





Competitiveness of the European automotive manufacturing industry

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Introduction

The European transport manufacturing industry is currently well positioned on the worldwide market with competitive products of high quality. However, global economic shifts, societal trends and environmental challenges will put its leadership role into question. Disruptive technologies like electrification, automation and digitalisation offer opportunities for novel business models and innovative transport solutions that will determine unique selling propositions of the future. Hence, industrial players from nontraditional domains with large financial resources and innovative skills like the IT sector may reshape the existing value chains of transport manufacturing at a high pace. As many of them are located elsewhere in the world, predominantly in North America, but increasingly also in the emerging economies of China, East Asia and India, the competitive position of the established European industries will be challenged tremendously within the next decades.

For companies and policy makers to anticipate the challenges, to identify conceivable enablers and hurdles for counteraction, and to conclude on effective push or pull measures, the current state and the future development paths of the European transport manufacturing industries have to be thoroughly investigated. Such study has to cover not only all transport modes, but also in particular transversal aspects as the dynamics of the value chains, the changing user behaviour and the global economic trends that affect competitiveness.

The project ,Scoreboard of Competitiveness of the European Transport Manufacturing Industry' (SCORE) funded by the European Commission explored, assessed and forecasted how progress in research and development, new innovative technologies and future demand changes in combination with forthcoming geopolitical and geo-economic developments affect the global competitive position of the European transport manufacturing industry. The analysis focused on the four major transport manufacturing industry's segments automotive, aviation, ship-building and rail rolling stock, all for carriage of passengers and freight, and within a time horizon up to the year 2030 (and partly to 2050). The findings are summarized and visualized in a so called scoreboard that indicates in an easily accessible way the current and future competitive position of the European transport manufacturing industries compared to their global rivals.

The SCORE core consortium consisted of eight partners from seven countries. Within this publication some of the aspects the team from VDI/VDE Innovation + Technology analysed are reported. The full information from all partners and all reports for the considered transport sectors are available at the project website SCOREBOARD (http://transport-scoreboard.eu/). This publication contains only an excerpt of the research carried out with a focus on the current economic situation and future perspective of the European automotive industry.

Part A is analyzing the current competitive position of the European automotive industry with a focus on economic aspects like market dominance and market dynamics, value added within the manufacturing network, the supporting infrastructure or financial excellence in general.

Based on current and emerging trends, knowledge of risk sources and future global transformations, the future analysis in Part B anticipates developments that might affect global competitive positions of the European automotive industry in markets of interest until 2030. Considering cross-sectoral aspects, the impact of technological trends on the setup and dynamics of the value chain (chapter 2) and demand-side (chapter 3) are assessed. The analysis covers both passenger as well as freight transportation while in some cases there is no clear separation any more.

Part A: Current economic situation

by Leo Wangler, Guido Zinke

To assess the current competitive position of the automotive manufacturing industry in one comprehensive approach, twelve high-level focus areas were identified and refined in multiple discussions and expert interviews. The competitiveness analysis concentrates on qualitative and quantitative aspects within these focus areas. For the economy-related assessment the focus areas are:

Market Dynamics

Bringing together the supply and demand side, this focus area concentrates on the change of particular indicators over time. This includes the emergence of new players or market entrants that potentially lead to a distortion of the existing market setup. The aim is to get insights on growing and decreasing market shares, in order to be able to assess the increasing or decreasing competitiveness of relevant actors.

Competition

This focus area takes a closer look on the overall position of European car manufacturers in comparison to existing competitors in the world. The general competitiveness of the European economy is further analyzed by having a closer look on the market conditions measured by the Global Competitiveness Index (GCI). A strength, weakness, opportunity and threat (SWOT) analysis, rounds off this section on European competitiveness.

Financial Excellence

The discussion of financial excellence is based on several indicators. One important indicator is R&D investment. Due to the high risk of R&D, its financing is much related to private equity. Companies need financial excellence to be able to invest sufficiently into R&D. Besides R&D investments, further indications for financial excellence like sales and profits are taken into consideration.

Value Added

1

Within this focus area a closer look is taken at the specialization of countries on the automotive industries. This is done by indicators taking into consideration the number of big firms specialized in the automotive sector, total employment and value added.

http://transport-scoreboard.eu/project, last access June 1st 2018.

Supporting Infrastructure

Supporting infrastructure comprises geographic and economic-geographic indicators such as the strength of the national innovation system or regulatory aspects. This section is mainly assessed by taking a closer look at the results related to the Global Innovation Index (GII) which provides numerous indicators ranking the innovation performance worldwide.

In the following chapters, the analysis for these five focus areas is explained in depth. At the project SCOREBOARD's website¹, the full analysis for all 12 focus areas for the automotive industry and also for the other considered transport industries is available.

1.1 Market Dynamics

This section on market dynamics focuses on the change of particular indicators. Thus, general trends in all analyzed industries are disclosed. This includes the emergence of new players or market entrants that potentially lead to a distortion of the existing market set-up. The aim is to get insights on growing and decreasing market shares, in order to be able to assess the increasing/decreasing competitiveness of relevant actors.

1.1.1 Current fleet size and situation

The number of automobile factories in Europe amounts currently to 137. These factories are mostly specialized on conventional combustion engines. Alternative fuel cars, including electric, natural gas and Liquified Petroleum Gas (LPG) account for 5.5% of the total EU car-fleet, while for new car sales the relative share is at about 3%. 25% of all cars produced around the world are built in Europe. In total: 16 million passenger cars were made in the EU in 2015. Today, there are 253 million cars on Europe's roads. 27 new cars were registered per 1.000 inhabitants in the EU in 2015. A high share of 5.7 million European cars were exported worldwide in 2016, worth more than 129 billion euros (compare Figure 1).

2015 and within two decades decreased by 35.7%. In 2015,

13.7 million cars were registered in the EU, which marked an increase of 9.3 % within one year. More than 50 % of new cars sold are powered by diesel (ACEA 2017b).

1.1.2 Changing market dynamics due to urbanization

Especially in cities, demand will change in the future. The main drivers are new mobility trends like car sharing and autonomous driving. This will reduce the demand for privately owned cars, especially in established markets within Europe and the US. The main driver of the future rise in global car sales is therefore the overall positive economic development which will be found foremost in emerging economies like China and India (compare also WP 2.3) (McKinsey 2016, p. 9–10).

These new trends and developments in vehicle sales like car sharing, urbanization and macroeconomic developments (increasing incomes in emerging markets) have an impact on the industry, but vary by region and city type. In Europe (and North America) the current annual vehicle sales amounts 5 million (2015) in high-income dense cities. This number is expected to remain stable by 2030, but the proportion of new shared vehicles will increase. A slightly different picture can be found in high-income suburban areas where the number of shared vehicles will grow even more while the number of private ve-













in Europe.

The average age of cars in the EU is close to 10 years

Figure 1: Current fleet size and situation - worldwide (Automotive). Source: (ACEA 2017a).

hicles will decrease. The overall demand is estimated to remain relatively stable (McKinsey 2016, p. 9–10).

In comparison to high-income regions, it is expected that low-income regions will not see this significant rise of shared vehicles in the near future. More privately owned vehicles will be on the roads by 2030. This trend is driven by the expected increase in incomes in emerging economies. As this growth is expected to happen mainly in urban areas, small rural areas in emerging economies (e.g. in China or India) will not see this increase in demand for new cars in the future. The total share was 8 million sold cars in 2015 which is expected to remain rather stable (for further demand aspects compare also WP 2.2) (McKinsey 2016, p. 9–10).

1.1.3 New technology trends and the related market dynamics

According to the global automotive executive survey (KPMG 2016) 50% of the executives see the topic 'connectivity and digitization' as the most relevant key trend until 2025. It is followed by trends in new driveline technologies such as hybrid electric vehicles (49.5%), battery electric mobility (46.5%) and fuel cell electric vehicles. Likewise the growing market in emerging economies was assessed by 46.3% of executives polled as

important driving force in the upcoming years. Another 41.8 % viewed mobility-as-a-service as another major trend together with customer data/big data. The shift in business models to mobility as a service is shown in Figure 2.

This also changes forms of organizing future production. Auto executives mentioned platform strategies and modular productions systems (38.5%) as well as the rationalization of production in Western Europe (29.1%). According to the surveyed executives, the trend of autonomous and self-driving cars is getting increasingly relevant (rank 9 in 2016). While the downsizing and optimization of the internal combustion engine was still voted on place 2 in 2015, it was less prominent in the executive's answers (rank 10 in 2016). This might change in the future; however, it is still unclear how long this transition towards a carbon free mobility will last.

In the survey conducted by KPMG (2016), 40% of respondents in Western Europe said, that they still prefer to own a car rather than use mobility services. This number is a bit lower in Eastern Europe (38%). In the US the approval to the statement is even higher with 50%. The opinion differs strongly in emerging markets: in China only 20% of the respondents said they would prefer to own a car and 19% in India and ASEAN (KPMG 2016). This consumer view somehow contradicts our previous



Figure 2: Increasing complexity of market landscape. Source: (McKinsey 2016, p. 13). Explanatory note: OEM=Original Equipment Manufacturer; Tier1: Suppliers at the first level

finding based on expert opinions (McKinsey 2016) that in the future car sharing will mainly happen in established economies (e.g. Europe and the US). Thus, it also might be that car sharing becomes soon very popular in emerging economies and will gain importance for future demand structures within these regions/countries.

1.1.4 Current and future profits in the automotive sector

Traditional automotive revenues derive mostly from the selling of vehicles, leading to a market volume of about USD 3.500 billion. One-time vehicle sales amount to USD 2.750 billion and the aftermarket to USD 0.720 billion. The third stream, recurring revenues sums to a relative low share of USD 0.30 billion (McKinsey 2016, p. 6).

These revenues are expected to grow and diversify with new services to a USD 1.5 trillion market in 2030. High expected growth rates are related to new business models and services commercializing the upcoming IT-potential.

The annual growth rate of the automotive industry is expected to reach 4.4 % by 2030, due to the new revenue streams stemming from new technologies and new business models. The three main revenue streams (one-time vehicles, aftermarket and recurring revenues) will increase strongly. But also one-time vehicle sales are expected to grow to USD 4.000 billion, due to an annual increase of vehicle unit sales by 2 % worldwide. This dynamic is mainly driven by an expected income growth in emerging economies (compare also WP 2.2). Another factor is the amount of price premiums paid for electric vehicles and autonomous driving technology features (McKinsey 2016, p. 6).

The aftersales market is expected to grow to USD 1.200 billion. Major reasons are the mentioned increased vehicle sales and the higher spendings for maintenance of shared car fleets. At the same time the maintenance costs for electric powertrains will decrease by 20–30 %. Furthermore, the growth is driven by a lower average crash repair (up to 90 %) per autonomous vehicle, which increases purchasing power and a certain amount of this money will increase the demand for automotive devices even further (McKinsey 2016, p. 6).

The automotive revenue pool will be driven by innovations related to new technologies, as well as new business models related to sharing concepts and connectivity solutions, and for this reason this will lead to increasing recurring revenues, with a 30 % jump by 2030 (up to ~ USD 1.5 trillion). This development is mainly influenced by shared mobility, e.g. new car sharing and e-hailing services. More than USD 100 billion will be generated with data connectivity services like apps, navigation, entertainment, remote services, and software upgrades. (McKinsey 2016, p. 6) There is the challenge to cope with this market dynamic and build a new knowledge base in new ITbased business models.

1.1.5 Market attractiveness for future market dynamics

The survey by KPMG (2016) shows further that the majority of respondents see the Chinese market as the main future driver for innovations (16%). The other markets in the top 5 include Germany (11%), USA (9%), India (8%) and Japan (5%). Further favorable places to launch innovations are states like Australia, Canada and France (voted with 5% each). Also in the top ten are Brazil (4%) and Austria (3%) (KPMG 2016).

A closer look at the attractiveness of different markets around the world leads to the impression that regions like China (16%), Germany (11%) and India (9%) are most likely to attract foreign direct investments from automotive companies. While 20% of Western European companies would invest in Germany, China (14%) and France (10%), Eastern European companies would rather choose Austria (9%) over France on the third place after Germany and China. Similarly respondents from North America ranked China as first destination to invest (17%) followed by USA (16%) and Germany (12%). On the other hand one third of Chinese companies are keen to invest in China, while a minority considers Germany (10%) and Australia (6%).

