An Overview of Technology, Benefits and Impact of Automated and Autonomous Driving on the Automotive Industry

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Abstract

Autonomous driving is becoming a central moving force towards the change in vehicles and therefore among others the automobile and mobility business, as well as numerous other industries, which today still believe that they do not have a relationship to digitalized autonomous vehicles. The changes in different industries, which can be initiated by autonomous vehicles, are a good example of changes, which can be initiated by digitalization on market places. This article is based on the hypothesis that the development of automated and later autonomous vehicles are an unstoppable development, which will be of great use to the economy and society. Against this background, the article illustrates what is to be understood by the concepts of automated and autonomous driving, and what useful effects can be expected for a number of stakeholders. In addition to this, the article explains the technical fundamentals of automated vehicles and the changes in the traffic-related industry. In the last part, the article elaborates the impact on the automobile and traffic industry.

39.1 Introduction

Automated and autonomous driving has become a topic, which has gained broad attention in the public during the last few years. The handling of the update for automated driving, which has been available for the Tesla S for approximately one year, demonstrates the

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intensity and emotionality of the public discussion. Immediately after the availability of this functionality euphoric reporting started. Autonomous driving with the Tesla S and the download of the software to the vehicle overnight was hailed by the press and by many potential customers as a masterpiece of innovation [1]. Tesla was incorrectly named as the pioneer of autonomous driving. Vehicles built by Audi, BMW or Daimler are more advanced in development and covered large distances completely autonomously or with speeds up to 240 km/h on closed racing circuits at a much earlier time [2]. However, Tesla and Google's small cars with panda faces dominate the discussion about autonomous driving [3]. From the start, it was predictable that automated and autonomous driving would lead to serious accidents, just the same as traditional driving. Very quickly, videos of the Tesla S appeared on YouTube, where it showed it being driven completely driverless, against the provisions of Tesla [4]. When "expectedly" information about a fatal accident with a Tesla S, which was travelling autonomously, appeared in June 2016, reporting tipped in the other direction [5]. The previously positive reporting changed to negative almost overnight. The fact that the driver of the Tesla S used the vehicle contrary to the provisions of Tesla played merely a subordinated role in the public discussion. Only a fact-based and unemotional discussion can indicate the uses and dangers of automated and autonomous driving, and establish a base for future-oriented decisions. This article seeks to make a contribution to this discussion. It is based on the fundamental statement that the uses of autonomous vehicles exceed the risks, and that autonomous driving as part of the digitalization of vehicles is an unstoppable development. The competitiveness of the European automobile industry will be determined decisively by the way digitalization is handled. In view of the dominance of American companies, especially the so-called internet giants such as Amazon, Apple, Google and Facebook, the discussion about automated and autonomous driving is a central one for the industrial location Europe.

Against this backdrop this article deals with the different aspects of automated and autonomous driving. In the first section we define automated and autonomous driving. The second part of our article is concerned with the uses of automated and autonomous vehicles. The third part shows changes in the vehicle, the traffic-related aspects and changes in the IT infrastructure. The last section handles changes in the automobile industry, and future developments in the mobility sector.

The article is based on discussions with experts and extensive literature analysis on the topic "Automated Driving", which was carried out in cooperation with Audi AG between July 2015 and August 2016.

39.2 Automated & Autonomous Driving

The current development of vehicles, which are primarily steered by drivers to autonomous vehicles, i. e. completely self-driving vehicles, can be divided into several developmental steps. The Society of Auto Engineers [6] and the respective department in Germany [7] has provided a structuring for those development steps. However, the model of the National Highway Traffic Administration (NHTSA), the civil regulating authority of the USA, has established itself as a "de-facto standard" worldwide [8]:

- ***No-Automation (Level 0):*** *The driver is in complete and sole control of the primary vehicle controls – brake, steering, throttle, and motive power – at all times.*
- ***Function-specific Automation (Level 1):*** *Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.*
- ***Combined Function Automation (Level 2):*** *This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.*
- ***Limited Self-Driving Automation (Level 3):*** *Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The Google car is an example of limited self-driving automation.*
- ***Full Self-Driving Automation (Level 4):*** *The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles.*

Computer-assisted driving at level 1 and 2 is described as automated driving, while driving at level 3 is designated to be highly automated driving. The term autonomous driving is reserved for driving at level 4.

Automated and autonomous driving at the experimental stage is already reality today. Numerous vehicles already have relatively extensive packages of assisting systems, which correspond to level 1 or level 2. Examples of these assisting systems are emergency braking systems, lane or park assistant systems, and automatic vehicle interval control, sometimes called "adaptive cruise control".

Automated driving at level 3 will probably be feasible in the next few years, for example with the highway assistant, which will probably be on the market in 2017 or 2018, for instance with the Audi A 8. Autonomous driving is currently taking place at low speeds on closed off sections or testing grounds, or with special permissions in public transport. Google is testing autonomous vehicles in the vicinity of Mountain View. A vehicle made by Audi drove autonomously from San Francisco to Las Vegas [9]. A further vehicle developed by the automotive component supplier Delphi drove from the west coast to the east coast [10].

