and people with different skills."

The interviewees expected a clear strategic approach on the part of AIs under these known circumstances. Obviously, organizational structures become more complex with expansion. To become more dynamic and adaptable, flatter hierarchies like in startups are required (Interview 1, 2019). OEMs need to change to catch up with tech companies like Alphabet, also becoming nimbler. OEMs tend to plan car models years in advance whereas software products have generally short-term turnarounds and require agile production methods (Interview 2, 2019). The automotive industry is already shifting in this direction. But those who do not become more dynamic and adopt speedier processes will face massive problems in the future (Interview 2, 2019; Interview 3, 2019). Moreover, taking Germany as an example, new HR strategies would be useful. To acquire good software knowledge from international, well-educated graduates and experienced professionals, OEM locations in Germany like Sindelfingen or Wolfsburg are not attractive to this labor force. Rolling out more attractive work locations would be helpful for hiring well-qualified high-tech personnel. Additionally, partnerships and acquisitions are already taking place between AIs and tech companies, the pace should be increased. There needs to be strategic decision-making concerning collaboration with tech startups or with other OEMs, like the partnership between Daimler and BMW for developing AD (Interview 1, 2019).

Nevertheless, it is not simple to produce vehicles in large quantities which remains an advantage for AIs. Other companies, in particular startups, will have a hard time to keep up the manufacturing capabilities of OEMs. As an example, even Tesla which is a car manufacturer working on innovative vehicles, has problems keeping to a production schedule with large volumes. Additionally, OEMs are good at managing the entire supply chain which entails complex processes to produce a vehicle from start to finish. OEMs are also ahead in determining overall safety concepts compared to startups or companies that have recently entered the market. Startups and new entrants will suffer hurdles when it comes to safety standards and getting vehicles approved. The topic of safety topic is even greater regarding AD, and OEMs already have their own safety requirements and resources to address safety issues. But as the role of OEMs and other players in the supply chain are not clear and apparent at this point in time. It is difficult to make statements about the future production processes of AVs (Interview

3, 2019). According to interviewee 3, software companies are staying away from vehicle production and rather solely developing the technology to integrate with vehicles from traditional car manufacturers. Overall, the interviewees could not state a clear role for AIs in the future supply chain of AVs.

One development in the future will be opening up cities, meaning to collaborate and negotiate with regions and cities. Rights to create pilot projects will be competed for in specific areas. This will require intense collaborations with regulators of countries and cities and new levels of competency and expertise (Interview 1, 2019). For China, as an example, the collaborations will take place in smaller geographies since regulations and laws are not country wide in China. For Europe, regulations and laws are more centralized and country wide. This creates harder challenges to negotiate for appropriate comprehensive regulations and laws (Interview 3, 2019).

4.6 Appropriate Business Model

Another main challenge for AIs relates to the question how to make money out of AD. Approaches may be different but there is no avoiding considerable expenditures with low returns in the beginning. The main challenge is eventually to produce AVs in large volumes at affordable prices. What is an appropriate business model for this? Commercializing AD requires figuring out the business case particularly since OEMs have responsibilities to shareholders (Interview 1, 2019). In the beginning the business model should be based on on-demand-mobility (ODM). But it will be exorbitantly expensive to equip only some vehicles with AD technology. There may be a few customers desiring to own an AV for private use, but the majority of customers would not be open to spending the sums of money needed to acquire an AV. Whether deciding for the ODM business model or entering the market by commercializing private AVs, both do not appear to be attractive business models for realizing returns (Interview 2, 2019). According to interviewee 3, the most appealing initial use case for AD will be fleets or platooning "(convoying to make more efficient use of road space)" (Maurer et al., 2016, p. 156).

AD is most attractive for a tech giant like Google. Google has the financial resources to develop the technology to integrate it into purchased vehicles. All the data can be maintained by Google which would suit Google well. For AIs, the most attractive business model is not clear so far and must be further investigated (Interview 1, 2019).

4.7 Changing Customer and Trust Building

AD brings many advantages and should gradually become more desirable to people. Presently, there remains a lot of skepticism about accepting the technology. Safety and security remain questionable, so the public does not trust the technology. Next, many individuals around the world enjoy driving. In fact, people enjoy driver-assisted systems but do not want to relinquish their hands on the wheel and foot on the gas. The feeling of freedom while having control over one's own vehicle provides a sense of empowerment. Finally, if AVs increase in price compared to regular cars, it is unlikely customers would be willing to pay for the additional benefits (Herrmann et al., 2018).

Interviewee 3 pointed out that his team is not convinced that level 5 automation will ever be attained for AVs. A vehicle, acting like a human under all weather and environmental conditions, is not realizable in their view. Level 4 AV is feasible but there will always be the option to interact with a human driver within the vehicle and the need for human intervention in extraordinary circumstances. Thus, if the industry only makes it to level 4, AVs might still be accepted and adopted by people (Interview 3, 2019). For level 5 vehicles all the initial concerns will continue to persist that have been there since the outset, and these skepticisms arise already for level 4 vehicles (Herrmann et al., 2018).

There are options for AIs to build up trust in customers. Firstly, transparency is important and car manufacturers should convey information about the entire system to the customer, how it works and what its limitations are (Interview 3, 2019). Advertisements about safety should be planned and pilot projects without human interventions allowing AVs to drive around successfully should make the technology more accessible to customers (Interview 1, 2019). Secondly, OEMs should avoid the mistake of introducing not market-ready AVs too early. As an example, Tesla introduced its vehicle with a level 2 system as level 3 system which potentially led to breach of trust. People consider that driving a level 3 system and transferring too much control to the technology can cause accidents (Interview 1, 2019; Interview 3, 2019). Thirdly, there should be a step by step approach oriented towards gradual customer conversion by introducing automated features progressively and encouraging customers themselves to choose as many features as possible (Herrmann et al., 2018; Interview 1, 2019). Fourthly, customers should get to know the first AVs not by privately using them but by using robo taxis first. The go-to-market strategy should comprise of the following two steps: 1. Reach the broad masses through offering autonomous ride hailing services, meaning robo taxis and 2. As people

become familiar with the technology and the technology is further advanced, OEMs should start commercializing AVs for private use (Interview 1, 2019).

Nevertheless, similarly to other disruptive innovations, trust will be low in the beginning (Interview 1, 2019; Interview 2, 2019). The broad masses might not even be convinced by hard facts initially but, conversely, early adopters who are innovative and technologically oriented will always (Herrmann et al., 2018; Interview 2, 2019).