1.1.6 Image on the capability to cope with market dynamics by manufacturer

European vehicle manufacturers like BMW, Volkswagen (VW) or Renault-Nissan-Mitsubishi and Daimler are assessed differently in terms of their role as innovation and technology leaders in the future. On a global scale the BMW group has by far the highest perception both as leader in electric mobility (roughly 18%) and in the field of self-driving cars (20% of the respondents). The Volkswagen Group and the Renault-Nissan-Mitsubishi Group are still in the top 10 of the automotive manufactures but far below Toyota from Japan (2nd highest percep-

tion, 15%). Also non-European companies such as Tesla Motors (US), the Honda Group (Japan) and the Ford Group (US) have a good image as innovator and technology leaders. The European company with the lowest perception as innovator is Fiat Chrysler Automobiles with 3% close behind the Daimler Group (KPMG 2016).

1.1.7 Summary of the main findings

Leading manufacturers on global markets are European Original Equipment Manufacturer (OEM) as well as manufacturers and suppliers. Different sources are responsible for the increasing market dynamics. First, changing demand structures, with an increasing demand in emerging economies (compare WP 2.2) lead to more dynamics within the industry. Second, new business models and changing consumer habits are shifting demand from owned cars to shared cars. Third, new disruptive technologies like autonomous driving and new driveline technologies (e.g. the transition to hybrid and electric vehicles) generate further market dynamics. European car-producers are currently well equipped to cope with these dynamics. However, they also do not seem to be more progressive compared to other car producers (e.g. from Asia). New entrants like Tesla seem to have a high comparative advantage in new technologies (electro mobility) as well as in generating IT-based innovations. Thus, incumbent European car producers are under high pressure to successfully manage their enterprises within these uncertain market environments, in order to keep the currently good international market position.

1.2 Competition

This section on competition takes a closer look at the overall position of European car manufacturers relative to existing competitors in the world. The general competitiveness of the European economy is further analyzed by having a closer look on the marked conditions measured by the Global Competitiveness Index (GCI). A strength, weakness, opportunity and threat (SWOT) analysis, rounds off this section on European competitiveness.

1.2.1 Market shares by automobile type worldwide

As shown by Figure 3, three car producers from Europe are listed under the top ten of the OICA car producer ranking. One of the biggest and therefore most competitive car producers in

Word motor vehicle production OICA correspondents survey Word ranking of manufactures

Year 2015					
Rank	Rank Group				
	Total	90,086,346			
1	ΤΟΥΟΤΑ	10,083,831			
2	VOLKSWAGEN	9,872,424			
3	HYUNDAI	7,988,479			
4	G.M.	7,485,587			
5	FORD	6,396,369			
6	NISSAN	5,170,074			
7	FIAT	4,865,233			
8	HONDA	4,543,838			
9	SUZUKI	3,034,081			
10	RENAULT	3,032,652			
11	PSA	2,982,035			
12	B.M.W.	2,279,503			
13	SAIC	2,260,579			
14	DAIMLER AG	2,134,645			
15	MAZDA	1,540,576			
8 9 10 11 12 13 14 15	HONDA SUZUKI RENAULT PSA B.M.W. SAIC DAIMLER AG MAZDA	4,543,838 3,034,081 3,032,652 2,982,035 2,279,503 2,260,579 2,134,645 1,540,576			

Figure 3: World motor vehicle production. Source: OICA (2015)

the world is Volkswagen, which is ranked second after Toyota, the Japanese car producer with the highest amount of sold cars (more than 10 million). The Korean brand HYUNDAI is ranked third, with almost 8 million sold cars in 2015. American brands like GM (4th rank) and Ford (5th rank) sold together almost 14 million cars. Overall, the Japanese car manufacturers are highly competitive. With Toyota (1st rank), Nissan (6th rank), Honda (8th rank) and Suzuki (9th rank) four Japanese companies are listed in the top ten. Together they sold more than 20 million cars in 2015.

1.2.2 Sales volumes in different regions of the world

The highest share of sold light duty vehicles is in China, with 22 million registered vehicles in 2014. Similar to Europe, passenger cars account for the largest share of 94%. A small share of registered cars is made up of light-commercial vehicles (6%) (OICA 2015).

The number of registered vehicles in the United States in 2014 was 15 million. The breakdown to different car segments shows that 10% are SUVs (sport utility vehicles) and about 50% are

from other car segments. From these 15 million vehicles are about 40% categorized as trucks. This share can further be divided in the following subcategories: truck SUVs (24%), truck pickups (12%), minivans / vans (4%).

There are about 14 million light duty vehicles registered within the EU in 2015; the majority of these are passenger cars with 89% of which 87% are from car-like segments. A minor share is made up of light-commercial vehicles dominated by vehicles in the van-like segments.

1.2.3 Sales volumes of personal cars in the EU

The sales volume of personal cars in the EU-28 increased slightly from around 12.5 million cars in 2010 to 13.5 million in 2016. However, this development had not followed a straight line, since the sales figures dropped between 2010 and 2013 by 2.5 million to 10 million sold cars. Thereafter, the sales volumes continued to rise again annually until 2016. The country with the currently highest sales volume is Germany, followed by the United Kingdom, France and Italy. States at the bottom of the list include Spain, Belgium, Netherlands and Austria (icct 2015).

The brand with the highest share in car sales in Europe is the German manufacturer VW (27%). Ranked second, with around half of VW's share is PSA (Peugeot Société Anonyme) (14%), closely followed by French manufacturer Renault (11%) and the US company Ford (10%), with its production plants in Europe (e.g. in Cologne in Germany).

In the single digit percentage range are Hyundai (7%), Mercedes Benz (6%), BMW (6%), General Motors (mostly Opel)² (5%), Fiat (5%), Nissan and Toyota (both 4%). The lowest share in European car sales with 1% holds Mazda (compare Figure 2). It can be seen that European car manufacturers have relatively high market shares at the European market. There exists a correlation between local manufacturing and market shares of certain brands (e.g. French car producers sell a relatively high share of cars in France).

The number of sold cars in Europe decreased from 10 million in 2008 to 9 million in 2015. In the period from 2008 to 2013 the figures decreased strongly, to fewer than 8 million. Thereafter, sales figures marked a continuous rise until 2015. This devel-



Figure 4: Market Shares (%) of Leading Suppliers (2015). Source: icct (2015)

opment was influenced by subsidies paid at the financial crisis to car consumers, e.g. in the context of the German wracking-fee). The sales figures from all manufacturers mirrored this development. An exception can be observed for Volkswagen, which shows relative stable sales figures. VW is also the manufacturer with the highest number of sold cars between 2008 and 2015 with almost 2 million cars per year. On the ranks 2 to 5 are the producers Renault, Ford, Peugeot and Fiat.

A look at the market shares of leading suppliers shows a similar picture: more than 10 % is owned by VW, followed by Renault (<8 %), Ford (<7 %), Peugeot (5 %) as well as Citroen, Opel, Audi, BMW, Mercedes Benz (4 % each). Another 35 % of the market share is occupied by other small suppliers.

1.2.4 Market Shares of drive systems in Europe 2015

The market share of drive systems in Europe varies from country to country. On a European scale the two most popular drive sys-



Figure 5: Global Competitiveness comparison over time. Source Author' calculations.

tems in the EU-28 are diesel cars, with more than 50 % market share. Currently, as result of the so-called 'Diesel gate'³, this picture changes slightly, as petrol-driven combustion engines become more popular. A minor percentage of roungly 3 % are hybrid cars and petrol-driven / natural gas cars (4 %). The smallest market share, with less then 1 %, are battery electric / fuel cell cars.

A closer look at the state level shows that most EU-28 states have the same distribution of market shares dominated (\sim 50%) by diesel. Only Italy has a bigger market share of petrol-driven / natural gas with about 15%.

The sales figures of all new cars indicate that the share of hybrid-electric cars in the EU varies by country. While the overall market share of hybrid-electric vehicles is 1.5 % in the EU-28, the share of GDI (gasoline direct injection) is about 40 % in 2015. France (2.2 %) and Spain (1.8 %) are the countries with the highest share of hybrid-electric vehicles. Diesel is the drive system with the highest share of newly registered cars in the EU with about 52 %. This percentage remained more or less stable between 2010 and 2015 with a plus 5 % increase in 2011–2012. Above European average are countries like Italy and the United Kingdom, both with around 55%, and Spain with 63%. Especially demand for diesel cars in Spain showed a sharp increase from 2011 (40%) till 2015. On the contrary, demand for diesel in UK dropped from 72% in 2012 to less than 60% in 2015. An even bigger fall of diesel car sales was recorded in France between 2011 (70%) and 2015, with a reduction of nearly 23% to a market share of 48% (icct 2015).

1.2.5 Global Competitiveness Index (GCI) Score Ranking

To assess the overall competitiveness of EU and their worldwide competitors within the automotive sector, the following analysis focusses on the GCI ranking of different countries and regions in the world. This analysis is not sector-specific, however, it summarizes overall competitiveness of countries and due to the relevance of the car-industry in different countries/regions, the GCI-results can be generalized to the sector level.

The GCI Score of Europe (for a description of the GCI compare WP 2.3 as well as GCR 2017) increased slowly between 2007 and 2016 from roughly 4.8 to 4.85. Regarding the regional competitiveness Europe takes the 3rd position after North Amer-

³ In 2015 it was revealed that Volkswagen had employed software in Diesel cars to reach the required emissions standards when in testing. The emissions under real driving conditions were however much higher. This caused massive problems for the sales of diesel powered cars and furthermore for the image of car producers as well. As a matter of fact a lot of car manufacturers were struggling to meet the strict emission standards for diesel cars and cheated during the official test procedures. Additionally to the already convicted OEMs, there are simultaneous investigations against several others, where essential discrepancies between the official testing results and the measured emissions during utilization were detected. Involved car manufacturers are amongst others: Volkswagen, General Motors, Fiat Chrysler, Daimler, Ford, Volvo and Renault.

ica (1st) and is slightly behind East Asia and Pacific. After the top 3, but close ahead is the Middle East and North Africa. On rank 4 is Eurasia, which was able to catch up with Latin America and the Caribbean from 2011-to date. LAC is holding according to the GCI score the 5th place before South Asia (6th) and Sub-Saharan Africa (7th). The different regions of scope were overall able to increase their competitiveness in the past 10 years – some more than others (GCR 2017).

In the following China, the US and Europe are analyzed in more detail, as these regions are in the major focus of this SCORE project.

- China holds rank 28 with a GCI score of 5.0 (2016–2017) for the third year in a row. The areas of competitiveness in which the country is able to improve are higher education (54^{th),} innovation (30th) and business sophistication (34th). On the first pillar of institutions China holds position 45 with an overall score of 4.3. In the area of infrastructure the Chinese economy ranks 42 with a score of 4.7 following a positive trend. China holds a strong 8th rank in the macroeconomic environment pillar, although the trend is going down. On the level of the efficiency enhancers China ranks 56th in the pillar of goods market efficiency, on 39th regarding labor market efficiency and 56th in financial market development. Still, China legs behind in technological readiness (74th) at a score of 4.0 but showing an overall positive trend. With a view to the market size China is the best-performing country with a score of 7.0 (GCR 2017)
- ▶ The United States are ranking on the 3rd position in the regional competitiveness comparison. Its position is driven by innovation, business sophistication, market size, financial market development, labor market efficiency, and higher education and training. In the basic requirements pillars (institutions, infrastructure, macroeconomic environment, health and primary education) the US is not ranking in the top 10. In the 1st pillar institutions the US holds rank 27 with a score of 5.0 that is showing a positive trend. Also the pillar infrastructure (11th) reveals a positive trend. Only ranking 71st in macroeconomic environment (score 4.6) the US still show a strong upward trend. Regarding the efficiency enhancers subindex, the US are not within the top 10 on technological readiness or goods market efficiency. Both in the domain of financial market stability and market size the country ranks very high (place 3 and 2) (GCR 2017). As current political developments within the US impose high uncertainties for the economic development, it seems

difficult for the US to maintain their good position in the near future.

The Global Competitiveness Index of Germany scores 5.6 by holding rank 5 closely behind the best European country the Netherlands (4th). In the domain of technological readiness Germany is in the top 10 and in respect of market size even in the top 5. Its macroeconomic environment is overall stable. In respect of innovation and sophistication factors Germany ranks in the top 5 with a score of 5.6. In the efficiency enhancers subindex the German economy ranks 20th on the financial stability pillar, 23rd in goods market efficiency and 22nd in labor market efficiency (GCR 2017).