Even optimistic estimates go on the assumption that autonomous vehicles will, at the earliest, go into production between 2025 and 2030 [11, p. 8]. Against this background, many statements and reports on the chances and dangers of autonomous driving are to be viewed as speculation rather than based on facts and research. Major leaps in development are not to be expected. The Apple iPhone and the ensuing development it created, for example the app worlds, among them being Apple and Google, who initiated an app explosion, prove that unexpected disruptive developments are possible. Like these developments, app worlds have developed disruptively along new technical possibilities in the last ten years, automated and autonomous driving will steadily continue to develop over the next years.

There could possibly be resistance against new technologies. The past has proven that organized societal resistance can lead to the end of a technology, in spite of expert opinions, as can be seen from the example of nuclear energy, to name just one. The philosopher Nida-Rümelin demands, against this backdrop, an open discussion about the chances and dangers of automated and autonomous driving [12, 13]. Also against this background, the Tesla competitors should participate in the discussion about accidents through automated driving in a factual and businesslike manner. The discussion about the so-called dilemma situation should also be conducted at a broad societal level. When talking about dilemma situations we mean situations in which a robot must decide between two or more catastrophic situations. A classical question is, for example: "Will an autonomous vehicle, when faced with the situation of an unavoidable driving maneuver, run over a pedestrian or will it collide with an obstacle thus endangering the driver". Ultimately, these decisions are based on philosophical discussions, which have been conducted for years, on the so-called "Trolley Problem". From today's view, it remains a thought experiment as to how an autonomous vehicle must and will react to a dilemma situation. Nevertheless, the automobile industry will have to face this discussion and forward its assessment and possible solutions at a broad societal level. The discussion as to the feasibility and future of automated and autonomous driving in the US senate [14] and many parliaments worldwide and roundtable discussions [15] in Germany all offer constructive contributions to these discourses.

Automated and autonomous driving does not only concern vehicles carrying persons, although these are currently often at the center of discussion. The starting point of the development of autonomous vehicles were two competitions run by DARPA, part of the American Ministry of Defense, in a desert-like area in the years 2004 and 2005, and a challenge in an urban area in the year 2007 (Urban Challenge [16]) The military continues to be an important driver in the development of automated and autonomous driving. Moreover, there is intensive work being done worldwide on automated and autonomous trucks [17–19], trucks for farming [20] and special vehicles, for example for mining [21].

39.3 Benefits of Automated & Autonomous Vehicles

The most important benefits of automated and autonomous vehicles is the reduction of the risk of accidents. Every year more than 1.2 million people die as a result of traffic accidents: In Germany approx. 3500 people die in traffic every year and more than 300,000 are injured, many of them seriously. According to coinciding estimates approx. 90% of these accidents were caused by human error [22]. Automated and autonomous vehicles, i. e. robots, work without error as long as they are programmed correctly. Robots are always attentive, never tire and carry out the programmed maneuver under all circumstances. In view of this, it can be assumed that the number of accidents will decrease with an increasing degree of automation. The higher the level of development of these robots, the more complex the traffic situations they can recognize, compute and master. Already currently the figures issued by insurances indicate that, for example, the automatic emergency brake assistant reduces rear-end collisions by 38%, the lane keeping assistant reduces accidents by 4.4% and the lane changing assistant by 1.7%. Whoever is driving on the highway using the adaptive cruise control knows how comforting it is when the robot "thinks in advance" and initiates a braking maneuver if another vehicle surprisingly pushes in ahead of you.

A further benefit of highly automated and autonomous vehicles in future, is the fact that the driver can better utilize the time spent in the vehicle. Initial tests show that the time can be used for entertainment, for example in the form of movies, work, and also resting up. Rupert Stadler, Audi CEO, speaks in this context of about 25 h, which customers can gain through the use of highly automated and autonomous driving [23]. A study by Horvath and partner, which was conducted in cooperation with the Fraunhofer Institute for Industrial Science, showed that the additionally gained time in the vehicle could lead to a billion Euro market [24].

Autonomous driving will make a contribution to increasing social justice. Older citizens, sick and physically challenged people are partially excluded from automobile individual mobility today. They cannot or are not permitted to drive vehicles themselves. Autonomous vehicles enable them to use this form of individual mobility, since a robot is the driver. In a video on user behavior in the case of autonomous vehicles from Google, shows a blind elderly man, as a representative of this group of people, who is quite obviously enjoying the trip [25].

Further benefits are expected from the influence on inner city traffic and city planning, once autonomous vehicles have become reality. Public space can most probably be utilized differently and more advantageously. It can already be seen that automated parking, which will be offered in vehicles in the near future, will improve the usage of parking space in park garages by approximately 30%. New traffic and city development concepts will be possible. In the context of the Audi Urban Future Initiative [26] the city of Somerville, a suburb of Boston, demonstrates what a suburb with autonomous vehicles could look like. It is planned to realize this concept in the near future [27].