New technologies still confuse customers because new functionalities and features require crucial changes in customer behavior. This is why customers sometimes fail to see advantages of new benefits and refuse to quit usual behavioral patterns or accept new technological applications (Herrmann et al., 2018). Notwithstanding this fact, interviewees agreed that customer demands will not get overshot by the introduction of AVs since automated features will be introduced in a staged, step by step manner allowing time for the public to become accustomed to changes as with any innovation. Given the rise in automated features and digital benefits within regular cars, the profile of the traditional driver has already changed as a customer. An AV will not have the same perceived value for customers as cars have today. It is up to companies to figure out what the demands of future customers will be. Since the riding time in an AV can be used more efficiently or simply for resting, car manufacturers must equip vehicles with suitable amenities (Interview 1, 2019; Interview 2, 2019). A recent example related to the Mercedes-Benz voice assistant is the MBUX baby-protocol feature that helps put babies to sleep to ensure a calmer ride (Mercedes-Benz, 2019, Interview 2). Sustainability concerns are of increasing importance in people's minds and the trend is towards not owning a car (Interview 1, 2019).

5 DISCUSSION

First and foremost, this research has focused on the business of OEMs, meaning AIs, in the context of AD. It has not dealt with a variety or regions or countries, and only employees from German AIs were interviewed. This reduces the scope of the findings and expresses on the point of view of these corporations while excluding the standpoint of competing companies such as tech enterprises and startups, as well as companies from other countries such as the U.S. or China. Furthermore, the interviewees only expressed their own opinions based on their expertise and experiences in the field of AD. Thus, the findings should be treated narrowly, and

it should be not made sweeping generalizations based upon them. Although only three interviews were conducted, it was possible to obtain a comprehensive qualitative and objective overview of the industry and at the same time deeper understandings for the purposes of the dissertation topic.

The findings describe current radical changes and shifts within the automotive industry due to the increasing technological importance and digitalization. Increasing automation across the board is transferring control from humans to machines and technology. The automotive industry is currently experiencing an immense technological shift and AD will likely cause the biggest changes in the sector since automobiles were first introduced by completely eliminating human drivers in vehicles. As already known from the literature on strategy, incumbents developing DIs are threatened or when disruption occurs in their industry they risk going out of business. It cannot be clearly stated from the interview findings if AD represents a DI or SI as opinions diverge on the subject. The tendency is to treat AD as a DI, as AD will cause immense changes and shifts within the automotive industry and creates novel behavioral norms for customers concerning mobility due to the elimination of an active driver. Like most DIs, characteristics pertaining to AD, like AVs, are not valued by customers in the current mainstream market. The technology also requires novel processes or resources within incumbent firms and creation of separate and autonomous business units to facilitate development of the DI. Looking at AD from the perspective of a timeline, AD can be also defined as SI due to the fact that AVs of the maximum automated level 5 are simply an improvement upon previous innovative features with the level 1 to 4 framework. Apart from this, it should be added that the technological progress of AD is not sufficiently advanced to make definitive statements about whether to define it as DI or SI. Although it can be characterized as a DI, the dyadic point of view depending on whose perspective you adopt demonstrates ambiguity on this matter.

Furthermore, players from different industries are entering the automotive market which leads to a blurring of market and sector boundaries which affects the businesses and strategies of AIs. The future role of AIs in the AD market is definitely not clear while they have to orient themselves to a significant market transformation. Failure to do this will mean difficulty catching up with new entrants and incumbents must use their technological competencies to enter the AV market with already established capabilities.

The main findings in terms of strategic impacts affecting AIs are the following: 1) It might not be advantageous as an AI to aim to be the first mover introducing AD 2) Technological know-

how must be acquired through partnerships or acquisitions of software companies or through new strategies, like HR initiatives to acquire talent 3) Core competencies have shifted towards software expertise and to strategies for opening up cities or regions 4) Trust building actions must be implemented to create confidence and acceptance of the technology for customers 5) Which digital features future customers of AV desire must be investigated 6) The optimal AD business model must be still figured out. The interview results are mostly consonant with the authors writing on the subject and complement claims in the current literature. In the following paragraphs these findings are elaborated.

First of all, AIs should not aim to be first movers in the AD market. They should preserve their reputations for safety image and not risk breaching customer trust by hitting the AD market too early. It is instead recommended to let the technology emerge first, while observing what works and what doesn't to enter a developed market and facing more certainty. In fact, the recommended strategy is to let pioneers like Waymo hit the market first, allowing customers to become accustomed to the technology by using AD ride hailing services. It is preferable to enter the market at a stage when both the technology and customer trust are more advanced. This result concurs with Richard Rumelt and Clayton Christensen who recommend flexibility and letting others position themselves first to achieve visibility to elements of certainty in emerging markets. The question still remains if AIs should compete in AD ride hailing services or if they should let this market be dominated by the established players, Uber and Lyft. This would mean solely entering the AD market at a later stage to commercialize AVs for private use. AIs might further get involved at the early stages of AD to serve as car parts manufacturers providing the hardware.

According to the literature, incumbents struggle to keep up with the R&D lead of startups focused on DI. DI threatens incumbents weakening their competitiveness advantage and causing them to be replaced by new entrants. The interview findings indicate the need to increase partnerships with tech companies and startups to keep pace with pioneers like Alphabet. Recent acquisitions, such as Ford and VW acquiring ARGO AI, show that AIs already are engaging in this strategy. When making acquisition or partnership decisions, it is important to decide whether partnering with other OEMs, investing in tech companies and startups, or both. AD initiatives require novel processes, resources and the creation of separate business units. Interviewee 1 recommended implementing new HR strategies by creating autonomous business units at attractive locations to hire talent and develop AD competencies. Another skillset that must be developed is to open up cities and regions for pilot projects. This

is advantageous as companies can take a lead in shaping regulations for specific areas. Alternatively, AIs will benefit from entering areas where regulations are already in place.

The findings revealed crucial actions needed to build up customer trust. AIs familiarize customers gradually with the technology. As drivers become more familiar with increasing automation and different features in cars, they will be more receptive to adopting a fully AV when this becomes available. Although the interviewees agreed that AD will not overshoot customers' expectations, roll out should occur gradually, so that the technology does not seem overly disruptive all at once. When commercializing AVs, pricing could exceed customers' willingness-to-pay so price points are relevant. This point does not matter for ride hailing services where customers do not need to spend money for an entire AV but only pay for the single ride. Additionally, as customer behavior and desires change, AIs must make determinations about the future instead of simply following current customer demands. This coheres with Christensen's findings not to focus on current customer requirements but rather to develop niche markets for DIs successfully to take root and to avoid strategic failures.