The overall findings of the GCI-index underline previous findings: Europe and US are highly competitive at the moment, however, China shows an upward trend and will become a major player in the near future.

1.2.6 Assessing European competitiveness by a SWOT-Analysis

In order to round off this section on competitiveness, the European innovation system is assessed from four different perspectives: strengths, weaknesses, opportunities and threats (SWOT Analysis). The SWOT analysis allows the examination of the general situation of Europe's competitiveness in the automotive value chain (the following SWOT analysis summarized results from Ricardo Energy & Environment 2016).

Strengths

Europe holds a strong position in the traditional automotive industry. The same pattern is seen in providing services for vehicle use stage like intelligent transport systems, battery management systems or payment systems. Moreover, Europe is the leading 'test place' for car sharing solutions such as Renault's 'TwizyWay' or BMW's 'DriveNow'. Furthermore, Europe takes a leading role as growing market for connected vehicle solutions. Another advantage lays in the high concentration of lightweight businesses allowing to cooperate, to reacte in a flexible way to changing circumstances and thus, to rapidly implement new ideas.

Weaknesses

The weaknesses of the European vehicle market lays in the limited knowledge in the main electric vehicle technologies like electrochemistry (producing battery cells) and power electronics. Hence, its value chain is highly dependent on component suppliers outside the EU. Besides, at a legal level Europe lacks the timely development of necessary frameworks to ensure the interoperability of infrastructure. This is a critical factor for data security and liability issues, e.g. shared and connected mobility services. Even more, the region shows a shortage of skilled labour that is important to ensure the vehicle after-market and maintenance services for upcoming technologies.

Opportunities

The EU market has the chance to increase its market share by exporting more EV technologies and infrastructure components to worldwide markets . Moreover, there is a high potential to generate additional revenue with 'direct-to-consumer' services, including shared and connected mobility services. Last but not least the promotion and development of alternatively fuelled vehicles would boost Europe's energy balance.

Threats

The majority of European consumers is not aware of the advantages innovations like connected or electric vehicles can bring to their daily lives which results in a lack of technology confidence. Another threat lays in the rather poor investment climate for the high upfront investments in R&D, especially for EV recharge infrastructures. In addition, the barriers to entry for innovations (shared or connected services) are low, and thus making market easily accessible for new the players.

1.2.7 Future competitiveness of OEMs

Due to the increasing complexity of the competitive landscape for individual mobility, OEMs are compelled to compete in several areas in the future. While OEMs in the past mainly had to compete with one another (and the quality of combustion engines was one major factor of success), the competition is expected to shift till 2030. Since new players are entering the market, such as mobility providers (car sharing, e-hailing), tech giants like Google and Apple, but also other OEMs (e.g. Tesla as well as new brands specializing on electro mobility) emerge, the established OEMs will be forced to compete in a complex market landscape.

Currently, European car producers seem to be in a good position to defend their high international market shares. According to

the KPMG Global Executive Survey 2016, Toyota and BMW are in the best position and are expected to increase market shares in the future (58 % opinion of the respondents). Ranked third is the German manufacturer VW, with 56 % of respondents expecting a positive development in market shares. Non-European OEMs like Hyundai, Ford, Honda and General Motors follow on the places four to seven. The Renault-Nissan Group is ranked 8th, with 42 % of executives assuming that this company will expand its market position in the future. Daimler will remain in a stable market position, according to this study (53 % opinion by of the respondents), while only 34 % expect a growth in market shares. Tata is also expected to keep the market share at a stable level (51 % opinion by of the respondents) (KPMG 2016).

1.2.8 Summary of the main findings

European car manufacturers are leading and have a comparative advantage to competitors. The weaknesses of the European vehicle market lays in the limited knowledge in the main electric vehicle technologies like electrochemistry (producing battery cells) and power electronics. Hence, its value chain is highly dependent on component suppliers outside the EU. Apart from this, the overall size of the European market, the good infrastructure, solid institutions and the powerful innovations are strong pillars of the current and future competitiveness of European car manufacturers. Disruptive changes described in the section ,Market dynamics' lead to uncertainties regarding the future development of the future market positions of those OEMs that are currently leading. The European car manufacturers are faceing many challenges and opportunities. This comes along with risks for incumbent manufacturers, as technology changes offer opportunities for new entrants challenging the existing business models. Companies have to be able to deal with these market dynamics and increasing competition in order to be able to defend the existing competitive advantage.

1.3 Financial Excellence

The discussion of financial excellence is based on several indicators – one of them is R&D investment. Due to the high risk of R&D, its financing is much related to private equity (Bronwyn H. Hall and Josh Lerner 2010). Companies need financial excellence to be able to invest sufficient into R&D. Beside R&D investments further indications for financial excellence like sales and profits are taken into consideration.

1.3.1 R&D investments

The EU Industrial R&D Scoreboard

The *EU Industrial R&D Scoreboard*⁴(*EU 2016*) is part of the Industrial Research and Innovation Monitoring and Analysis (IRIMA) project of the European Commission. It addresses the understanding of trends in R&D investment by the private sector and the factors affecting it.

Data for the *Scoreboard* have been collected by *Bureau* van *Dijk Electronic Publishing GmbH* from companies' annual reports and accounts. This year's *Scoreboard* refers to the 2015 fiscal year accounts (it therefore already includes some financial aspects related to the so-called '*Diesel-Gate*').

The Scoreboard is covering the top 2.500 (1.000) companies in the world. In the further course of the text we cite this dataset by 'top 2.500 list'. One major focus is on R&D investments but it also covers major financial indicators such as profits or revenues. The companies of the 2.500 list are responsible for more than 90 % of worldwide business enterprise expenditures on R&D. Nevertheless, SME are not represented at all, which leads to a distortion, considering that SME's are responsible for about 40–60 % of the value added in manufacturing industries (OECD 2017a).

A second distortion is related to the fact that the data covers firm outcomes. Thus, all companies' activities are allocated to the country of their registered headquarters. As a result, there is no insight in the geographic distribution and the territory of their activity (especially with regard to the country level). On the regional level (e.g. Europe as a region) we are nevertheless confident that there is a strong correlation between the headquarters of the automotive industries and the geographical allocation of investments. It also has to be kept in mind that the headquarter takes the decision on future investments and strategies and for that reason with regard to financial excellence it is convincing to make use of company level data. For these reasons we are convinced that this dataset covers relevant facts with regard to financial excellence.

The dataset copes with double counting by not listing subsidiaries of any other company. Only consolidated group accounts of the ultimate parent company are listed in the *Scoreboard*. Industry sectors are classified according to the NACE Rev.2 and the Industry Classification Benchmark (ICB).

Moreover, due to different national accounting standards and disclosure practices, companies in some countries are more likely than others to disclose R&D investment consistently. In some countries, on the other hand, R&D costs are often integrated with other operational costs and can therefore not be identified separately. Thus, companies from many southern European countries are underrepresented while UK companies are overrepresented. Further methodological problems arise as some companies include engineering costs related to product improvement into their R&D expenditures whereas some others don't. This implies that R&D of these companies is compared to European companies with different accounting standards.

For companies outside the European area, all currency amounts have been converted into Euro exchange rates ruling at 31 December 2015. Thus, the scoreboard indicates the domestic currency results rather than economic estimates of current purchasing parity results.

Figure 6 shows that the big European automotive-companies have the highest shares of R&D investments.⁵ They spend globally about 50 Billion Euro into R&D, far more than companies operating in the second biggest sectors ('Pharmaceuticals and Biotechnology'). The sector Technology Hardware and Equipment ranks fourth on industry's R&D investments. Compared to this, the investment pattern of US companies is slightly different, as the highest R&D investors are 'Software and Computer Services' and 'Pharmaceuticals and Biotechnology'. This

⁴ Commission (2016)

⁵ Please note (as also mentioned in the highlighted box) that the data used in this section is from a company perspective. This means that the R&D expenditures are total expenditures of the companies and do not stand for country specific data. Thus, a regional or national separation of investments is not feasibly when the analysis is based on the top 2.500 list. Beside this weakness there is a strong correlation between headquarters within Europe an R&D spending within Europe. Overall the top 2.500 is rich on information on financial excellence. It is used as the main source of data for this section on financial excellence.



Figure 6: R&D ranking of industrial sectors and share of main world regions for the world's top 2.500 companies. Source: EU (2016), p. 55.

is crucial because in the near future the electronic and software devices within the automotive sector will gain importance.

There is a large potential for new entrants like Tesla, if they are able to take advantage of their competitive edge in software and computer devices, by transferring this knowledge to the automotive sector. Japanese firms have specialization patterns similar to European firms. The R&D spendings of the automotive sector are significantly the biggest. Japanese firms are also strong in developing 'Electronic and Electrical Equipment', another specialization which gets more relevant for the car industry in the future, especially with respect to autonomous driving (Kryukov 2013).

Table 1 scores the leading automotive enterprises (for an overview on the data please see the Box 'On the EU Industrial R&D Scoreboard') according to their R&D investments (in the home country and abroad). Car producing companies located in Germany have the highest shares of R&D investments (37 Billion Euro) globally. German companies are investing approximately 20 % more than Japanese companies (29 Billion Euro). The R&D investments of American car-producing companies are lower, in 2015/2016 their share is 55 % below (the overall share is 16,6 Billion Euro) the R&D investments of German companies. China's companies are ranked sixth, with a total investment share of 4,5 Billion Euros.

The European car manufacturers (on the top 2.500 list) are spending 50 Billion Euro into R&D (48,2 Billion Euro without the UK) in total. Thus, the total amount of R&D spendings in the automotive sector are from European companies is comparable to the sum of the R&D spendings of Japan, US and China (added up to 50,64 Billion Euro) toogether. Within Europe, German companies are playing a strong role for the strength of the European car sector within R&D, as the R&D spendings of the German companies account for more than two thirds of the total R&D spendings of all European companies (registered at the top 2.500 list) operating within the car segment.

When interpreting these data it has to be kept in mind that total R&D investments of the companies with their headquarters within Europe do not necessarily stand for total R&D in-

Country	Investment in R&D 2015/16 (€million) into Automobiles and Parts	Benchmark	Score
Germany	37022,47	100,00 %	1
Japan	29427,58	79,49 %	2
US	16673,37	45,04 %	3
France	6156,66	16,63 %	4
Italy	5022,86	13,57 %	5
China	4541,83	12,27 %	6
South Korea	3684,56	9,95 %	7
India	2700,26	7,29 %	8
UK	1790,39	4,84 %	9
Turkey	269,49	0,73 %	10
Taiwan	241,11	0,65 %	11
Austria	112,82	0,30 %	12
Canada	109,11	0,29 %	13
Switzerland	56,20	0,15 %	14
Sweden	22,63	0,06 %	15
Europe (limited to the countries depicted at this table)	50127,84	-	1

Table 1: Ranking for the sum of R&D investments of firms operating in the sector automobiles and parts. Source: Datasource (EU 2016), calculation and depiction by VDI/VDE-IT

vestments within Europe. For Example: Volkswagen might also have R&D spendings in Mexico, which is statistically added to the total R&D spendings of Volkswagen and shows up in the numbers related to Germany.

For this reason R&D inflows and outflows are depicted at Table 2. It can be seen, that the net balance of R&D in Europe is negative, about 1,25 billion Euro net R&D investments are made outside of Europe. As the estimated R&D spendings for automobiles (parts are excluded) in Table 2 are 33 billion Euros, the share of outword R&D investments is 4 %. This shows that there has to be a strong correlation between the headquarters of OEMs and the total share of R&D spending within countries and regions.

Table 3 shows that there is a remarkable dynamic regarding R&D-investments over time. Firms with their headquarters in emerging economies (e.g. Turkey) were able to increase R&D investments in the automotive sector by about +51 % within the last three years. However, the level of total R&D investments is rather low (compare table 2). This is also true for companies

located in China. They were able to increase R&D investments by 21 %, starting on a relatively low level. With respect to an increase in R&D investments in Europe over the past three years, companies from the UK are leading. They were able to increase R&D investments by 10.3 %. Car producers located in Germany (+8,6 %), France (+4,48 %) had higher growth rates on R&D spendigs than US companies (+4 %). The increase of R&D spending by Italian firms (2,44 %) and Austrian firms (-1,61 %) was below the level observed for US companies.