The benefits mentioned are difficult to quantify. Nevertheless, there are first attempts. A study by Morgan Stanley estimates the benefits of automated and autonomous vehicles in a pessimistic scenario 0.7, an optimistic scenario 2.2 and in a realistic scenario 1.3 quadrillion USD [11, p. 8]. The 1.3 quadrillion are made up of mainly 488 trillion through savings by avoiding accidents, 507 trillion through productivity gains through better utilization of the time spent in the vehicle, 158 trillion through fuel savings and 138 trillion through the avoidance of traffic jams. A study by the Rand Corporation [28] goes on the assumption that autonomous driving reduces accidents, makes a contribution to social justice, avoids traffic jams, reduces land usage and reduces environmental damage, among others.

39.4 Automated & Autonomous Vehicles and Their Infrastructure

Automated vehicles can be seen as so-called cyber physical systems, i. e. a combination of physical product and associated computer supported information processing. Cyber physical systems address the close connection of embedded systems for the control and steering of physical processes using sensors and actuators via communications connections with the global digital net (cyberspace). The higher the proportion of information- and communication technology, i. e. the degree of automation in the vehicle, the larger and therefore more central will be the proportion of computer supported information processing in adding value and in the development of a vehicle.

Automated and autonomous driving can be described by the structure "Entry – processing – output", well-known from information processing. The input of the data, which the vehicle requires for automated driving, occurs via sensors. The sensor technology required for automated driving, is illustrated in Fig. 39.1 as an example on an Audi RS 7

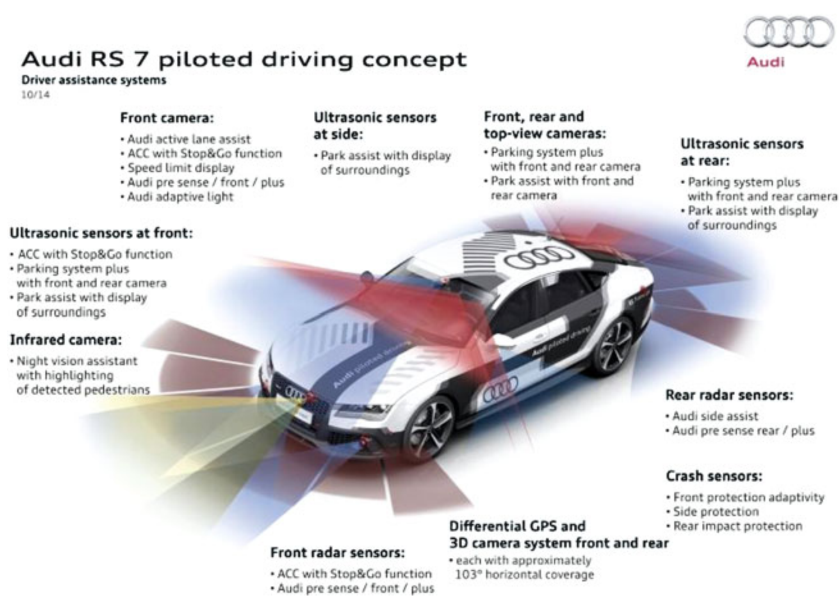

Fig. 39.1 Audi RS 7 piloted driving concept

[29]. This vehicle is able to drive automatically at speeds of up to 240 km/h on a closed racetrack. The cars available from other manufacturers currently possess – although there are manufacturer-specific differences – basically a sensor technology, which is comparable to that of the Audi RS 7. Not every model of car, however, has all of the sensors built into the Audi RS 7.

The sensor technology of the RS 7 consists of GPS, ultrasonic sensors, radar- and camera systems. Each of these sensors captures different aspects of the environment on the basis of specific features. Therefore, ultrasonic sensors, for example, are efficient only in the nearby area and are used for parking assistants. Radar systems are effective for greater distances and are used for automatic vehicle interval control (in Audi terminology: ACC Adaptive Cruise Control). Infrared sensors are used predominantly at night. Camera systems capture and identify objects, such as other vehicles, for example, and other motorists or pedestrians and follow these. The GPS system is a further part of the sensor technology, which recognizes the location and movements of a vehicle. Differential GPS is based on the well-known and commonly used GPS, but it is more precise. The Lidar (Light Detection and Ranging), a sensor technology based on laser technology, which is related to radar technology, will, in future, enhance the sensor technology of automated and autonomous vehicles in the near future and will increase the precision and range of environmental detection. Additionally, the entry of the destination takes place via the user interface of the navigation system. The development of the sensor systems and the software to recognize objects, identify them, track them and, in a best case scenario to predict their behavior is a focus of research and development for automated and autonomous vehicles. In the area of object recognition, identification and tracking, a jump in development is expected through the increased utilization of machine learning, or deep learning [30].