One major strategic challenge is how to find an attractive and appropriate business model as an AI. The difficulty is making AD affordable since R&D requires immense investment while being able to scale AV production. It is complicated weighing at which stage in the business maturation cycle it will become profitable for a company to enter the AD market and in what role in the supply chain should the company endeavor to compete. Given these considerations and as already stated, it is important to determine strategically whether or not to enter the autonomous ride hailing service market as a first business step. Besides all strategic challenges, the general capabilities of manufacturing vehicles in great amounts, implicating complex supply chain processes and elaborated safety concepts remain an advantage for AIs which were developed and improved over a long time. Entrants might not be able to adopt such capabilities when expertise focuses on software and technology.

The aforementioned strategic challenges are interrelated and create path dependencies. Due to resource limitations, high levels of uncertainty and complexities concerning AVs it is not possible to provide determinate strategic decisions that must be made by AIs. Nevertheless, it is possible to deploy insights and weigh probabilities for better outcomes.

As the topic could not be investigated deeper due to time and space constraints, adding more interviews would further amplify and complement the research outcomes elucidated here. It is crucial to take all involved stakeholders into account to avoid strategic failures in the future.

The literature concerning AD is mostly focused on technology, infrastructure, the environment, customers and how these impact each other. Strategic considerations have yet to be fully developed, particularly with regard to leading car manufacturers. This is a gap that was sought to fill.

6 CONCLUSION

This dissertation aimed to connect AD with strategy for AIs, an area which constitutes a gap in the current literature. The research question, investigated via the literature and primary research was: *How does autonomous driving affect automotive incumbents' businesses and strategies?* The material on strategy relied on Clayton Christensen's thesis regarding DI as it bears upon incumbents. The literature survey informed the primary research and generated valuable interview guidelines for interviewing three experts from the German automotive sector working for incumbent companies in their strategic AD divisions. The interviews revealed useful insights for understanding how AIs are affected by the AD disruption and how their strategic decision-making is being challenged and shaped accordingly.

The findings demonstrate the high levels of complexity and uncertainties of AVs as well the threats AIs are facing which points to various weaknesses and strategic challenges which they must address. Different parties and constituencies are implicated by the AV paradigm shift which does not only concern companies and technology but also involves countries, cities and regulators. Moreover, the psychological dimension trust is necessary if full customer adoption is to occur. An AI solely aiming for technological breakthroughs, without giving consideration to infrastructures needs, laws and regulations or the customer skepticism is not advantageous. Nonetheless, progress in the sector is predicated on achieving technological advances for product maturation. This remains the biggest actual challenge for companies surrounding AD. The research revealed that specifically for AIs it is not advisable to aim for first mover advantages. Additionally, technological competencies should be acquired through strategic partnerships with other AIs, acquisitions of tech startups or other companies, or by implementing novel HR strategies. Finally, the ideal or optimal business model is not clear and must be determined by each AI against the backdrop of an overall AV terrain which has yet to be defined.

REFERENCE LIST

Adner, R. (2002). When are technologies disruptive? A demand-based view of the emergence of competition. *Strategic Management Journal*, *23*(8), 667–688.

Aral. (2019, August). Survey in Germany with 1001 participants. Retrieved December 4, 2019, from: https://de.statista.com/statistik/daten/studie/270596/umfrage/interesse-an-autonomen-fahrzeugen/

Autor, D. H. (2015). Why Are There Still So Many Jobs? The History and Future of Workplace Automation. *Journal of Economic Perspectives*, *29*(3), 3–30.

Bagloee, S. A., Tavana, M., Asadi, M., & Oliver, T. (2016). Autonomous vehicles: Challenges, opportunities, and future implications for transportation policies. *Journal of Modern Transportation*, *24*(4), 284–303.

Baheti, R., & Gill, H. (2011). Cyber-physical Systems. *The Impact of Control Technology*.

Bailo, C., Dziczek, K., Smith, B., Spulber, A., Chen, Y., & Schultz, M. (2018). *The Great Divide: What Consumers Are Buying vs. The Investments Automakers & Suppliers Are Making in Future Technologies, Products & Business Models*. Center for Automotive Research. Retrieved September 20, 2019, from: https://www.oesa.org/sites/default/files/resource/OESA_Resources_Ind_Overview_CAR_The-Great-Divide-What-Consumers-Are-Buying-vs-The-Investments-Feb%202018.pdf.

Baldwin, R. (2019). *The Globotics Upheaval: Globalisation, Robotics and the Future of Work*. Weidenfeld & Nicolson.

Blanas, S., Gancia, G., & Yoon, S. (2019). *997_Who is Afraid of Machines*. 63. 69th Economic Policy Panel Meeting

Bonnefon, J.-F., Shariff, A., & Rahwan, I. (2016). The social dilemma of autonomous vehicles. *Science*, *352*(6293), 1573–1576.

Business Insider. (2016, April 7). Companies making driverless cars by 2020—Business Insider. Retrieved October 22, 2019, from https://www.businessinsider.com/google-apple-tesla-race-to-develop-self-driving-cars-by-2020-2016-4#if-tesla-succeeds-in-building-a-fully-autonomous-car-by-2020-uber-has-declared-it-will-buy-500000-2

Christensen, C. M. (1997). *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Boston: Harvard Business School Press.

Christensen, C. M., Anthony, S. D., & Roth, E. A. (2004). *Seeing What's Next: Using the Theories of Innovation to Predict Industry Change*. Boston: Harvard Business School Press.

Coppola, R., & Morisio, M. (2016). Connected Car: Technologies, Issues, Future Trends. *ACM Computing Surveys*, *49*(3), 1–36.

Daimler. (2019, July 4). Daimler und BMW Group: Langfristige Entwicklungskooperation für automatisiertes Fahren. Retrieved December 16, 2019, from: https://www.daimler.com/innovation/case/autonomous/entwicklungskooperation-daimler-bmw.html

Danneels, E. (2004). Disruptive Technology Reconsidered: A Critique and Research Agenda. *Journal of Product Innovation Management*, *21*(4), 246–258.