Figure 7 shows the development of R&D spendings over time (2000–2015), with a focus on the leading car manufacturers. A significant increase in R&D can be observed for Volkswagen (VW). Other car-manufacturers like Toyota, Ford, Honda, BMW or Fiat increased R&D spendigs in the past years, but on much lower scales, compared to Volkswagen.

This is crucial, as the section on market dynamics shows that BMW or Toyota are perceived to be more innovative compared to Volkswagen. It seems that there are different levels of efficiency related to the R&D spendigs of different companies.

	KU-28 R&D Flows Net Balance		KU R&D Net Balance				
Sector	Outrand		By geographical areas				
	Home	(O)	Inward (I)	Total (I–O)	Rest of Europa	USA	Rest of the world
Aerospace & Defence	7 616	1 514	1 661	146	-29	83	93
automotive	33 071	5 135	4 271	-918	-125	455	-1 248
Chemical	3 630	1 136	1 541	405	305	61	39
Health Industries	19 614	10 036	13 507	3 471	4 436	-349	-616
ICT Producers	16 587	7 127	7 439	312	149	1 082	-919
ICT Services	7 266	2 007	2 914	908	30	1 411	-534
Industrials	9 984	3 956	3 959	3	787	-98	-686
Other Sectors	14 272	8 744	4 194	- 551	643	-2 911	-2 283
Total	112 040	39 656	39 432	-224	6 196	-268	-6 152

Table 2: Estimated inward and outward R&D flows for EU by sector (million Euro). Source: (EU 2016, p. 82)

Country	Investment in R&D, 3-yeras-growth (CAGR-3y, %) Automobiles and Parts	Benchmark	Score
Sweden	NA	NA	NA
Turkey	51,54	100,00 %	1
South Korea	25,55	49,58%	2
China	20,93	40,62 %	3
India	18,83	36,55%	4
Taiwan	17,75	34,44 %	5
UK	10,45	20,28%	6
Japan	8,87	17,22 %	7
Canada	8,64	16,77%	8
Germany	8,62	16,72 %	9
France	4,48	8,70 %	10
US	3,99	7,74 %	11
Italy	2,44	4,74 %	12
Austria	-1,61	-3,12 %	13
Switzerland	-2,95	-5,72 %	14
Europe (limited to the countries depicted at this table)	1,31	-	13

Table 3: Ranking of R&D 3 years growth of firms operating in the sector automobiles and parts. Source: Datasource (EU 2016), own calculation and depiction by VDI/VDE-IT



Figure 7: Line plots of R&D investments over time (year 2000–2015) by company for the largests R&D investments Source: (EU 2016, p. 73)

The indicator on R&D intensity (R&D-spending divided by total revenues) is a further proxy to assess financial excellence. Table 4 shows that the R&D intensity of UK companies is the highest, with a total share of 13%. Italian firms rank second, their R&D intensity is 7%. The R&D intensity of German firms is 5,4%, which is 60% lower than the R&D intensity of the car producers in the UK. Other car producing companies from France, the US, Canada, Sweden, China or Turkey all have an R&D intensity which is above 3,5%. Surprisingly low is the R&D intensity of Japanese firms, according to the dataset, its share is below 3,5%. The level of an R&D intensity of 3.5% is of particular interest, as this level is definded as an R&D level defining higher value production (FhG ISI 2000).

Country	R&D intensity (%) Automobiles and Parts	Benchmark	Score
UK	13,38	100,00 %	1
Italy	7,02	52,48 %	2
Germany	5,41	40,46 %	3
Taiwan	4,80	35,89 %	4
France	4,39	32,82 %	5
US	4,37	32,68 %	6
Canada	4,29	32,08 %	7
Sweden	3,85	28,76%	8
China	3,83	28,61 %	9
Turkey	3,74	27,93%	10
Japan	3,13	23,42 %	11
Switzerland	2,91	21,75%	12
South Korea	2,67	19,95 %	13
India	2,65	19,78%	14
Austria	КА	КА	
Europe (limited to the countries depicted at this table)	6,81		3

Table 4: Ranking of R&D intensity of firms operating in the sector automobiles and parts. Source: Datasource (EU 2016), own calculation and depiction by VDI/VDE-IT

Whereas R&D spendings are more related to process and product innovation, 'capital expenditures' seem to indicate confidence of firms on future sales potentials.

1.3.2 Capital expenditures

Table 5 takes a closer look at the global capital expenditures of the different car manufacturers: Japanese companies have the highest capital expenditures, followed by US car producing companies and German companies. Japanese car-manufacturers invested about twice as much as German car producers in 2015/16.

Many investments have a long time horizon. For this reason it is also convenient to take into consideration the 3 years growth in capital expenditures into consideration. With respect to this indication, the leading companies are located in South Korea, which increased investments within the automotive sector by almost 30%. The US car producers increased investments by about 10%, the increase in capital expenditure of Chinese companies was 7%. European car producing companies increased capital expenditures between 7% (Germany) and 1% (France). For Swedish firms a disinvestment of -10% can be observed.

Country	Capital expenditures 2015/16 (€million) Automobiles and Parts		Score
Austria	NA	NA	NA
Japan	56664,73	100,00 %	1
US	34632,89	61,12 %	2
Germany	27856,71	49,16 %	3
South Korea	15573,83	27,48 %	4
Italy	9093,99	16,05 %	5
China	7301,68	12,89 %	6
France	5883,38	10,38 %	7
India	4869,82	8,59%	8
UK	1098,55	1,94 %	9
Taiwan	398,69	0,70 %	10
Turkey	349,84	0,62 %	11
Canada	128,82	0,23 %	12
Switzerland	110,27	0,19%	13
Sweden	10,99	0,02 %	14
Europe (limited to the countries depicted at this table)	43943,62		2

Table 5: Ranking of capital expenditures (2015/2016) of firms operating in the sector automobiles and parts. Source: Datasource (EU 2016), own calculation and depiction by VDI/VDE-IT

Country	Capex 3 years growth (CAGR-3y, %) Automobiles and Parts	Benchmark	Score
Austria	КА	КА	
South Korea	27,39	100 %	1
Turkey	27,36	99 %	2
Switzerland	17,62	64 %	3
India	12,48	46 %	4
Canada	10,70	39 %	5
US	9,85	36 %	6
Japan	8,07	29 %	7
China	7,44	27 %	8
Germany	7,19	26 %	9
Italy	5,02	18%	10
UK	3,02	11 %	11
France	0,75	3 %	12
Taiwan	-5,77	-21 %	13
Sweden	-9,44	-34 %	14
Europe (limited to the coun- tries depicted at this table)	1,31	-	10

Table 6: Ranking of capital expenditures 3 years growth of firms operating in the sector automobiles and parts. Source: Datasource (EU 2016), own calculation and depiction by VDI/VDE-IT

Country	Profits 2015/16 (€million) Automobiles and Parts	Benchmark	Score
Austria	NA	NA	NA
Japan	55966,40	100,00 %	1
Germany	33778,47	60,35 %	2
US	21860,74	39,06 %	3
South Korea	10637,19	19,01 %	4
France	7754,87	13,86 %	5
China	6431,77	11,49 %	6
Italy	4065,01	7,26 %	7
India	4052,05	7,24%	8
UK	2081,67	3,72 %	9
Taiwan	810,49	1,45 %	10
Turkey	599,28	1,07 %	11
Canada	137,78	0,25 %	12
Switzerland	117,12	0,21%	13
Sweden	87,71	0,16%	14
Europe (limited to the countries depicted at this table)	47767,72		2

Table 7: Ranking of profits 2015/2016 of firms operating in the sector automobiles and parts. Source: Datasource (EU 2016), own calculation and depiction by VDI/VDE-IT

1.3.3 Profits

The closer look on profits as a further indicator on financial excellence shows again the strength of the Japanese car industry (1st rank). Germany's and US car manufacturers rank second and third. The relative share of the total profits generated by German car producers is 40% below the revealed profits of Japanese car manufacturers.

Table 8 shows that Japan was able to increase its profits by almost 24 % over the past three years. The range for the increase in profits for European car producers lays between 15,5 % (in France) and -3 % in Italy. German car producers were able to increase profits by almost 8 % within the past three years.

Country	Profits 3 years growth (CAGR-3y, %) Automobiles and Parts	Benchmark	Score
Japan	23,69	100 %	1
Switzerland	17,89	76 %	2
India	17,80	75 %	3
France	15,51	65 %	4
Sweden	15,36	65 %	5
China	13,83	58 %	6
Turkey	13,06	55 %	7
US	11,45	48 %	8
UK	11,04	47 %	9
Germany	7,69	32 %	10
Taiwan	5,11	22 %	11
South Korea	2,10	9 %	12
Italy	-2,00	-8 %	13
Canada	-3,01	-13 %	14
Austria			
Europe (limited to the countries depicted at this table)	9,5214514		10

Table 8: Ranking of profits 3 years growth of firms operating in the sector automobiles and parts Source: Datasource (EU 2016), own calculation and depiction by VDI/VDE-IT

1.3.4 Summary of the main findings

The following spider charts summarize the main findings of this subsection on financial excellence. Figure 8 summarizes total capital expenditure, total R&D spendings and total profits for the currently most successful car-producing firms (listed under the top 2.500) and the location of their headquarters in Europe, Japan, and the US. The financial excellence of Chinese firms has further been implemented into the analysis, as will have by far the biggest car market in the future.

The benchmark sets the outcome of each country/region into a relative relationship to the leading country/region (which then gets 100%). Figure 8 shows that European companies have a

strong financial excellence, compared to the main competitors, especially in direct comparison to the US and China. With respect to the indicators total sales and total R&D expenditures European car-makers are leading. European enterprises have a 40% higher R&D spending than Japanese companies does.

With respect to total capital expenditure, Japanese car manufacturers are in a leading position and about 20% ahead European car manufacturers. The scoring of total profits shows a similar picture, Japanese car manufacturers have a leading position. Their profits are about 18% higher than those of European counterparts. Figure 8 shows in addition to this, that the financial excellence of European and Japanese firms is outstanding and much higher compared to US competitors. Chinese companies are still playing a minor role, however, this might change in the future.

Figure 9 shows the ranking for those indicators on financial excellence which consider growth rates (3 year growth of capital expenditure, 3 year growth of R&E spending and 3 year growth of profits) and profitability (in percent). European companies are currently leading with respect to profitability, but with respect to 3 year growth of capital expenditures they are behind companies located with their headquaters in the US, Japan or China. European companies perform also rather weak in terms of growth of R&D expenditures and growth of capital expenditures. With this regard, Chinese have an overall good performance. This is not supprising as the starting level is much lower (compare Figure 8). However, the example of Japanese firms demonstrates that the current strucutral change within the automotive sector allows to have high growth rates (as demonstrated by Figure 9) as well as high total shares in financial excellence (Figure 8).

In summary this final assessment of indicators on financial excellence of the leading car manufacturers around the world shows that Europe's industry is currently in a leading position with respect to financial excellence. The assessment of the 3 year growth rates shows that European companies were able to defend their leading position in the past.

Japanese companies can be perceived as European companies' main competitors. The strength of Japanese companies in financial excellence is demonstrated by the fact that high growth rates are achieved even though the overall performance is already quite high. The current expansion of the capital base by Japanese car manufacturers seems to point into the direction that Japanese companies are currently more confident about future sales potentials than this is the case for European companies. The overall assessment shows that the Japanese auto-



Figure 8: Spider chart on main indicators representing financial excellence (total R&D, total capital expenditures and total profits), for Europe, Japan, US and China. Source: Datasource (EU 2016), own calculation and depiction by VDI/VDE-IT

motive industry seems currently in a better position than European car makers to be successful in fostering structural change towards new mobility concepts. European car producers are mainly focused on R&D investments, without increasing overall capital expenditures. This also shows up in the 3 years growth rate on capital expenditures which is on a rather low scale. These result point into the direction that car-producing companies in Europe are currently reluctant. One reason might be that they are still facing a lot of uncertainty about future market developments. This shows up in high capital expenditures and high shareholder profits (high profitability).

This brings us to the conclusion that the current comparative advantages in car manufacturing within Europe cannot be taken for granted. There are examples for car manufacturers which were not able to maintain competitiveness continuously. Some countries/regions like Sweden have lost competitive advantages during the last decades. The persistence of such trends is demonstrated by the fact that Sweden shows currently a disinvestment in capital expenditures by -10 % (Figure 9).