The perceptions of the individual sensors are compiled during processing to show an image of the environment. The processing system knows the destination from the entry into the GPS system and the route to this via the maps. On this basis how the vehicle should move is calculated in real time. Processing of the entries into driving commands is a computing process, which has to take place in real time. It places high demands on the computing process. The processors, which are responsible for this, will in future constitute a central component of vehicles. Individual experts are of the opinion that this central unit will equal the engine in significance for the vehicle. The issuing of the driving commands is effected by so-called actuators to the electronic accelerator, the electronic brakes and the electronic steering. In the automated vehicle, these power units are addressed via the network, i. e. "by wire" and moved by electric motors. The movement of a vehicle exclusively "by wire" is a jump in development, which is a deep encroachment into the development and operation of vehicles.

The actual process of automated and autonomous driving will be completed by further entry, processing and output functionalities. Above all, the interface to the driver, the so-called user interface, is of great significance. A central aspect in automated and autonomous vehicles is the process by which the driver wants to, or has to, because of a dangerous situation, return to taking control while the vehicle is travelling in automated mode. Problems, which have to be solved for this process are, for example, how the driver will be informed that he or she needs to take control, or how he or she receives the information that he or she can safely control the vehicle. Already today there are different interfaces to the driver in automated vehicles, for example warning lights, which are projected into the windscreen, acoustic signals or vibration of the steering wheel with or without automatic steering correction if the vehicle begins to leave the designated lane. A further aspect which will play a major role in future is the interface of highly automated and later autonomous vehicles with the environment, for example pedestrians.

When vehicles travel for longer periods of time in highly automated or later autonomous mode, it will be possible to construct and use the interiors of vehicles differently. In this context, one speaks of a change from driver-orientation to benefit-orientation. The benefit-creating usage of time in the vehicle is in the foreground. The steering wheel, for example, is reduced in significance in a highly automated vehicle. The Mercedes F015, a prototype of an autonomous vehicle, has only a rudimentary steering wheel. Autonomous vehicles will not have a steering wheel anymore. The Mercedes prototype and the Google vehicles illustrate that highly automated and autonomous vehicles enable innovative design of the interior. What these vehicles will eventually look like will be decided by the customer, or how they will imagine spending their time when the vehicle is travelling autonomously.

In future, not only the interior but also the external appearance, or the concept of the vehicle will most probably change [31]. The Google prototypes are built for low speeds and short distances, the so-called "last-mile". Their area of operation is the autonomous short-distance traffic, for example home from the railway station. Road trains, a type of bus with a capacity of up to 20 people, represent a mixture of classic bus and taxi. They serve the more individual transport of several people over short or medium distances. Contrary to these automatically travelling special vehicles will be the highly automated and later autonomous universal vehicles. They are similar to today's vehicles, but enable highly automated and autonomous driving.

Independent of the development of automated and autonomous driving, today's vehicles have already been connected over the last few years, mostly via the mobile network. Currently this interconnectedness is largely used for local communication, for text messages, and for entertainment. The interconnection of vehicles (Car2Car.communication) with the infrastructure (Car2Infrastructure-communication) and with cloud services will play a large role in highly automated and autonomous driving. Car2car-communication, for example, will enable the process where cars will transmit information about speed, directional change or danger situations directly to all other vehicles in the vicinity. Car2Infrastructure, for example, connects a vehicle with traffic signs or traffic lights. Of special significance for highly automated and autonomous driving is the interconnection of the vehicle with cloud services. Highly precise maps are of central significance for highly automated and autonomous driving. Through interconnection with, for example, highly precise maps available from the cloud, the steering of the vehicle can be improved in extension with the environmental images received in the vehicle by the sensors. Information about temperature, weather, roadworks or danger situations can be made available to the highly automated and autonomous vehicles. At a price of 2.4 billion euro Audi, BMW and Daimler have bought HERE, the map division of Nokia against this background [32]. The aim is to make available to highly automated and autonomous vehicles digital services, for example in the form of maps or route information, in the sense of a digital ecosystem together with other partners, based on the highly precise map material from HERE [33]. During the CeBIT 2016 in Hannover, Huawei presented a first prototype for 5G networks. This technology will be of great significance when large amounts of data are exchanged between vehicles, with the infrastructure or with cloud services [34, 35].