DHBW Ravensburg. (2019, March). Survey in Germany with 500 participants. Retrieved April 12, 2019, from https://de.statista.com/statistik/daten/studie/270612/umfrage/nachteile-von-autonomen-fahrzeugen/

Eichsteller, M. (2018, April 2). Jaguar & Waymo kooperieren: Autonomes Fahren beim I Pace. Retrieved December 16, 2019, from: https://emobilitaetblog.de/jaguar-waymo-kooperieren-autonomes-fahren-beim-i-pace/

European Commission. (2018, May 17). *On the road to automated mobility: An EU strategy for mobility of the future—COM(2018) 283 final*. Retrieved October 28, 2019, from: https://eur-lex.europa.eu/legal-content/DE/TXT/HTML/?uri=CELEX:52018DC0283&from=EN

Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations. *Transportation Research Part A: Policy and Practice*, *77*, 167–181.

Faisal, A., Yigitcanlar, T., Kamruzzaman, M., & Currie, G. (2019). Understanding autonomous vehicles: A systematic literature review on capability, impact, planning and policy. *Journal of Transport and Land Use*, *12*, 45–72.

Ferràs-Hernández, X., Tarratas-Pons, E., & Arimany-Serrat, N. (2017). Disruption in the automotive industry: A Cambrian moment. *Business Horizons*, *60,* 885–863.

Fraunhofer Institute for Production Technology IPT. (2019). Industry 4.0—Networked, Adaptive Production. Retrieved April 10, 2019, from: https://www.ipt.fraunhofer.de/content/dam/ipt/en/documents/broschures/Industry%2040-Networked%20Adaptive%20Production.pdf

Govindarajan, V., & Kopalle, P. K. (2006). The Usefulness of Measuring Disruptiveness of Innovations Ex Post in Making Ex Ante Predictions. *Journal of Product Innovation Management*, *23*(1), 12–18.

Guarnieri, M. (2010). The Roots of Automation Before Mechatronics [Historical. *IEEE Industrial Electronics Magazine*, *4*(2), 42–43.

Henderson, R. M., & Clark, K. B. (1990). Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. *Administrative Science Quarterly*, *35*(1), 9–30.

Herrmann, A., Brenner, W., & Stadler, R. (2018). *AUTONOMOUS DRIVING How the Driverless Revolution Will Change the World*. Bingley: Emerald Publishing Limited.

Hevelke, A., & Nida-Rümelin, J. (2015). Responsibility for Crashes of Autonomous Vehicles: An Ethical Analysis. *Science and Engineering Ethics*, *21*(3), 619–630.

Hitomi, K. (1994). Automation—Its concept and a short history. *Technovation*, *14*(2), 121–128.

Interview 1. (2019, November 21). Conducted for this study.

Interview 2. (2019, November 27). Conducted for this study.

Interview 3. (2019, November 29). Conducted for this study.

Kaur, K., & Rampersad, G. (2018). Trust in driverless cars: Investigating key factors influencing the adoption of driverless cars. *Journal of Engineering and Technology Management*, *48*, 87–96.

Leung, E., Paolacci, G., & Puntoni, S. (2018). Man Versus Machine: Resisting Automation in Identity-Based Consumer Behavior. *Journal of Marketing Research (JMR)*, *55*(6), 818–831.

Li, J., Zhao, X., Cho, M.-J., Ju, W., & Malle, B. F. (2016). *From Trolley to Autonomous Vehicle: Perceptions of Responsibility and Moral Norms in Traffic Accidents with Self-Driving Cars* (SAE Technical Paper No. 2016-01–0164).

Lipson, H., & Kurman, M. (2016). *Driverless: Intelligent cars and the road ahead*. Cambridge, Massachusetts: The MIT Press.

Litman, T. (2019). *Implications for Transport Planning*. 40. Victoria Transport Policy Institute.

Liu, S., Tang, J., Zhang, Z., & Gaudiot, J. (2017). Computer Architectures for Autonomous Driving. *Computer*, *50*(8), 18–25.

Lovallo, D. P., & Mendonca, L. T. (2007, August). *Strategy's strategist: An interview with Richard Rumelt*. The McKinsey Quarterly, (4), 56-67.

Lu, N., Cheng, N., Zhang, N., Shen, X., & Mark, J. W. (2014). Connected Vehicles: Solutions and Challenges. *IEEE Internet of Things Journal*, *1*(4), 289–299.

Marchant, G. E., & Lindor, R. A. (2012). The Coming Collision between Autonomous Vehicles and the Liability System. *Santa Clara Law Review*, *52*(4), 1321–1340.

Martínez-Díaz, M., & Soriguera, F. (2018). Autonomous vehicles: Theoretical and practical challenges. *Transportation Research Procedia*, *33*, 275–282.

Maurer, M., Gerdes, J. C., Lenz, B., & Winner, H. (Eds.). (2016). *Autonomous Driving*.

Mayring, P. (2015). *Qualitative Inhaltsanalyse, Grundlagen der Technik (12. Auflage)*. Weinheim: Beltz UTB.

Mercedes-Benz. (2019). Mercedes-Benz präsentiert das MBUX Baby-Protokoll. Retrieved December 11, 2019, from: https://www.mercedes-benz.com/de/innovation/mercedes-benz-praesentiert-das-mbux-baby-protokoll/

Miller, K. D. (1993). Industry and Country Effects on Managers' Perceptions of Environmental Uncertainties. *Journal of International Business Studies*, *24*(4), 693–714.

Mosquet, X., Dauner, T., Lang, N., Russmann, M., Mei-Pochtler, A., Agrawal, R., & Schmieg, F. (2015, April). *Revolution in the Driver's Seat: The Road to Autonomous Vehicles*. The Boston Consulting Group.

Moy, R. L. (2004). Seeing What's Next: Using the Theories of Innovation to Predict Industry Change (a review). *Financial Analysts Journal*, *60*(6), 83–84.

Queirós, A., Faria, D., & Almeida, F. (2017). STRENGTHS AND LIMITATIONS OF QUALITATIVE AND QUANTITATIVE RESEARCH METHODS. *European Journal of Education Studies*, *3*(9), 369-387.

Raynor, M. (2007). The Strategy Paradox. *Deloitte Review*, (1), 39-47.

Royakkers, L., & van Est, R. (2015). A Literature Review on New Robotics: Automation from Love to War. *International Journal of Social Robotics*, *7*(5), 549–570.