The analyses further shows the very strong position of German car producers. At the firm level, Volkswagen can be seen as a German/European giant with systemic characteristics for Germany's car industry. The dataset analyzed shows a strong performance with regard to financial excellence by Volkswagen. However, the so called 'Diesel-Gate' and Volkswagen's rather conservative business strategy, especially with a focus on future technologies (with regard to electro-mobility they seem to be far behind competitors), might impose future risks on Germany's economy.

Further uncertainties come along with the Brexit, as GB companies are currently, together with France, Europe's second biggest car producers. This brings us to the conclusion that it will be a feasible but challenging mission for European car producers to maintain the current financial excellence in the future.



Figure 9: Spider chart on main indicators representing changes in financial excellence (R&D, capital expenditures and profits) and profitability, for Europe, Japan, US and China. Source: Datasource (EU 2016), own calculation and depiction by VDI/VDE-IT

1.4 Value Added

Within this Focus Area, a closer look is taken at the specialization of countries on the automotive industries. This is done by indicators taking into consideration the number of big firms specialized in the automotive sector, total employment and value added.

1.4.1 Relative weight of the car manufacturing industry

A first hint on the economic importance of the car industry within the different countries we take a closer look on the total number of enterprises listed in the top 2.500 list (Table 9). Japan is leading, with 42 car producing companies, followed by China and the US. Germany ranks fourth (with in total 16 car producing companies that belong to the list of the 2.500 biggest enterprises).

Country	Number of enterprises under the top 2.500 in Automobiles and Parts	Benchmark	Score
Japan	42	100,00 %	1
China	31	73,81 %	2
US	23	54,76 %	3
Germany	16	38,10%	4
South Korea	11	26,19%	5
India	6	14,29 %	6
UK	6	14,29%	7
France	5	11,90 %	8
Italy	5	11,90 %	9
Taiwan	4	9,52 %	10
Austria	2	4,76%	11
Turkey	2	4,76%	12
Canada	1	2,38%	13
Sweden	1	2,38%	14
Switzerland	1	2,38%	15
Europe (limited to the countries depicted at this table)	33		2

Table 9: Ranking of the total number of firms operating in the sector automobiles and parts Source: Datasource (EU 2016), own calculation and depiction by VDI/VDE-IT

Table 10 shows the relationship between the total number of enterprises and the enterprises within the car industry (both indicators are taken from the top 2.500 list). This indication gives a first hint about the relative importance of the car industry for the overall economy within particular countries.

In China, the relative share of the car producing companies is 10%. In the US the relative share is 3%, indicating that there are only a few big car-manufacturers within the US, relative to the big US companies operating in other sectors.

However, this analysis is incomplete as the size and added value is unknown and cannot be connected to the countries. For instance, it might occur that a company is located in the US generates most of its value added within Mexico. This analysis does further abstract from the importance of small and medium enterprises (SMEs), which account for the majority of the companies (e. g. in Germany its share is above >90 % of all companies). For those reasons further indicators have to be taken into consideration, to get a more complete picture on value added.

Country	Total No. of Enter- prises under the top 2.500 in Automobiles and Parts	Total No. of Enterpris- es in Automobiles and Parts under the top 2.500	Share	Benchmark	Score
Turkey	6	2	33,33 %	100,00 %	1
India	25	6	24,00 %	72,00 %	2
Italy	29	5	17,24%	51,72 %	3
South Korea	75	11	14,67 %	44,00 %	4
Austria	15	2	13,33 %	40,00 %	5
Germany	132	16	12,12 %	36,36 %	6
Japan	356	42	11,80 %	35,39%	7
China	327	31	9,48 %	28,44 %	8
France	83	5	6,02 %	18,07 %	9
UK	133	6	4,51%	13,53 %	10
Taiwan	111	4	3,60 %	10,81 %	11
Canada	32	1	3,13%	9,38%	12
US	837	23	2,75%	8,24 %	13
Sweden	40	1	2,50 %	7,50 %	14
Switzerland	58	1	1,72 %	5,17 %	15
Europe (limited to the countries depicted at this table)	432	35	8,1 %		9

Table 10: Ranking of the relative share of firms operating in the sector automobiles and parts. Source: Datasource (EU 2016), own calculation and depiction by VDI/VDE-IT

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1.4.2 Total employment

The picture on value added gets more complete by taking total employment into consideration (Figure 10). Within Europe, 12.6 million people or 5.7 % of the EU employed population, work in the automotive sector. Automotive manufacturing alone accounts for more than 3.3 million employees and in total, the automotive sector represents 10.9 % of EU's manufacturing employment.



Figure 10: EU's total emplyment at different industries. Source: (ACEA 2017a)

Figure 11 allows a more detailed view on the different job segments related to the automotive sector in Europe. Especially service, transport and construction are of high relevance, as they account for about two thirds of the jobs within automotive. But also direct manufacturing is of high importance, as this is one of the key elements for a dynamic innovation system.

Automotive sector: direct and indirect employment in the EU

in thousands / 2012

		ufacturing	SC	DIRECT MANUFACTURING	2,296					
			loį	Motor vehicles	1,042					
	ect		E S	Bodies (coachwork), trailers and semi-trailers	155					
	dir		2	Parts and accessories	1,100					
	sdc	3.1 m jobs man								
	ع		×	INDIRECT MANUFACTURING	830					
				Rubber tyres and tubes, retreading and rebuilding of rubber tyres	115					
	~		jot	Computers and peripheral equipment	71					
			E 8	Electric motors, generators and transformers	232					
	_	_	0.8	Bearings, gears, gearing and driving elements	196					
				Cooling and ventilation equipment	214					
12.1 m jobs										
		9.0 m jobs non-manufacturing		AUTOMOBILE USE	4,300					
			S	Sale of motor vehicles	1,485					
			jo	Maintenance and repair of motor vehicles	1,493					
	ect		E B	Sale of motor vehicle parts and accessories	704					
	dir		4	Retail sale of automotive fuel in specialised stores	758					
	s in			Renting and leasing of motor vehicles	159					
	doį		-uo	-uo	-uo	-uo	-uo			
	9.8 m		C	TRANSPORT	4,067					
			 Sdo	Other passenger land transport	1,638					
			N	Freight transport by road	2,429					
			0.5 m jobs	CONSTRUCCION	625					
				Roads and motorways	565					
				Bridges and tunnels	61					
					01					

2014	Employees in 1.000 Automobiles and Parts	Benchmark	Score
China*	4249	100,00 %	1
European Union	2095,338	49,31%	2
United States	1279	30,10 %	3
Japan	1069	25,16%	4

Table 11: Ranking of the employment of firms operating in the sector automobiles and parts. Source: Datasource (EU 2016), own calculation and depiction by VDI/VDE-IT

	Employees in 1.000 Automobiles and Parts	Benchmark	Score
Germany	851	1	1
Poland	251,7	0,295769683	2
Czech Republic	175,497	0,206224442	3
Italy	164,8	0,193654524	4
United Kingdom	148,016	0,173931845	5
Spain	140,4	0,164982374	6
France	121	0,142185664	7
Slovak Republic	67,805	0,079676851	8
Sweden	63	0,074030552	9
Austria	31,87	0,037450059	10
Portugal	31,59	0,037121034	11
Belgium	31,4	0,036897767	12
Netherlands	20	0,023501763	13
Slovenia	14,4	0,016921269	14
Finland	6,9	0,008108108	15
Denmark	3,599	0,004229142	16
Norway	3,4	0,0039953	17
Estonia	2,6	0,003055229	18
Greece	1,897	0,002229142	19
Latvia	1,74	0,002044653	20
Total	2132,614		

Table 12: Manufacturing employment in the car industry. Source: Datasource (OECD 2017c), own calculation and depiction by VDI/VDE-IT

The data shown in Figure 10 and Table 11 is limited, as it shows employment from a company perspective. It is therefore convenient to tave a closer look at the total employment in car-manufacturing from a country perspective in order to assess value added. Table 12 shows the relative importance of the car industry within the different European countries with a focus on employment shares. Again, the focus on employment shows how Germany's well-being is dependent on manufacturing within the carsector. Total employment rate is 70 % higher than in Poland, the country with the second highest employment in car-manufacturing within Europe. According to the OECD-statistics Poland, Czech Republic, Italy, UK and Spain together have in total 878.000 employees within the automotive sector – this is comparable to the overall employment in Germany alone.

These numbers demonstrate the high risk that comes along with this major specialization of the German industry within the automotive sector. If German car manufacturers fail to be successful in coping with new developments within the car industry, this might have an impact on other European countries as well, as value chains between European countries are closely connected. Automotive production within Spain, the Slovak Republic, Austria, Slovenia and other European countries is mainly done for OEMs located in Germany (or France) (e.g. the brands Skoda and Seat which are owned by VW, Dacia is a brand owned by Renault and so on).

1.4.3 Value added

For a detailed analysis of value added we use its indication, based on the STAN-Database of the OECD. This indicator represents the gross income from operating activities, after adjusting for operating subsidies and indirect taxes. Value added is calculated from turnover, plus capitalised production, plus other operating income, plus or minus the changes in stocks, minus the purchases of goods and services, minus other taxes on products which are linked to turnover but not deductible, minus the duties and taxes linked to production (OECD 2001).

The indication of value added (Figure 12) shows that from an international perspective Europe has the highest share of value added within the automotive sector, which is close to 200 billion Euros. The US were able to create 120 billion Euro value added with car production and the value added by Japanese car-manufacturers is according to the statistics 105 billion Euro.



Figure 12: Value added by the car industry (US; Japan, China and Europe) in 2011 and 2014. Source: Datasource (OECD 2017b), own calculation and depiction by VDI/VDE-IT

In line with previous indications, Figure 13 shows that the German value added within the automotive sector is outstanding. In 2014, it reached a share of 115 billion Euros. The value added by the automotive industry in the UK (14,8 billion), Italy (10,6 billion) and France (9,7 billion) is much lower. Remarkable is the share of value added achieved by China, which is reported to have summed up to 102 billion Euro in 2011.



Figure 13: Value added by the car industry within different European countries in 2011 and 2014. Source: Datasource (OECD 2017b), own calculation and depiction by VDI/VDE-IT

Figure 14 illustrates the development of value added over time. It can be seen that the financial crisis has left a gap in most countries with regard to value added in the automotive sector and since then, a growth in value added can be observed. China was able to increase its value added remarkably over the last decade. It was gained relative international competitiveness also due to the fact that its economy was not affected by the financial crises. For this reason a linear trend can be observed for the rise of the Chinese car manufacturing industry.



Figure 14: Development of value added in the car industry over time. Source: Datasource (OECD 2017b), own calculation and depiction by VDI/VDE-IT

1.4.4 Summary of the main findings

The main findings of this subsection on value added are summarized by Figure 15. With respect to the European economy Figure 16 demonstrates the dependence of European countries on the automotive sector. The value added is 40 % above it share within the US (2nd rank). The importance and relevance of Europeans car industry also shows up in the number of enterprises in the top 2.500 list: Europe has the second highest share of big companies specialized on automotive and parts. With respect to total employment China has a higher share, however, the country's population (with its 1,3 billion inhabitants) is about 2.6 times as big as Europe's with about 0.5 billion inhabitants. All indicators point into the direction that the automotive sector is of high relevance for Europe, and for some countries like Germany it seems to be systemic. This leads us to conclude that Europa has a comparative advantage in terms of value added. The systemic role of the car sector for the German economy bears high risks for the European Economy. Volkswagen, as Germany's biggest car producer (which is highly engaged in other European countries as well), has major responsibilities for the current 'Diesel-Gate'. The future success of European and especially Germany's car manufacturers in these changing environments is of high relevance for future value added within European industries.

1.4.5 Focus Area Supporting Infrastructure

Supporting infrastructure comprises geographic indicators, economic-geographic indicators such as the strength of the national innovation system, or regulatory aspects.



Figure 15: Spider chart on main indicators representing value added (number of enterprises, value added, employees in automobiles and parts) for Europe, Japan, US and China. Source: Datasource (OECD 2017b), own calculation and depiction by VDI/VDE-IT

1.5 Supporting Infrastructure

This section on supporting infrastructure is mainly assessed by taking a closer look at the results related to the global innovation index. In addition, the indication is interpreted based on an expert survey assessing the future strength of the car-related innovation system.