39.5 Automated & Autonomous Vehicles and Their Infrastructure

Highly automated and later autonomous vehicles will change the automobile industry. In a structure-changing manner, as we know it from, for example, electronic commerce, we will see the corresponding changes from a market penetration exceeding approximately 10%. The proportion of online purchases expressed as a percentage of total purchases in Germany in 2015 amounted to approximately 11.5% [36]. The repercussions on the retail trade are considerable. It is to be expected that the automobile industry will soon feel the effects of highly automated and autonomous driving and that this will cause structural changes shortly after 2020. These disruptive effects of automated and autonomous driving in the automobile industry will further be exacerbated by additional megatrends:

- The development towards electric vehicles is a trend change for the established automobile industry, whose consequences are currently not foreseeable. Tesla has proven that many customers in the high price bracket are willing to purchase electric vehicles, regardless of the fact that electric vehicles are afflicted with many uncertainties.
- A further megatrend, which can alter the changes in the automobile industry, results from the so-called "share-economy". Enterprises such as, for example, AirBnb or Uber have shown that the so-called share-economy was able to shake the lodging and taxi industries in its foundations. The trend of many young people to see themselves as participants of the so-called share-economy will have an effect on the mobility sector. Offerings such as Drive-Now and Moovel by Daimler or Mobility in Switzerland show that the share-economy is also moving into individual traffic.
- The growing environmental consciousness and, concretely, the aim of more and more people to reduce their carbon footprints, increases the speed of the change.

These three megatrends will intensify the structurally changing effects, which occur through the development towards autonomous vehicles.

39.5.1 The Growing Impact of Information Technology

Automated and autonomous vehicles can, as already indicated, be seen as so-called cyber physical systems. The proportion of information and communication technology to the added-value and the functionality of the vehicle is a deciding factor in automated and autonomous vehicles. In a study by the Fraunhofer Institute for Industrial Engineering and Organization, which was conducted by mandate of the Federal Ministry for Economy and Energy, it is estimated that the market volume of systems for highly automated driving will grow from 4.38 billion euro in 2014 to 17.3 billion euro in 2020 [37]. The valued percentages in this market are spread as follows: 36% for sensor technology, 19% for control units, 18% for software development, 17% for validation and testing (incl. sales margin) and 10% for user interface, maps and back-end services as well as systems integration [37].

The automobile industry has to establish expertise in the information and communications technology at the same high level as in the classic competencies, which it built up in over 100 years. Different automobile manufacturers and suppliers, which are affected by precisely these changes, are making great efforts to master this challenge. The absolute figure as well as the relative number of people working on information and communications competencies, above all software development, is rising. Continental, one of the large component suppliers, has already employed more than 10,000 software developers since 2012 [38]. Numerous automobile manufacturers, such as VW, BMW or Daimler and also suppliers such as Bosch or Michelin have established labs in Silicon Valley in order to be closer to the development of information and communication technology. The VW lab is integrated into the campus of Stanford University [39]. Many prototypes of automated and autonomous vehicles were developed in this laboratory in cooperation with the Engineering Department of Stanford University. General Motors works together with Carnegie Mellon University, one of the other hot spots of automated and autonomous driving [40]. Toyota invests a billion dollars in machine learning in universities on the west and east coats of the USA [41]. All of these efforts indicate that the traditional automobile industry and its suppliers have started with the so-called digital transformation. This transformation process is proving to be very difficult when talking to leading personalities from the automobile industry. The further development of vehicles to cyber physical systems is not undisputed with many experienced employees of the automobile industry. The cultural change of companies, which, in the past, produced mechanical products with a few electronics, to move to products for which, in future, software is the deciding component and the metrics of Silicon Valley apply, is a difficult step for traditionally thinking and classically trained engineers. A further reason for resistance is the development from driver to benefit orientation, which is being initiated by autonomous driving. For many traditionally thinking proponents of the automobile industry it is simply not feasible that, in future, not the sporting driver, but a programmed robot has control over the vehicle. The change in the sector is visible: In his speech at the Consumer Electronics Show 2014, Rupert Stadler made clear that digitalization in the automobile industry has top priority

[42]. Numerous CEO's of the automobile industry have followed his example. Today the CES is not only one of the most important fairs for consumer electronics, but also one of the most important automobile fairs.

39.5.2 New Competitors & New Suppliers

The digital transformation of the automobile industry opens, just like every technological change, chances for new suppliers. Above all, the combination of electro-mobility and digitalization motivates people from outside of the industry and start-ups to invest in mobility. Tesla is a well-known example, Faraday [43] is a further automobile manufacturer, which is developing in Silicon Valley. Mobileye, an Israeli high-tech company, which develops camera systems and the corresponding software, among others, delivers central components for automatic and autonomous driving to many traditional automobile manufacturers.

In the vicinity of Stanford University in Silicon Valley not only labs of the traditional automobile industry have been established, but also new players have been created. The most well-known example is Google, which is engaged in autonomous mobility. Google has enticed away numerous people, who worked on autonomous vehicles at Stanford or Carnegie Mellon University, for example Chris Urmson [44]. The next internet giant, which could become active on the automobile market is Apple. There have been rumors to this effect for some time. For these internet giants the development to autonomous driving, or the digitalization of vehicles is an ideal starting point. With their competency in information and communication technology, above all the ability to master complex problems with algorithms, and to utilize new technologies, such as machine learning in any given area, the internet giants are opening up the automobile market from the software side. One cannot say in the year 2016 whether these strategies will ultimately be successful, but they will definitely accelerate the digitalization process and contribute to the structural change in the automobile industry.