SAE, J. (2018). Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. *SAE International*.

Senge, P. M. (1997). THE FIFTH DISCIPLINE. *Measuring Business Excellence*. New York: Currency Douebleday.

Shaheen, S., Totte, H., & Stocker, A. (2018). Future of Mobility White Paper, ITS Berkeley. Retrieved October 22, 2019, from: https://escholarship.org/uc/item/68g2h1qv.

Volkswagen Newsroom. (2019). Volkswagen Newsroom. Retrieved October 23, 2019, from: https://www.volkswagen-newsroom.com:443/de/pressemitteilungen/ford-und-volkswagen-weiten-weltweite-kooperation-auf-autonomes-fahren-und-elektrifizierung-aus-5188

Wakabayashi, D. (2018, March 19). Self-Driving Uber Car Kills Pedestrian in Arizona, Where Robots Roam. Retrieved November 7, 2019, from:

https://www.nytimes.com/2018/03/19/technology/uber-driverless-fatality.html

Wallace, A. (2010). Application of AI to AGV control?agent control of AGVs: International Journal of Production Research: Vol 39, No 4. Retrieved October 2, 2019, from https://www.tandfonline.com/doi/abs/10.1080/00207540010007310

Wernerfelt, B., & Karnani, A. (1987). Competitive Strategy Under Uncertainty. *Strategic Management Journal*, *8*(2), 187–194.

Wollschlaeger, D., Foden, M., Cave, R., & Stent, M. (2015). *Digital disruption and the future of the automotive industry*. IBM Center for Applied Insights. Retrieved October 18, 2019, from: https://www-935.ibm. com/services/multimedia/IBMCAI-Digital-disruption-in-automotive.pdf

Wollschlaeger, M., Sauter, T., & Jasperneite, J. (2017). The Future of Industrial Communication: Automation Networks in the Era of the Internet of Things and Industry 4.0. *IEEE Industrial Electronics Magazine*, *11*(1), 17–27.

Yadron, D., & Tynan, D. (2016, June 30). Tesla driver dies in first fatal crash while using autopilot mode. *The Guardian*. Retrieved December 11, 2019, from: https://www.theguardian.com/technology/2016/jun/30/tesla-autopilot-death-self-driving-car-elon-musk

Yigitcanlar, T., Wilson, M., & Kamruzzaman, M. (2019). Disruptive Impacts of Automated Driving Systems on the Built Environment and Land Use: An Urban Planner's Perspective. *Journal of Open Innovation: Technology, Market, and Complexity*, *5*(2), 24.

APPENDICES

Appendix I: Semi-structured interview guideline

Interview Intro
1. Salutation and thank you for the time
2. Short description of the topic
3. Short description of the interview process and approx. duration
4. What did you study? And in which field did you do your PhD? Which current position do you have at the AI?

Interview Guideline	Question
1	What's your realistic estimation, when will autonomous passenger cars be commercialized for end-consumers and available on public roads?
2	Which company is from your point of view the incumbent/pioneer in the market of AVs and why?
3	What technological breakthrough need to be achieved to get to Level 5 AVs? And what are the main technological difficulties?
4	What needs to happen so that car manufacturers can introduce AVs for end-consumers on public roads?
5	Does it make more sense to be the first mover or wait to let the others position themselves?
6	How do car manufacturers ensure that they possess the right Know-How and the technical requirements to develop AVs? And what will be the main and important resources for car manufacturers in the future?
7	How are organizational structures and organizations processes influenced by the development of AV innovation?
8	How would you describe the car manufacturer's dependence on (tech) startups or companies like software companies? Indispensable or do startups and co. rather demonstrate a competitive threat?
9	How do the partnerships of car manufacturers in general change due to new technologies like connected cars or autonomous cars? Also meaning with governments/regulatory institutions?

10	How does the competitive advantage of car manufacturers changes/needs to change since the automotive industry shifts away from the traditional car manufacturing towards becoming an expert in software and hardware due to connected and autonomous vehicles? What does it mean for the corporate strategy of car manufacturers?
11	How do car manufacturers plan to deal with ethical and moral questions according to AVs on public roads? What is strategically required to create trust for end-consumers?
12	Do you "overshoot" the customer's demand by offering AVs or do you provide customers something they desire? Is it possible to lose customers rather than to win them?
13	Do you clearly view AVs as a disruptive innovation/technology or only as an improvement of passenger cars? And why?
14	What would you say are the biggest strategic challenges associated with developing this new technology given uncertainties about the future?

Appendix II: Interview 1

Interview Intro:

4.

- Studied BWL in bachelor with focus finance in master with focus innovation management and family businesses
- Doctor in field of technology adoption (kind of innovation management): how do incumbents adopt disruptive technologies and how does it get back to the company and the transformation of the company
- Currently at the strategy department for autonomous driving in a vehicle project for the automotive incumbent's self-driving car (strategic project lead) for the robo taxi

Semi-structured interview answers:

Question 1)

- Depends on how you define Level 5, if it's defined as an autonomous car without human interaction in a fixed, mapped area I would say round about 2026/27, but meaning for autonomous ridesharing / ridehailing services
- Important to make a discrete distinction between autonomous ridesharing / ridehailing services and AVs for the private use of end consumers
- AVs for private use end consumers will be later due to the enormous costs based on the complex ADS (autonomous driving system) and therefore super high price for the end

consumer → takes more time until AVs are ready to be commercialized to the private use market, so minimum 5 years later than the autonomous ridesharing concepts are introduced (but these will only be the early adopters and not the broad mass)

- Furthermore, it will take longer due to the issue about acceptance and trust: when consumers first get to know this technology based on concepts like robo taxis, they begin to build up trust for this technology, but this will take some years
- Still, in the beginning I don't think private AVs will completely work for public roads, Level 5 vehicles will be probable first work for highways or "dedicated lanes" (separate lanes on streets that are only implemented for AVs)

Question 2)