1.5.1 Global Innovation Index

The Global Innovation Index (GII) is published by Cornell University, INSEAD, and the World Intellectual Property Organization (WIPO, an agency of the United Nations). Its aim is to capture multi-dimensional facets of innovation. The GII stands on two main pillars – the Innovation Input Sub-Index and the Innovation Output Sub-Index. Both pillars build on further indices. There are five input pillars capturing elements of the national economy that are related to innovation: (1) Institutions, (2) Human capital and research, (3) Infrastructure, (4) Market sophistication, and (5) Business sophistication. The innovation output dimension is captured by two pillars: (6) Knowledge and technology outputs and (7) Creative outputs. These pillars divide further into sub-pillars which are further composed of individual indicators. The GII 2017 is compiled out of 81. The scores for each pillar and sub-pillars are calculated as weighted averages. For a more detailed description please have a look at the Global Innovation Index 2017 (GII 2017).



Figure 16: Methodology of the Global Innovation Index (GII). Source: (GII 2017)

1.5.2 Innovation Ranking and Input/Output Relations

Based on the methodology presented in Figure 17, four measures are used for the further analysis:

- Innovation Input Sub-Index: average of the first five pillar scores
- Innovation Output Sub-Index: average of the last two pillar scores
- The overall GII score: average of the Input and Output Sub-Indices
- The Innovation Efficiency Ratio: Ratio of the Output Sub-Index over the Input Sub-Index

The overall GII score is then simply calculated as the average of the Input and Output Sub-Index scores. The Innovation Input Sub-Index consists of five input pillars that capture elements of the national economy that enable innovative activities: (1) Institutions, (2) Human capital and research, (3) Infrastructure, (4) Market sophistication, and (5) Business sophistication.

The Innovation Output Sub-Index gives a picture on the innovative activities within the economy. Two output pillars can are separated: (6) Knowledge and technology outputs and (7) Creative outputs.



Figure 17: Spider chart on the main outcomes with respect to the global innovation index for Europe, Japan, US and China. Source: Datasource (GII 2017), own calculation and depiction by VDI/VDE-IT
The measure Innovation Efficiency Ratio is the Output Sub-Index score divided by the Input Sub-Index score. It can be seen as an indicator for the efficiency demonstrating how much innovation output countries get for their inputs.

As Figure 17 shows, the European countries listed within the GII perform relatively good, with respect to innovation input and innovation output. This shows up in a high innovation efficiency ratio (innovation output divided by innovation input). The overall performance of Europe within the GII is good and comparable to the performance of China and Japan, however, the overall performance of the US is better.

Figure 18 depicts the European countries listed in the GII, showing their individual performance. It can be seen that the 'new' member states of the European Union have still some potential to increase their innovation performance. Countries of the former EU-15 (like Belgium, Denmark, Finland, France, Germany, Netherlands, UK ...) show a relative good performance. Increasing the innovation capacity within new European member states will help Europe to close the gap to leading countries like the US, (compare Figure 17).



Figure 18: Spider chart on the main outcomes with respect to the global innovation index for different European countries. Source: Datasource (GII 2017), own calculation and depiction by VDI/VDE-IT

1.5.3 Analysis of central innovation factors

Figure 19 shows the different innovation input and output pillars of the GII. Europe shows a relatively good performance with a focus on institutions, human capital, research and infrastructure and creative outputs. However, with respect to major outputs like market sophistication, business sophistication as well as knowledge and technology outputs, the overall European performance is rather weak and could be improved.



Figure 19: Spider chart on the main outcomes with respect to the sub-indices of the global innovation index for Europe, Japan, US and China. Source: Datasource (GII 2017), own calculation and depiction by VDI/VDE-IT

The country-specific view (Figure 20) in line with the previous analysis shows important differences between European countries: Again, major improvements are needed within the 'new' European member states. However, Italy can be seen as an example for the fact that a relatively weak innovation performance can also affect 'old' European member countries.



Figure 20: Spider chart on the sub-indices of the global innovation index for different European countries. sSource: Datasource (GII 2017), own calculation and depiction by VDI/VDE-IT

1.5.4 Knowledge and Technology Transfer

Crucial for assessing the supporting infrastructure are innovation linkages between different actors of the innovation system (Figure 21). A relatively good performance of the European industry can be observed for R&D financed by abroad, which indicates the attractiveness of the European innovation system also for non-European countries. With respect to university/ industry research collaboration and state cluster development, Europe has potential to improve its performance compared to countries like the US, Japan or China. However, Europe is not left behind and keeps the connection to the leading countries. Relatively weak is Europe's performance with respect to patent families filed in at least two offices. One reason might be that many patents are only filed in at the European Patent Office (EPO) and not abroad. With respect to the indicator 'Joint venture/strategic alliance deals' Europe is behind the US but ahead of Japan and China. Especially with regard to new technology challenges in the automotive industry, strategic alliances might become more important in the future.



Figure 21: Spider chart on the main outcomes with respect to the sub-indices on knowledge and technology transfer of the global innovation index for Europe, Japan, US and China. Source: Datasource (GII 2017), own calculation and depiction by VDI/VDE-IT

Figure 22 shows the heterogeneity between the European countries regarding innovation leakages. It can be seen that GERD financed from abroad is typically an area in which 'new' European member states (like Slovakia or Czech Republic) perform relatively good, whereas France, Germany, Italy or Spain receive relatively low R&D revenues from abroad. Italy is quite strong in cluster development, which is also true for the UK, Germany and the Netherlands. With regard to University/industry research collaboration, Finland gets the highest rank, but other countries like Germany, Ireland, Netherlands, Sweden or the UK show also a relatively good performance. The indicator ,patent families filed in at least two offices' meaning that patents are filed in at least two patent offices is very heterogeneous among the different countries. In this regard the Scandinavian countries Denmark, Finland and Sweden show good performances. But also Germany and the Netherlands file more patents in at least two offices. Italy and France have a relatively low performance in this regard. But also 'new' EU member states like Romania, Slovakia, Slovenia, Croatia or Czech Republic have very few patents that are filed in at least two patent offices.



Figure 22: Spider chart on the sub-indices on knowledge and technology transfer of the global innovation index for different European countries. Source: Datasource (GII 2017), own calculation and depiction by VDI/VDE-IT





Figure 23: Competitiveness of national innovations systems. Source: (E&Y 2013, p. 19)

As the previous figures demonstrate, the European innovation system is well established. Its impact can also be traced back to the automotive industry. On the very forefront as innovation hub in the automotive sector is Germany with the highest competitive environment (44 %), ranked first place. Other European countries in the top 20 include Sweden (rank 8), followed by France (9), the Czech Republic (11) as well as UK (12), Italy (13) and Spain (18).

Besides these Western European Countries also central European states such as Slovakia, Poland and Hungary achieve a strong position as innovative automotive hubs with a fairly competitive environment. On an international level strong innovation hubs can be found in Japan (rank 2), South Korea (3) and USA (5). The BRIC states are likewise important players when it comes to innovative automotive projects: China holds rank 4 (18 % assigning very competitive innovation hub), Brazil on 6th place and India on 7th (both 10 % very competitive).

1.5.5 Summary of the main findings

The European innovation system is strong. Differences can be observed for 'old' European countries and 'new' European countries. If Europe is able to improve the innovation systems of new member states the overall innovativeness of Europe will rise. The relative strength of the European innovation system is an important indication for the good preconditions of Europe to cope with the described market dynamics within the automotive sector. However, the related technology shifts remain challenging, as established car manufacturers have to integrate these disruptive changes into their own business models. This requires a cultural shift in well-established and (so far) well-functioning business models of European car producers.

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Part B: Automotive industry – disruption ahead?

by Konstantin Konrad, Sebastian Stagl, Beate Müller

'An exciting new era of change is sweeping the global automotive industry. In fact, I believe the industry will experience more change in the next 5 years than it has in the last 50 years.... It is impossible to overstate the magnitude of change I'm talking about....But the competition in this industry is fierce and getting stronger every day. In fact, this is one of the rare times in the history of the industry when virtually every auto company is profitable. As you would expect, confidence is running high among all of our competitors.' (General Motors CEO Mary Barra, 2015) [1].

The European car industry is witnessing a turning point in its history. The decline of its traditional market and the growing pressure of local producers create an immense stress on the European OEMs and their suppliers. As with the EU maritime industry, a shift towards the premium segment, cutting-edge technologies, technical and non-technical innovations are often envisioned as the next stage for the EU car producers. At present the industry is facing an extremely dynamic and potentially disruptive era. Enabled by sophisticated IT technologies, completely new business models come into reach and will sustainably reshape the value chain as we know it. Recent developments indicate an end of the traditional car ownership concept and the introduction of a new area of mobility service providers (Strategic Analytics, 2017). This rapid and vital development is mainly driven by digitalization, shared mobility concepts and automation resulting for the automotive industry in the evolution of Advanced Driver Assistance Systems (ADAS) towards the introduction of self-driving technologies and completely autonomous cars and trucks. The estimation of the digital market potential varies between different studies but the common ground is that the digital area offers new business possibilities and will enlarge the traditional automotive market substantially. Intel for example estimates a \$7 trillion passenger economy [2], McKinsey expects up to \$1.5 trillion - or 30 percent more - in additional revenue potential in 2030 [3]. These long-term perspectives already have strong effects on the present strategies and industry roadmaps. While earning good money with reasonable margins at present, the traditional car manufacturers have to concentrate on a variety of new and emerging technologies in parallel. OEMs have to work in various technology fields (new propulsion technologies, digitalization, mobility services, artificial intelligence, lithium-ion battery production and many more) simultaneously. All these technology fields are more or less new to car manufacturers and impose tremendous challenges on them. These developments will substantially change the whole value chain, force OEMs and suppliers to form new partnerships and open the market for new rivals. The competitive advantage of the European Automotive Manufacturing industry is at stake like it was never before. Nevertheless, Europe picked up the challenge, and is in a good position to defend it and also benefit from upcoming business opportunities.

1.1 Future demand requirements and technological trends

From a technology perspective the future analysis concentrates mainly on two crucial fields for the car industry: Electric Vehicles (EV) and Connected and Automated Driving (CAD). The necessity to focus on these future technologies becomes evident when taking a closer look at some of the aspects of technical leadership and the entry and resources of new rivals:

- Strict future orientation: For a moment Tesla became the 4th most valuable car company in the world despite producing solely fully electric vehicles in comparably low production quantities. Nevertheless, Tesla's stock valuation surged and surpassed traditional car manufacturers like BMW, General Motors and Ford. The clear focus on disruptive technologies like CAD (Teslas's Autopilot became a brand name over time and caused somewhat of a customer hype but also a lot of discussion and confusion) in combination with pure battery electric vehicles and a visionary marketing concept seems to pay off at the end [4].
- New competitors with large capital resources at the consumer interface: When looking at the digital automotive market and the strategy of large high-tech enterprises like Google or Apple, the necessity for change becomes evident again. Apple CEO Cook recently elaborated Apple's strategy to enter the automotive market for the first time in more detail. He clearly anticipates major disruptions and focusses on the company's activities for developments in the areas of self-driving technologies, electric vehicles and ride-hailing services [5]. The company is investing incomparable amounts in these future technologies. For example they announced an invest of 1 billion Dollars in the Chinese ride-hailing company Didi Chuxing [6]. Google on the other hand created its own brand Waymo focussing on self-driving technologies with large invests and plans to enter the automotive market as well. The 'Google Car' became famous as it was among the first cars on the road without steering wheel [7]. At present, both companies seem to target supplying technologies for automotive rather than producing cars by themselves. Although having global

activities in China, the U.S. tech giants face tough competition. There are a lot of Chinese counterparts like Baiduu, Didi and Tencent who also compete in the race for the self-driving technology [8].