39.5.3 New Locations

Silicon Valley has been distinguishing itself for the last few years as the center for the future in the automobile and mobility industry. When talking to insiders of Silicon Valley one has been hearing now for several years "The valley loves mobility". Numerous companies and entrepreneurs are convinced that the increasing digitalization of vehicles, together with mobility platforms on the internet, such as Uber, offers the hard- and software industry in Silicon Valley the chance to penetrate the vehicle and mobility market. The unique mixture of innovation power, entrepreneurship and currently almost unlimited financial means in Silicon Valley, presents a good foundation for penetrating new markets. The simple motto of these new suppliers is "The more software, the more Silicon Valley".

When talking to politicians in Detroit, Munich and Stuttgart, one indeed gets the impression that these traditional locations for the automobile industry are in direct competition with Silicon Valley. For the automobile industry, on the other hand, there are no alternatives to a certain degree to the establishment of at least research and development centers on the west coast. Whether, in future, hundreds or thousands of software developers will program software for automated and autonomous driving for traditional automobile manufacturers in Silicon Valley cannot be predicted at the moment. It is, however, at least a realistic option.

A central aspect in the development of new future-oriented locations for the automobile industry is legislation. Automated and, in any case, autonomous driving requires changes in existing laws. A real competition among legislators can be observed. In the USA, the states California, Nevada, Michigan and Florida have taken the initiative [45]. In Germany, a draft legal bill for autonomous driving was tabled in summer 2016 [46].

39.5.4 From Car Produce to Mobility Provider

For a few years now the mobility landscape has been changing. Car-sharing for example, has been spread for example by Daimler's Car2Go, BMW's Drive-Now, or Audi's Unite [47] and also by vendors such as Mobility in Switzerland. Uber and Lyft, being so-called mobility platforms, are very successful in attacking established taxi companies. Additionally, they are building large customer bases, which can be analyzed for the mobility requirements of these customers. Railway companies such as the German Federal Railway or the Swiss National Railway collect extensive data on the mobility requirements of their customers on their websites (bahnd.de and sbb.ch). Automobile manufacturers are beginning to get increasingly involved in this market. Daimler has consolidated its mobility platform in Moovel [48] and plans to buy up taxi companies across Europe [49]. Daimler already participates in Mytaxi. Moreover, there are cooperations with German Federal Railways [50]. General Motors holds interests in Lyft [51]. According to press reports, Uber is negotiating with Daimler as to the purchase of a large number of S class models, which are suitable for autonomous driving [52]. Railway companies are busy in the sense of strategic early recognition with the effects of autonomous driving. There are indications that mobility platforms will play the central role in reaching so-called "Seamless mobility", i. e. optimal connection of different means of transportation. Autonomous automobile mobility will be an important contribution to the "Transportation chain". In view of this background, tests with the previously mentioned road-trains or the so-called "Last-mile-vehicles", which are similar to the Google vehicles, must be seen as a contribution to future mobility. In this view, automobile manufacturers should rethink their position in the transportation chain. Examples from other sectors, such as retail trade or the travel industry show that the companies, or platforms, who have customer contacts and customer data will ultimately determine which vendors under which conditions will be used in future, and who are able to set up digital ecosystems. In any case, it is becoming apparent that the requirements of the young generation, the so-called digital natives, will change the understanding of mobility.

39.6 Outlook: the First Steps on a Long Journey

Automated and autonomous vehicles are cyber physical systems, i. e. the mechanical components are enhanced by extensive information and communication technology. This means that in research and development, and also in the maintenance of the vehicles in future extensive competencies in information and communication technology will be required.

In view of this, the automobile industry and the entire mobility sector are facing a major upheaval. Software, whether it be in the car itself, or as a mobility platform, will become a, perhaps even the deciding, factor in competition. For the traditional manufacturers and component vendors, this represents a major challenge against this background of digital transformation.

The further development of vehicles primarily controlled by humans to automated and ultimately autonomous vehicles is unstoppable and offers numerous opportunities for economy and society. The inherent dangers must be extensively and openly discussed in political and social arenas.

At present, we still cannot predict how quickly or when autonomous vehicles will be available on the market, reach greater market penetration and start the disruptive process of change in the mobility sector. There are currently already automated vehicles on the market. The structure change has already started. Mobility vendors, which are unable to develop their core competencies will face great, perhaps existential problems. It seems clear today that stakeholders in the ecosystem "Mobility" will have to concern themselves with the digital transformation, in the sense of the Chinese philosopher Confucius, who said: "Every journey starts with the first step".