- Yes, there is a market leader, but first of all I see 4 groups of companies participating in the autonomous driving market: traditional OEMs (Daimler, BMW, VW, etc.), tech companies (Google, Intel, Nvidia, etc.), tech startups and ride hailer (Uber, Lyft) → lead to blurring borders
- Currently leading is Waymo (Google subsidiary), they are 2-3 years ahead in the autonomous driving development → they develop their own autonomous driving system and buy the vehicles from Jaguar, Volvo, etc. to integrate the system since there core competency is comes from the tech side of Google to develop good computers/software, cameras and sensors, but they are less professional in car manufacturing
- In general, there can be different approaches to enter the value chain of autonomous vehicles (like Waymo does)
- At the automotive incumbent I'm working for it's the exact opposite, they can produce good cars but don't have the computer/software expertise
- Another pioneer is General Motors, they are cooperating with Cruise (acquired Cruise)
- And then there's Tesla, where you never know what comes next and how they could disrupt the automotive market → They often announce new stuff and have another understanding of definitions and concepts → to give you an example: Tesla develops AVs only with camera technology whereas every other player in the market is convinced that limiting the system to cameras can't work to develop an AV
- So, Tesla is somehow at the front but it's difficult to make a clear statement about Tesla

Question 3)

- The overall technological concept is not safe yet and the vehicles are not able to drive as autonomous as we wish → doesn't work yet without human interaction, meaning the technological stage of maturation is not reached so far
- Still a big lack of working sensors and cameras
- All the previous announcements of companies, like Waymo, to have AVs ready but in the end didn't meet the announced deadline, illustrate this issue as many companies shifted the date again into the future → they recognized sooner or later that autonomous driving is more complex than they were thinking it actually is

Question 4)

- First of all, the technology itself: because it didn't reach the stage to develop a Level 5 AV
- Second, the infrastructure: because the vehicle must be able to communicate (V to X communication) which needs min. 5G and the fact that in the beginning AVs and "normal" cars will be on roads at the same time
- Third, the legal side: there's no single country so far that developed a complete legal framework/construct for AVs (s. also Q10)
- Fourth, the challenge of costs: you must be able to commercialize it lucratively → this is also linked to the topic of shared mobility that OEMs find the appropriate business case to commercialize it
- In comparison, the cost challenge might not be a problem for Waymo with Google in the background as money plays a less important role
- But for corporations/OEMs with shareholders in the back they have to figure out an attractive business model → even there's no return in the first years, sooner or later there must be a return
- The current biggest challenge of those four named and the main enabler, is the technological stage of maturation → but the costs will decrease in the next years, sooner or later there won't be any more these immense costs (due to the technological development) and also the legal part will get there sooner or later

Question 5)

- On the one hand, it depends on the company, according to the fact that autonomous driving is a risky and complex innovation topic where the question arises if you want to be and if you can be the first mover
- Speaking for the incumbent I'm working for, the standard of it is "to be the best or nothing" and to be an innovation pioneer but according to this topic where there's no trust of customers and the risk of accidents is existing, the question is if an OEM lime I'm working for wants to push of being the first mover → the first mover takes the risk of being in charge for the first accidents when introducing AVs
- Conclusively, in the case of private AVs it's smarter to see what happens and what others in the market are doing
- On the other hand, it depends on the product/service: in the context of ridehailing, it is about the question if you're entering the market too late when the market is probably already saturated → By competing with the leaders Ubers, Lyft, etc. there might be no chance to enter the market some years later when they already developed market and countries → so for the approach of being a first mover or not. It has to be distinguished between private AVs and ridehailing
- A general question is about regions
    - especially for German OEMs it will be difficult to enter the US ridehailing market (due to Uber and Lyft)
    - China as well a critical market: when it comes to AVs they will "shut" the country politically and legally
    - China already illustrates a threat in e-mobility and the same case might emerge when it comes to AVs (e.g. Uber already has hard times with competing with Didi in China)

- Additional challenge for car manufacturers is their premium standard as they mostly define themselves in terms of prices, so safety, comfort, quality and design is given → when entering the ridehailing market, prices will drive this mass market in the future where OEMs will have hard times to compete in the pricing since it is also difficult for them to bear the costs on its own (e.g. VW is much bigger than the premium producer Daimler)
- But in general, the very clear strategy for everyone (especially OEMs) is to enter the ridesharing/ridehailing market, go to specific cities, further develop the technology until it reaches the stage of maturation, build up trust with customers and then at some point approach end consumers for private use AVs → these two steps are the clear strategy

Question 6) and 7)

- It needs to change a lot in the future looking at OEMs organizational structure
- Obviously, every company's structure gets more complex when growing but OEMs are often obsolete and have a too strong "thinking in components" → if still you want to be set up efficiently in a big corporation the organizational structure needs to change like in startups or tech companies with flatter hierarchies
- Next question is how to build up the software competence which can be done through developing a HR strategy: It is a location topic as locations like Sindelfingen, Wolfsburg or Ingolstadt in Germany are not attractive to high-tech experts → They rather go to Berlin, Tel Aviv or Silicon Valley → it needs new locations to hire the best tech-people
- Next question is about collaborations: Every OEM is in the need of a corporation partner to develop AVs → You need to strategically decide with whom you want to collaborate, on the one side with tech experts or startups and on the other side with other OEMs because the costs of development are so immense, you are forced to share them (and the smaller you are, the more you need to share them) → also a reason why the two OEMs Daimler and BMW are collaborating for developing AVs
- Another big task is to find out which products are desired/demanded by consumers in the future: Connectivity, autonomous driving, and which use

Question 8)

- The dependence is growing, but if it's a threat or a chance for collaborating is difficult to state
- In general, the automotive industry is in its bi biggest economic upheaval since its origin 130 years ago and autonomous driving revolutionizes everything
- The main factor when it comes to this question of how dependencies on other companies and startups change it a shift in core competencies in the automotive industry away from hardware and manufacturing a good vehicle towards software/computer → the heart of a car was always its engine but the heart increasingly changes to be a computer
- The core competency shifts because manufacturing a car is not that difficult anymore and more and more companies are able to do so → problem: OEMs don't possess these competencies of software, sensors, chips, cameras etc., they must build it up

- And there are companies that enter the automotive industry like Google because this is its origin competence and Google can apply it in other industries like the automobile industry
- So the question is, where do you "meet": are companies more willing to agree in partnerships (friendly), do OEMs want to take their own path, how do tech startups see this issue (do they maybe want to start building cars on their own to take over everything? Or do they want to avoid the fixed costs and let OEMs produce cars to just implement the technology in there and then sell it?)? → So, there are different scenarios where OEMs can do well or not, meaning from a good partnership, to just being a hardware supplier, to getting pushed out of the entire market
- The customer perception of cars changes as well: in the future you will measure the car performance by its connection, voice control, touchpads, the size of screens in the car, these things will attract customers
- Example Tesla model Y: was more described as a smartphone than a car in the press