- Expectations for disruptive changes: The Federal Chancellor of Germany Angela Merkel mentioned to the weekly journal 'Der Spiegel' at a meeting at the European Council that 'everybody is aware that the car industry will not survive in its present form' [9]. As Germany is the leading European country for car manufacturing for the time being, this message can be interpreted as a very strong hint for the necessity to react on expected changes and adjust the industry segment to future and emerging technologies. Besides politicians and industry experts [1] several consultancy agencies have a more or less comparable opinion and proclaim their own vision and scenarios of the futuristic automotive value chain which differ fundamentally from the present structures [10, 11].
- Key technological trends identified by industry stakeholders: Traditional car manufacturers are well aware of those disruptive technologies and their strategic importance for their future prospects. In KPMG's 18th consecutive Global Automotive Executive Survey 2017 [12] almost 1.000 senior executives from the world's leading automotive companies and 2.400 customers were interviewed. The analysis is split between the upstream (product-driven) and the downstream (service-driven) market and has a strong focus on ICT companies. Results indicate the vital importance of battery electric vehicles and CAD for the future.
- ▶ Focus on electric mobility (industry): Last but not least, several car manufacturers recently announced the introduction of several electric vehicles. This includes Volkswagen (which plans to build 2 to 3 million all electric vehicles by 2025), [13] Porsche (which plans to have approx. 50 % of its production to be electrified in 2023) [14], Daimler (which recently announced to intensify their already ambitious electrification plans) [15], Volvo (this car manufacturer plans to have every manufactured vehicle electrified by 2019, however this may be a joint strategy with the mother company Geely) [16] and others [17]. This can be interpreted as one of the mitigation activities by the automotive industry to set the public discussion about the emission scandals at ease. In 2015 it was revealed that Volkswagen had employed software in Diesel cars to reach the required emissions standards when in testing. The emissions under real driving conditions were however much higher. This caused massive problems for the sales of diesel powered cars and furthermore for the image of car producers as well. As a matter of fact a lot of car manufacturers were struggling to meet the strict emission standards for diesel cars and cheated during the official test procedures. In addition to the already convicted OEMs, there are simultaneous investigations against several others, where essential discrepancies between the official testing results and the measured emissions during utilization were detected. Involved car manufacturers are amongst others: Volkswagen, General Motors, Fiat Chrysler, Daimler, Ford, Volvo and Renault [18, 19, 20, 21].



Figure 24 – Key technological trends identified by KPMG's Global Automotive Executive Survey. Top trends are Battery electric vehicles and connectivity & digitalization identified by upstream players (product-driven – traditional OEMs and suppliers) and downstream (service-driven – ICT players or mobility service providers) (Source: KPMG)

Focus on electric mobility (politics)

But not only the industry itself reacted to the emission scandal, there is also a lot of dynamics in the political discussions regarding an end of combustion engines. France will end all sales of petrol and diesel powered cars by 2040 in order to meet its targets under the Paris climate accord. In Germany there are similar discussions, also targeting a different timeline up to 2030 [22, 23]. Norway has even more ambitious plans with a time horizon up to 2025, the Netherlands are targeting the same time limit for only zero-emission vehicles being allowed [24, 25] and recently the United Kingdom announced their commitment to banish combustion engines starting 2040 [26]. There is almost no doubt that there will be exceptions for combustion engines but the general approach points in a clear direction for the future and towards electrified powertrains. China announced the implementation of a sales quota for electrical powered vehicle. At present the policy is in a draft stage, but will influence Europe's competitiveness in the Chinese market massively. Recent negotiations between the German chancellor Merkel and the Chinese Premier Li Keqiang to postpone the quota for another year indicate the importance and the struggle for German (and European) car manufacturers to meet the formulated obligations. However, the latest draft published by the Ministry of Industry and Information Technology is still planning with the quotas coming into effect in the year 2018 [27]. Another major policy factor pushing electrification is the Paris Agreement for which 196 nations negotiated greenhouse gas emissions mitigation strategies [28].

Increased Safety aspects: Although European roads are the safest in the world, approximately 26.000 people died on European roads in the year 2015, and an estimated 135.00 people were seriously injured. The social costs for fatalities and injuries caused on the road sum up to over €100 billion [29]. Vision Zero (achieving zero fatalities and injuries on European roads) is one of the major goals for the European Commission. Technological breakthroughs and developments in ADAS have greatly improved vehicle safety over the past years. One of the major improvements is expected to be realized by the introduction of higher automation levels and functions (like autonomous emergency braking systems) and at its final stage the fully autonomous vehicle.

Regarding competitiveness aspects, Europe's capabilities will mainly be compared to the automotive industry in the United States and in China.

- The fundamental importance of China and the United States due to their tremendous market shares was already explained in detail in previous SCORE analyses. The United States are dominating the market with IT companies entering the automotive sector with incomparable data skills and enormous financial resources. Furthermore, the US are home to electric automotive pioneers like Tesla (which is targeting at the technical leadership of EV and CAD simultaneously), small spin-offs like Faraday Future or Atieva and several innovation labs of the most important OEMs and Tier1 suppliers [30]. Furthermore it has a tremendous market potential for the utilization of automated trucks.
- China is of special interest as it has by far the biggest market potential for EVs and strict regulatory structures by the government. The latest announcement of China's government to consider a fixed rate of EVs for the production of domestic cars has alarmed the European manufacturing industry [31]. Furthermore, in the area of CAD domestic IT-companies have comparable skills to the internationally dominating U.S. counterparts and are entering the market.

The subsequent analysis will mainly focus on developments within Europe, the US and China but might include additional regions accordingly, if a certain interest seems justifiable. In the following chapters, key technology trends and demand aspects with a time horizon up to 2030 are analyzed for the automotive value chain.

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2 Technology trends until 2030

In order to anticipate future dynamics of value chains in the European automotive manufacturing industries, key technological trends and innovative concepts are analysed and assessed in terms of their potential impact on existing structures.

Overall four research topics were identified and elaborated for the automotive industry in interactive workshops with industry experts and have been analysed by experts from VDI/VDE Innovation + Technology GmbH:

- Artificial Intelligence Is Europe's technology competitive when it comes to high-performance computing chips for artificial neural networks (ANNs)?
- Digitisation in terms of customer interface -New mobility patterns are reshaping the socioeconomic developments. Which drive technology will prevail in the future? Which is the role of digitalization to face new customer needs?
- Smart systems for automotive manufacturing In times of industry 4.0, intelligent and selfaware products enable mass-individualization. What requirements does flexible manufacturing need to fulfil in order to achieve the vision (advanced automation, zero default, individualization, etc.)?
- Fuel Cell Propulsion Technology -Fuel Cells seem to be one important path towards emission-free cars, especially if hydrogen is used as fuel. What is the current maturity of this technology and how is Europe's research and manufacturing capability in this area compared to its main rivals?

In the following chapter these topics are elaborated. At the project SCOREBOARD⁶, the full analysis for the other considered transport industries is available.

2.1 Chips for Artificial Intelligence for the Automotive Industry

by Edgar Krune

Artificial Intelligence (AI) is the key technology for self-driving cars. Al is able to process high amounts of data originating in various sensors attached to the car, to extract the relevant information and to steer a vehicle. The unforeseeable events and chaotic behaviour in traffic prevent any form of conventional programmable solutions. By means of deep learning algorithms, artificial neural networks (ANNs) are trained to sense the environment and to navigate a vehicle through traffic. Recent breakthroughs in such machine learning tasks turn self-driving cars into one of the most promising technological trends of the recent time. All major car manufacturers announced ambitious plans to bring self-driving cars on the streets within the next few years. Various prototypes have been presented by numerous protagonists. A key component for the introduction of autonomous driving is efficient hardware able to run the compute intensive algorithms. The compute intensive training is performed offline on supercomputers while real-time inference in the vehicle has to be performed on compute and power limited hardware. Today, the performance of available hardware solutions does not satisfy the requirements of machine learning algorithms. The resulting demand attracted the interest of IC manufacturers which put a lot of effort to design more efficient chip architectures for various AI applications. In automotive only few IC giants can compete in this race for better AI chips. In fact, Nvidia and Intel/MobilEye dominate this market today. So far, a software implementation of ANNs with execution on optimized system-on-chip (SoC) architectures with several accelerator cores is favoured. A hardware implementation of ANNs by means of neuromorphic chips promises much higher power efficiencies but until now most IC manufacturers show little interest in this technology.

All major OEMs and Tier1s start to cooperate closely with IC manufacturers which address their high hardware requirements. As a result, the IC giants gain a strong position in the automotive market and undermine the role of traditional Tier1s by offering more generalized automotive compute engines as well as corresponding software and virtual training environments. The alternative to such one-party solutions is an open platform which is favoured by OEMs and Tier1s. Both are possible in the future.

The innovation and life cycles of the IT industry is much shorter than those of the automotive industry. As a result, the hardware and software providers may become the motors for future innovations. A continuous improvement of sensors and AI algorithms will necessitate higher computing power and better hardware. It can lead to several hardware and software upgrades within one car life cycle improving the IC manufacturers' position in the value chain. Every update will increase the performance and the safety of self-driving cars. Efficient AI chips will become a unique selling point (USP) for autonomous vehicles and account for a higher user acceptance. The two current dominant chip providers are located in the USA. Currently, Nvidia uses the 12nm-FinFET while Intel/MobilEye plans to use the 7nm-FinFET semiconductor technology for their chips to achieve high power efficiency. The corresponding fabs able to manufacture in this technology are located in the USA and Asia. Therefore, Europe has a competitive disadvantage in the field of AI chips.

2.1.1 Description of the main concept

Al is the key technology for self-driving cars. Its enormous potential has been shown by numerous breakthroughs in the last years. The various sensors attached to the car produce high amounts of data that can easily accumulate to several TB per hour. Only AI is able to process such amounts of data in real-time, to extract the relevant information and to steer the vehicle. The unforeseeable events and chaotic behaviour in traffic prevent any form of conventional programmable solutions. By means of deep learning algorithms ANNs can be trained to solve tasks which are too complex to be solved analytically. Thanks to these capabilities, deep learning was called a breakthrough technology by the MIT Technology Review in 2013 [1]. An ANN learns to deal with the complexity by itself during a training process either by providing it with the correct answer for every input (supervised learning) or by providing it with a feedback at least once in a while (reinforcement learning). During training, every incorrect calculated output of the ANN is being punished while every correct given output is being rewarded. All connections between the artificial neurons adapt slightly by means of deep learning algorithms. Numerous iterations of such training steps continuously improve the ANN performance in taking decisions. When a certain defined percentage of correct given answers is achieved, the training is terminated and the ANN can be used for decision making - this is called inference. Using this technology enables cars to sense their environment thanks to various attached sensors such as cameras, radar, lidar and ultrasonic systems. A large amount of labelled data is necessary for the compute intensive training to enhance the reliability of object and drivable path detection. A more complex task for the AI is to learn a driving policy to navigate the car through the traffic. Today, OEMs have fleets of vehicles on the road collecting training data. Recently, virtual training environments have gained more interest since these enable faster accumulation of data as well as higher diversity of traffic scenes. The motivation is to achieve automated superhuman driving capabilities – which is widely seen as achievable. This is considered a requirement for the introduction of self-driving vehicles to be accepted by the users. The vast majority of car related companies are convinced to achieve this in the near future.

A very high data throughput is necessary to train an ANN. High-performance computing (HPC) is necessary to process the ,big data'. Therefore, supercomputer technology became essential for the progress in AI making companies the drivers of the AI technology with the corresponding know-how and infrastructure (supercomputers, datacentre). Moreover, inference requires high computing power. In addition, real-time capabilities are essential. Fortunately, strong hardware improvement is possible by means of optimization of the chip architecture to the arithmetic operations of the ANNs. One optimization strategy is to exploit the parallel structure of the calculations. In this case, the designers are speaking from an ,embarrassingly parallel' workload.

There are several hardware solutions which have been used to run AI applications. Central processing units (CPUs) are very flexible and are designed to execute numerous operations. But training an ANN on CPUs leads to very long computing time and to a very high power consumption since these are not optimized to the machine learning operations at all. Strong acceleration can be achieved by adaptation of the processor architecture to the computational operations. Arithmetic operations in ANNs correspond mainly to matrix multiplications. Graphics processing units (GPUs) are designed exactly for this task to process video data. Taking advantage of the corresponding parallelization accelerates the computing time significantly. Although a single operation of a GPU has a higher latency compared to CPUs, its much higher data throughput is crucial. Another hardware solution is based on field-programmable gate arrays (FPGAs) which consume low power and offer high flexibility. FPGAs enable designers to reprogram the underlying hardware architecture to support software changing in the best way and are the optimal hardware choice for small volume applications. Their disadvantage is the high programming complexity. Application-specific integrated circuits (ASICs) outperform FPGAs since they are specialized for a certain task. These multiprocessor SoCs incorporate GPUs, CPUs as well as accelerator cores optimized for certain operations like image

processing. The disadvantage is their inflexibility towards new operations and the very high development costs. Technically, a GPU is an ASIC optimized for processing graphics algorithms but is nowadays generalized for different computations.