References

1. ZEIT Online, [Online]. Available: http://www.zeit.de/mobilitaet/2016-04/automobilindustrie-digitalisierung-elektromobilitaet-autonomes-fahren-tesla-wandel. [Accessed 17 08 2016].
2. YouTube, Audi AG, [Online]. Available: https://www.youtube.com/watch?v=eOYsI1cqUrw. [Accessed 16 08 2016].
3. Google Inc., [Online]. Available: https://www.google.com/selfdrivingcar/. [Accessed 17 08 2016].
4. YouTube, [Online]. Available: https://www.youtube.com/watch?v=UgNhYGAgmZo. [Accessed 17 08 2016].
5. FAZ, [Online]. Available: http://www.faz.net/aktuell/finanzen/aktien/teslas-gescheiterter-versuch-des-autonomen-fahrens-14344126.html. [Accessed 17 08 2016].
6. Societe of Auto Engineers, [Online]. Available: http://www.sae.org/misc/pdfs/automated_driving.pdf. [Accessed 22 08 2016].

7. Bundesministerium für Verkehr und digitale Infrastruktur, [Online]. Available: http://www.bmvi.de/DE/VerkehrUndMobilitaet/DigitalUndMobil/AutomatisiertesFahren/automatisiertes-fahren_node.html. [Accessed 22 08 2016].
8. NHTSA, [Online]. Available: http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development. [Accessed 17 08 2016].
9. Audi USA, [Online]. Available: https://www.audiusa.com/newsroom/news/press-releases/2015/01/550-mile-piloted-drive-from-silicon-valley-to-las-vegas. [Accessed 17 08 2016].
10. Newatlas, [Online]. Available: http://newatlas.com/delphi-drive-completed/36859/. [Accessed 17 08 2016].
11. M. S. Research, "Autonomous Cars – Self-Driving the New Auto Industry Paradigm," 2013. [Online]. Available: http://orfe.princeton.edu/~alaink/SmartDrivingCars/PDFs/Nov2013MORGAN-STANLEY-BLUE-PAPER-AUTONOMOUS-CARS%EF%BC%9A-SELF-DRIVING-THE-NEW-AUTO-INDUSTRY-PARADIGM.pdf. [Accessed 17 08 2016].
12. FAZ, [Online]. Available: http://www.faz.net/aktuell/wirtschaft/julian-nida-ruemelin-im-interview-ueber-kuenstliche-intelligenz-14084351-p2.html. [Accessed 17 08 2016].
13. ZDF, [Online]. Available: https://www.facebook.com/aspekte.kultur/videos/vb.117455221614291/1332960416730426/?type=2&theater. [Accessed 17 08 2016].
14. U.S. Senate Comitee, [Online]. Available: http://www.commerce.senate.gov/public/index.cfm/2016/3/hands-off-the-future-of-self-driving-cars. [Accessed 17 08 2016].
15. Bundesministerium für Verkehr und digitale Infrastruktur, [Online]. Available: http://www.bmvi.de/DE/VerkehrUndMobilitaet/DigitalUndMobil/AutomatisiertesFahren/automatisiertes-fahren_node.html. [Accessed 17 08 2016].
16. DARPA, [Online]. Available: http://archive.darpa.mil/grandchallenge/. [Accessed 17 08 2016].
17. FAZ, [Online]. Available: http://www.faz.net/aktuell/gesellschaft/who-statistik-1-2-millionen-verkehrstote-weltweit-12114595.html. [Accessed 17 08 2016].
18. Volkswagen AG, [Online]. Available: http://www.volkswagenag.com/content/vwcorp/info_center/de/themes/2016/04/Guetertransport_der_Zukunft.html. [Accessed 17 08 2016].
19. Daimler, [Online]. Available: https://www.daimler.com/innovation/autonomes-fahren/mercedes-benz-future-truck.html. [Accessed 17 08 2016].
20. The Washington Post, [Online]. Available: www.washingtonpost.com/news/the-switch/wp/2015/06/22/google-didnt-lead-the-self-driving-vehicle-revolution-john-deere-did/. [Accessed 16 08 2016].
21. ABC, [Online]. Available: http://www.abc.net.au/news/2015-10-18/rio-tinto-opens-worlds-first-automated-mine/6863814. [Accessed 17 08 2016].
22. Versicherungsjournal, [Online]. Available: http://www.versicherungsjournal.de/versicherungen-und-finanzen/die-haeufigsten-ursachen-von-schweren-verkehrsunfaellen-126342.php. [Accessed 17 08 2016].
23. Handelszeitung, [Online]. Available: http://www.handelszeitung.ch/unternehmen/rupert-stadler-wir-muessen-audi-neu-erfinden-1014060. [Accessed 17 08 2016].
24. Frauenhofer-Institut, [Online]. Available: https://blog.iao.fraunhofer.de/images/blog/studie-value_of_time.pdf. [Accessed 17 08 2016].
25. YouTube, [Online]. Available: https://www.youtube.com/watch?v=CqSDWoAhvLU. [Accessed 17 08 2016].
26. Audi AG, [Online]. Available: http://audi-urban-future-initiative.com/. [Accessed 17 08 2016].
27. The Boston Globe, [Online]. Available: http://www.betaboston.com/news/2015/11/24/this-car-will-park-itself-somerville-audi-prepare-to-test-self-driving-tech/. [Accessed 17 08 2016].
28. J. M. N. K. S. K. D. S. P. S. C. O. O. A. Anderson, Autonomous Vehicle Technology – A Guide for Policymakers 2014, Rand Corporation, 2014.