Question 9)

- Another big issue of partnerships and collaborations is the collaboration with legal entities/governments, especially in the context of ridehailing
- One competence in the future will be to open up cities which means to collaborate and negotiate with cities like "you develop the infrastructure and we implement the vehicles"
- Questions arises, like who has the right to start pilot projects in specific areas? → this is something new which wasn't necessary to clarify previously

Question 10)

- Partly answered in answer 7) 8) 9)
- The shift of the competitive advantage to software/tech experts must take place
- The sole competence of OEMs can't remain the one of manufacturing cars in a great amount

Question 12)

- This needs to be done step by step, starting with shared mobility concepts to bring it step by step closer to the customer
- In the very beginning probably doing it solely by pilot projects without customer interaction by letting AVs drive around while doing elucidation and advertisement for safety
- And then the technology will establish in two steps: first step, through these robo-taxis to reach the broad mass and in the second step by approaching end consumer for the private use → Similarly to other technologies like the computer, firstly, only companies adopted it and later on people adopted it for the private use
- Nevertheless, the trust will be very low in the beginning, but that's ok as this is the case for almost every innovation → Back then, when cars were introduced, the trust was

extremely low, but I'm convinced that AVs are the future and the trust emerges step by step

- What Tesla is doing could have negative effects, though: they introduce beta versions and state this is an AV and then customers think "Tesla says it's autonomous, so I can lean back", and then first accidents happen → This is an example which doesn't facilitate to build up trust to the customer
- I don't think that customers get lost: it won't be the case that an OEM changes its portfolio from one day to another, solely selling AVs
- In the beginning you will probably have one autonomous model but at the same time you will keep offering previous models as well that are not fully autonomous (Level 5)
- But it might be possible that customers will get lost due to the fact that they don't want to own a private car anymore in the future
- AVs will be much more expensive: it will take a long time until it reaches the broad mass to purchase AVs for the private use because Level 5 AVs must get into a cost area where todays cars are as well, the same for electric cars
- As long as AVs will be significantly more expensive than "normal" cars, only a very few people (early adopters that are technological oriented) will own an AV
- As soon as the costs play along, it will reach the broad mass

Question 13)

- Yes, it's clearly a disruptive technology
- But you can disagree in terms of looking at the Level 5 AV in a timeline: then a Level 5 AV is only an incremental innovation, so coming from the automated systems like ADAS, until it reaches Level 5
- But it's clearly disruptive if you're looking at the big picture: it's actually the biggest disruption in the automotive industry since cars exist because the mobility itself changes completely → there's no need of a driver anymore, new business models emerge, the market setting changes due to the competencies that shift (20 years ago there were only OEMs in the automotive industry and now boundaries start to blur and companies enter the market that didn't even exist 10 years ago or had nothing to do with automobiles)
- The topic of data is also very interesting, e.g. for Google: through the mobility market they will have the possibility to access a big amount of data and sell them
- So autonomous driving disrupts the entire market structure
- Furthermore, the customer changes: a car won't have the same value as a car has today: more and more people don't want to own a car, environmental topics pop up, etc.
- In general, it can be said that there are many chances but as well many difficulties and threats, so you need a really good strategy to succeed in the future
- If you look again at the Chinese market it will be super dangerous in terms of innovations in general: Europe will have hard times → there will be more and more acquisitions (example: Kuka, a German listed engineering company that was acquired by a Chinese corporation) and the superrich companies like Google, Apple or Amazon will be able probably to "swallow up" a comparable small company like Daimler or BMW if e.g. the share price of Daimler decreases by 10€ at some point → so there's a big threat for Germany and the automotive industry

Question 14)

- The biggest challenge is to reach the technological stage of maturation

Appendix III: Interview 2

Interview Intro:

4.

- Studied business chemistry, PhD in chemistry, afterwards 3 years at BCG
- Currently at the automotive incumbent in the development and strategy resort that support the development of digitalization and autonomous driving

Semi-structured interview answers:

1)

- Depends on how you define autonomous driving, robo taxis (Level 5) in ca. 8 years
- Technical function though allows an 80-95 % functionality to let AVs drive
- As long as the last 5% are missing, legislators etc. won't allow AVs on the roads
- Nevertheless, in the next years additional automated/autonomous features will be integrated in vehicles → step by step partly AVs
- 3 different scenarios/use cases: highway, inner-city traffic and country roads
- Highway first, then inner-city, then country roads (most difficult)
- Robo taxi vs private use AV: one question to clarify is what actually the business model of AVs is or should be → you have one the one side ODM (on demand mobility) with which you need the AVs Level 5 that won't come in the next years, so there's currently no attractive business model / on the other side you have the private use AVs and to equip vehicles only with partly automated systems is exorbitant expensive → there could be a subset of customers that buy premium cars where a higher price though automated features doesn't matter that much but the majority won't spend this money → so how can you make money with AVs?

2)

- First Waymo and second Ford with its acquired Startup
- KPI for valuation of AVs is how often must the driver interact → to the different AVs, the case should be to let the vehicles drive the same path, with the same complex environment and the same pedestrians crossing the street etc., so this is difficult

3)

- The sensor system itself is not the main problem (you are able to implement cameras, lidar etc.) but one important point is the data processing of this sensor data: 1) to which quality do I process the data (data quality)? → e.g. one Tesla crashed because it confounded a cloud with a LKW, so the challenge for the system is do identify the data that are send correctly 2) location where the data are processed → big data amount due to visual data, laser data etc. where you need a high data speed → 1) possibility to process the data in the vehicle itself (challenge of all the hardware etc. to process the data in the vehicle) 2) possibility to process the data "offboard": in a central data center, one option is to send all the data from the cars of one manufacturer to a data center at a specific location which processes the data and sends it back to the vehicle(s) (problem of data transfer where you have to ensure the transfer of the data in real time) → problems of dead zones but with the new technology of 5G it could be possible

4) and 5)

- Customer acceptance will be no problem since AD is a well-known topic and is desired
- But one problem could be the regulations: e.g. which error rate is allowed that the AV is permitted, who is responsible for accidents / damages → so if you have the technology ready but the regulations are not, it doesn't make sense to have the technology ready so it's probably not the most worthwhile to be the first one having the technology ready
- But If you pioneering the advantage is to define standards with regulators that are beneficial for you
- It's not necessary to be the first one but it makes sense to be technological capable to enter the market if other did it already

6) and 8)

- You need to adopt the software abilities (VW and Ford with AI startup)
- So, you have new partners or suppliers that you have to integrate, which you didn't have before
- The other thing is that for the existing systems that are integrated in the cars you can include new different partners → e.g. Mercedes baby protocol which facilitates the driving for families
- So, it gets more and more important for OEMs to develop away from a pure manufacturer of cars to a "smartphone on wheels" → requires new partners

7) and 10)

- What must change is the speed and the workings → as an OEM you plan extremely (years) in advance and for software you have in general short-term goals and you interact more short-term and in intervals, meaning it is more agile to get faster to the goal

- I think it must happen and if it doesn't happen at one OEM this OEM has a big problem and currently there's no OEM that is near to Google or Microsoft and I think it already goes in this direction, but it must go more in this direction
- For those who doesn't make it to get faster these get a massive problem

9)

- I think it doesn't change something with governments (you already had to always work with governments as an automotive incumbent)
- What does change is the content and that it is completely new, so you have to set it up from the bottom
- And it expands by more dimensions, e.g. the moral/ethical factors like programming the moral decision of the computer, this is something which has to be clarified with public / governmental institutions

11) and 12)

- You won't reach the broad mass and there will be a part amount that won't be convinced even by hard facts (at least in the beginning)
- But there will also be another number of customers that you can rationally convince that it is safer than having a human as a driver and using the timer more efficient
- So, you won't have an acceptance from all customer

13)

- It will be more an evolution than a disruption because it won't be introduced from one day to another and disrupts markets, I think it could have disruptive effects for single player (not every play will survive) but I don't think it will has the "iPhone effect", meaning I don't think that the car needs to be reinvented, but some OEMs wills suffer It will occur step by step (e.g. autonomous feature for highways, and three years later for cities)

14)

- To produce AVs in large volumes at affordable prices
- 2 factors: the technology and the costs
- I think its technological possible if you develop AVs further (already seen at Google), with the one problem of the data processing → but the solution will occur if money is no issue
- But to develop the car (hardware and software) in bigger amounts and the immense development costs play a critical challenge for the organizations
- Question is: do the German OEMs make it faster to the technology readiness or do the tech giants like Google make it faster to industrialize the technology and produce cars

→ e.g. Google developed one car (technology works but do they can make it to produce more cars or Tesla that have hard times to scale up their vehicles)

Appendix IV: Interview 3

Interview Intro:

4.

- Studied industrial engineering
- PhD in operations management and working experience at BCG
- Currently at automotive incumbent in the development of AD and within the development department in the business development department → partnering with software companies and tech players

Semi-structured interview answers:

1)

- We (in the department I'm working) never talk about Level 5 because we think it will never hit the roads and will be developed
- We only talk about level 4 as the highest level
- Robo taxi mostly with safety driver → Waymo made it to drive without safety driver in a defined path, but it's super expensive and not possible to produce it in mass
- Level 4 robo taxis not before 2030 → before only pilots and a lot of marketing but until it becomes a product where all current problems are solved and until a company can make money with it not before 2030
- For Private use: In the beginning more interesting for fleets and for private use it will still take a lot of time

2) no answer was given

3)

- Relatively easy to get to a 95% safety vehicle, maybe 99%, but 100% or 99,9999% is super difficult
- 2 things that are underestimated: 1) Limit optimization and 2) Component prices (calculator + sensor technology are not at a price level where it's worth it to deploy it, also robo taxis)

4) no answer was given

5)

- I think the first ones (robo taxis) do a lot of pioneering not only regarding the technology but also regarding regulations
- At the moment there's no country that allows AD
- E.g. in china and USA deals between robo taxi provider and cities for the case of accidents that there won't be a "avalanche of lawsuits" for the provider
- So robo taxi provider will participate in the definition of the legislation which needs a lot of resources and money
- For the latecomers it then will be a "shaped field" that's why I don't think it's necessary to be the first one

6), 7) and 10)

- Every OEM develops in the direction of software, so there will be a shift of OEMs in this direction
- Nevertheless, it's not less complex do produce a good car at high amounts
- I think the traditional advantages of OEMs are still relevant
- But if you think about robo taxis, it won't be that important that the car is dynamic or is able to drive shar curves well
- But what OEMs are still really good at is to manage the entire system in the sense of the supply chain with suppliers, complex processes to produce an develop a car with partners → Integration and system design competence is still important and will remain important
- Probably not necessary to develop the software in-house
- So not decided which one has which role, but I think the OEMs will keep their role to integrate the overall system and to release the product in the end
- But the question will remain which place in the supply chain OEMs (and software companies) will have in the future → but I think the software firms will keep away the car production

8)

- Different approaches, 1) Ford and VW with Argo AI (they let them do all the tech work) or GM and Honda with Cruise or 2) in-house
- Who reaches the goal faster is not clear yet, I think tech startups can get faster to the product but they will get to their limits if they have to develop an overall safety concept and to get vehicles approved, where OEMs have a lot more experience in this field
- And OEMs have higher requirements to themselves for safety standards than startups

9)

- OEMs do this already → OEMs have a lot of resources to do lobbying and to take part in the legislation

- It's more important and more intensive for AD but sill, OEMs already do this
- E.g. in China, there are no laws that are country-wide but only city/region-wide, so it depends on the country if you should work closer with local regulators (for USA and China important) or country-wide (for Europe it's maybe more central)

11)

- I think OEMs have higher safety requirements than startups, so OEMs do think a lot about the safety topic
- Transparency will be important regarding how the system works, which are the system's limits etc.
- But the biggest mistake will be to introduce the product too early to the market which is not market ready (Tesla as an example that they market level 2 system as level 3 system)

12) no answer was given

13)

- I do think if the 3 conditions are fulfilled: 1) the car is able to do a lot like a driver 2) the car is affordable 3) no driver
- Then the mobility behavior will change, and it will be disruptive
- You will be able to give back time to customers and to spend their time with your own products → great potential which is thereby unleashed
- Overall: even if the German automotive incumbents are not the fastest, they already recognized the great change and start changing strategies
-

14)

- Technology as already said
- Robo taxi won't be better than a human taxi driver in the beginning (Taxi driver may be faster, knows shortcuts, can cheat his way through, and Robo Taxis keeps the mandatory speeds and so on), so robo taxis must be cheaper in the beginning and we're not yet at this stage