29. Audi AG.
30. nVIDIA, [Online]. Available: http://www.nvidia.com/object/drive-px.html. [Accessed 17 08 2016].
31. Roland Berger, [Online]. Available: https://www.rolandberger.com/de/Publications/pub_autonomous_driving.html. [Accessed 17 08 2016].
32. Heise, [Online]. Available: http://www.heise.de/newsticker/meldung/Audi-BMW-und-Daimler-besitzen-nun-offiziell-Nokias-Kartensparte-Here-3032337.html. [Accessed 17 08 2016].
33. Handelsblatt, [Online]. Available: http://www.handelsblatt.com/unternehmen/industrie/daimler-bmw-und-audi-krempeln-here-um-die-route-wird-neu-berechnet/12814486.html. [Accessed 17 08 2016].
34. Huawei, [Online]. Available: http://www.huawei.com/minisite/5g/img/GSA_the_Road_to_5G.pdf. [Accessed 17 08 2016].
35. CeBIT, [Online]. Available: http://www.cebit.de/en/news-trends/trends/big-data/articles/the-datamobile.xhtml. [Accessed 17 08 2016].
36. statista, [Online]. Available: http://de.statista.com/statistik/daten/studie/201859/umfrage/anteil-des-e-commerce-am-einzelhandelsumsatz/. [Accessed 17 08 2016].
37. Frauenhofer-Institut, [Online]. Available: http://www.bmwi.de/BMWi/Redaktion/PDF/H/hochautomatisiertes-fahren-auf-autobahnen,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdfS. 358. [Accessed 17 08 2016].
38. Continental, [Online]. Available: http://www.continental-corporation.com/www/presseportal_com_de/themen/pressemitteilungen/3_automotive_group/interior/press_releases/pr_2012_03_15_software_de.html. [Accessed 17 08 2016].
39. Stanford University, [Online]. Available: http://web.stanford.edu/group/vail/. [Accessed 17 08 2016].
40. General Motors, [Online]. Available: http://gm.web.cmu.edu/. [Accessed 17 08 2016].
41. Digital Trends, [Online]. Available: http://www.digitaltrends.com/cars/toyota-invests-in-ai-robotics-research/. [Accessed 17 08 2016].
42. YouTube, Audi AG, [Online]. Available: https://www.youtube.com/watch?v=1YEWyZCqJNI. [Accessed 17 08 2016].
43. Faraday Future, [Online]. Available: http://www.ff.com/. [Accessed 17 08 2016].
44. TED Inc., [Online]. Available: https://www.ted.com/talks/chris_urmson_how_a_driverless_car_sees_the_road?language=d. [Accessed 17 08 2016].
45. Stanford University, [Online]. Available: http://cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action. [Accessed 17 08 2016].
46. ZEIT Online, [Online]. Available: http://www.zeit.de/mobilitaet/2016-04/autonomes-fahren-gesetzentwurf-verkehrsrecht-alexander-dobrindt. [Accessed 17 08 2016].
47. Audi AG, [Online]. Available: https://www.audiunite.com/se/service/en_unite.html. [Accessed 17 08 2016].
48. Moovel, [Online]. Available: https://www.moovel.com/en/DE. [Accessed 17 08 2016].
49. Manager Magazin, [Online]. Available: http://www.manager-magazin.de/unternehmen/autoindustrie/daimlers-mytaxi-fusioniert-mit-taxivermittler-hailo-a-1104802.html. [Accessed 17 08 2016].
50. Flinkster, [Online]. Available: https://www.flinkster.de/. [Accessed 17 08 2016].
51. Manager Magazin, [Online]. Available: http://www.manager-magazin.de/unternehmen/autoindustrie/zukunftsmobilitaet-gm-steigt-bei-uber-konkurrent-lyft-ein-a-1070431.html. [Accessed 17 08 2016].
52. walstreet online, [Online]. Available: www.wallstreet-online.de/nachricht/8447306-s-klasse-autonom-milliardenauftrag-daimler-uber-forciert-autonomes-fahren. [Accessed 17 08 2016].

Further Reading

53. BMW AG, [Online]. Available: http://www.bmwi.de/BMWi/Redaktion/PDF/H/hochautomatisiertes-fahren-auf-autobahnen,property=pdf,bereich=bmwi2012,sprache=de,rwb=true.pdfS. S. 358. [Accessed 17 08 2016].