So far, the mentioned of-the-shelf hardware is not optimized for machine learning algorithms. This implies a high demand for innovations thanks to the varieties of AI applications. The enormous potential impact in all industry segments led to a race for more efficient chips between IC vendors, tech giants, IP vendors and various start-ups [2]. It is remarkable that various start-ups (mainly in the US and China) try to compete with big IC giants in such a cost-intensive industry branch. Designing an ASIC can cost up to hundreds of millions of dollars requiring a large team of expensive engineers. The long design process (typically two or three years) needs a large number of chip sales and regular improvement is necessary to adapt to fast changing software development. Especially the early state of the AI technology can lead to significant changes in the hardware development in the upcoming years [3]. Only the enthusiastic conviction that the new chips tailored for AI applications can strongly outperform state-of-the-art hardware can justify such investments and the bravery to compete with heavily experienced IC giants.

When researchers started to use GPUs to accelerate training of ANNs, the corresponding market leader Nvidia used this opportunity and started to adapt its products for machine learning applications and gained a strong market position. Although the inference can also be performed by GPUs, the typical power consumption is way too high for real systems. Convinced by the future of AI, Google already produced its second ASIC generation called the 'tensor processing unit' (TPU) to run deep learning algorithms in its Google cloud servers [3]. There is no intention to make these ASICs available to others. According to Google the acceleration by TPUs saved the company from building 12 additional datacentres to handle the AI workload [3]. The second TPU generation can be used for training as well as for inference and delivers 45 trillion floating point operations per second (TFLOPS) for machine learning [4]. So far, Microsoft favours Altera FPGAs from Intel for its Azure cloud servers to be able to adapt the hardware immediately to newest trends of AI algorithms [3]. Moreover, Microsoft announced the development of a 'holographic processing unit' (HPU) for augmented/mixed reality applications [26]. ASICs have been designed for the inference in certain consumer products such as smartphones. Since AI-based image processing is now able to achieve human-level performance in recognition tasks, several companies introduced optimized chips in their products. Huawei introduced the 'Kirin 970 SoC' with a 'neural processing unit' (NPU) for smartphones. Intel presented its 'visual processing unit' (VPU) for similar inference applications. These optimized chips led to a significant increase of power efficiency and shifted the inference from cloud servers to edge devices such as smartphones. For example, the start-up Graphcore based in the UK claims that its 'intelligence processing unit' (IPU) accelerators are up to 100 times faster and more efficient than the today's fastest systems [2]. A complete list of all companies focused on optimized AI hardware is out of the scope of this study.

In automotive, there is still a lack of optimized hardware solutions for machine learning algorithms. Today, traditional OEMs, Tier1s and new market entrants like tech giants (e.g. Google, Apple, Baidu), emerging OEMs (e.g. Tesla, BAIC) or mobility service providers (e.g. Uber, Lyft) start to cooperate closely with IC manufacturers (e.g. Intel/MobilEye, Nvidia). Therefore, various hardware innovations are expected in the near future. Intel entered the automotive market by buying Israeli supplier MobilEye in 2017 which is very active in the research of advanced driver assisted systems (ADAS). MobilEye developed its fifth generation SoC 'EyeQ5' for fully autonomous driving which will be in series production by 2020 [5]. Its predecessor chips were manufactured by STMicroelectronics but the fabrication of the new generation will shift to TSMC [30]. The target for the fifth generation chip is to achieve 24 trillion operations per second (TOPS) under a power consumption of 10W. The most advanced 7nm-FinFET technology is considered for production to address the performance targets [5]. Intel will combine the EyeQ5 chip with its 'Intel Atom' processor and develop an automotive AI computing platform for autonomous driving [5]. Intel/MobilEye claims that two EyeQ5 chips and an Intel Atom processor will be sufficient to enable fully automated driving. Meanwhile, 27 car manufacturers adopted their current SoCs according to MobilEye. The automotive supplier ZF built the 'ZF ProAl' supercomputing self-driving system which is based on the 'Nvidia DRIVE PX 2 AI' computing platform. ZF claims to follow a modular and scalable system architecture that can be applied to any vehicle and tailored according to the application, the available hardware and the desired automation level. Audi is using this platform in the worldwide first level 3 vehicle where Al steers the car in jam traffic on an autobahn up to a speed limit of 60km/h. Baidu cooperates with ZF and announced to use the ;ZF ProAI; platform for automated parking [6]. Meanwhile, Nvidia designed its new SoC 'Xavier' which will offer up to 30TOPS under a power consumption of 30W [7]. The chip is fabricated by TSMC in 12nm-FinFET technology [7]. But true level 5 autonomous vehicles will need at least two of such chips to provide sufficient computing power. Therefore, Nvidia's new 'DRIVE Pegasus AI' computing platform will incorporate two 'Xavier' SoCs and two discrete GPUs [7]. It will enable 320TOPS and consume up to 500W [7]. According to Nvidia the computing power should be sufficient for fully autonomous driving [7,8,9]. Tesla is reportedly working in cooperation with AMD on its own AI chips which would replace currently used Nvidia hardware [10]. AMD has strong expertise in building CPUs as well as GPUs and would be another IC giant entering the automotive market. The European company NXP developed its 'BlueBox' autonomous driving platform. It incorporates e.g. the 'S32V234' automotive vision and sensor fusion processor capable of processing AI applications. It supports all major AI tasks for autonomous driving such as object detection and localization, classification and decision making (path and manoeuvre planning). Furthermore, it enables mapping, V2X communication as well as fusion of data streams from various sensors (e.g. lidar, radar, cameras and ultrasonic systems). The performance is stated as 90,000 Dhrystone million instructions per second (DMIPS) under a power consumption of 40W. The Japanese company Renesas has a similar automotive computing platform with their 'R-Car' SoCs which achieve 40,000 DMIPS. Currently, the telecommunication company Qualcomm intends to acquire NXP. Qualcomm has strong expertise of fast and efficient SoCs from the smartphone market. For example, its 'Snapdragon 845' SoC includes AI processing capabilities [11]. Combining their expertise, Qualcomm and NXP are able to rival the current market dominance of Intel/MobilEye and Nvidia.

In the automotive sector, low power chips for AI-based image processing have been shown e.g. by DreamChip in course of the European 'THING2DO' project. But more general solutions are necessary due to the demand for higher computing power, lower power consumption and cost reduction. More sensors will be attached to the car in the future. The performance of object detection was increased under the frame of the ImageNet contest during the last years by means of higher model complexity. This tendency implies higher amount of parameters of the ANNs. Safety is the crucial issue for the breakthrough of self-driving cars. Therefore, more complex models will be presented to increase the robustness of object detection and decision-making by AI. It is a common sense that the number of accidents for autonomous vehicles has to be decreased by one or two orders of magnitude compared to human drivers [12]. Worse performance would not be tolerated by users and could prevent autonomous vehicles to be established in the market. Therefore, companies involved in the autonomous driving market will constantly improve their AI algorithms to outperform competitors. Higher safety or better AI capabilities will be a USP for autonomous cars. This corresponds directly to more complex AI algorithms, more computing power and a growing demand for better hardware. In automotive the new SoCs tailored for machine learning algorithms tend to be more complex since high data throughput is necessary and moving data between different chips deteriorates the performance. Moore's law assures continuous increase of the number of integrated transistors on chip. Therefore, the size of future optimized SoCs will scale up. For example, Nvidia's new 'Xavier' SoC is one of the most complex systems to date with more than 9 billion transistors. It should be noted that it took a team of more than 2000 engineers over a four-year period and an investment of \$2 billion in research and development to build this device [9]. It is questionable how many IC developers can keep up with this. Such investments will lead to high chip costs if these cannot be applied to other market segments taking into account that the number of sold cars worldwide (ca. 80 million/year [13]) is quite small compared to consumer products (e.g. smart phones: ca. 1500 million/year [14]). An overlap seems to be in the datacentre market [10]. The European Commission announced the intention to spend €1 billion for an ambitious initiative to build supercomputers in the EU to close its gap to the US, China and Japan in that segment [15]. Here, the development of a European low power microprocessor was announced based on European technology. The strong know-how in the field of HPC can be applied directly into the design of optimized AI chips. In fact, the European processor initiative proposes to create a long-term economic model by delivering a family of processors for the 3 market segments ,high performance computing', ,datacentres and servers' and ,autonomous vehicles' [27]. But for the time being it is too early to anticipate the long-term impact of this initiative.

The aforementioned chip designs correspond to a software implementation of ANNs and its execution on conventional von Neumann chip architectures. An alternative way is to implement ANNs directly in hardware by means of neuromorphic chips. This approach is investigated by academia and is widely ignored by the industry although it was called a breakthrough technology by the MIT Technology Review in 2014 [16] and the World Economic Forum in 2015 [17]. IBM was the first company to investigate neuromorphic computing and presented its ,True-North' chip in 2011 before the actual breakthrough of deep

learning and the resurgence of convolutional neural networks (CNNs) in 2012. In 2016, it was shown that a trained ANN can be mapped to such a neuromorphic chip and approach stateof-the-art classification accuracy [18]. The huge advantage was the very low power consumption of only 275mW while processing 2600 frames/s. Currently, Intel is working on its own neuromorphic chip 'Loihi' [19]. Here, the signal processing is based on asynchronous spiking similar to the biological neurons in the brain. This chip combines training and inference, supports different ANN topologies including recurrent neural networks (RNN), can be used for supervised as well as for reinforcement learning and is continuously learning [20]. Intel calls it a test chip and is going to share it with universities and research institutions. Samsung announced collaboration with leading Korean universities to develop a neuromorphic chip [28]. This technology is very young and a lot of research has to be done to explore its full potential and to verify its capabilities. The claims about its potential performance are orders of magnitude of higher power efficiency and orders of magnitude of faster learning capabilities [20]. If these promises are only half true, neuromorphic chips should attract high interest of the industry in the near future. Neuromorphic chips are ideal for classification tasks but not for precise calculations like conventional processors. Therefore, these have to be embedded in conventional hardware which deals with rule-based navigation in the traffic. In Europe, neuromorphic computing is currently investigated under the frame of the Human Brain Project since 2013. Here, two approaches are investigated. The BrainScaleS system approach is based on physical (analogue or mixed-signal) emulations of neuron, synapse and plasticity models with digital connectivity, running up to ten thousand times faster than real time [21]. The SpiNNaker (spiking neural network architecture) system is based on numerical models running in real time on custom digital multicore chips using the ARM architecture [21]. Although SpiNNaker does not incorporate actual neuromorphic chip architecture, the asynchronous spikes based communication between the vast amounts of chips is neuromorphe. Furthermore, the Belgian research institute Imec introduced its own neuromorphic chip in 2017 [22].

Al is an emerging technology for traditional car manufacturers as well as for Tier1s. These have to acquire the software knowhow to prevent being replaced by IT giants entering the market. Al is the key technology for self-driving cars which will significantly change the traditional mobility concept. Companies with large fleets of automated and connected vehicles will offer transportation as a service which will gradually decrease car ownerships. User acceptance is expected to grow fast thanks to such mobility-on-demand concepts, passenger comfort and possible entertainment offers during transportation. Self-driving capabilities will be gradually more valued as a USP for future cars. Estimations predict 33 million sales of autonomous cars by 2040 [23]. Although pricy self-driving cars would be affordable only for a minority at the market entrance, the majority of users will familiarize to this technology by means of mobility-on-demand services. Automation will support the strong sales argument of safer transportation. This argument will be continuously enhanced by means of more complex signal processing algorithms and better sensor performance corresponding to higher data rates from higher resolutions and frame rates. This will lead to the need for better hardware in order to process data in real-time. Here, the automotive industry depends on the IC vendors' expertise. Therefore, OEMs as well as Tier1s started to cooperate closely with IC vendors to enable optimized chips for new automotive applications. Automation and connectivity open a new market for sensor manufacturers, HD map providers and IC manufacturers. In general, hardware providers and suppliers will capture a larger portion of the vehicle's total value [24]. Here, the AI chip will be the brain of the automotive platform. According to MobilEye, the goal is to offer autonomous driving capabilities for a price of a few thousand dollars [29]. A significant portion of this value should result from the AI chips.

2.1.2 Analysis & Assessment of the impact on present industry structures

The international Society of Automotive Engineers (SAE) defined 6 automation levels in 2014. Starting without any automation on level 0, the automated driving capabilities are expected to evolve gradually up to fully automated driverless vehicles on level 5. The stepwise improvement depends on traffic conditions and automated capabilities. While first traffic jam pilots and automated parking assistance is being introduced today, fully automated level 5 vehicles are expected to be introduced around 2030 according to several roadmaps. For example, the European Automated Driving Roadmap from the ERTRAC working group Connectivity and Automated Driving predicts full automation by 2030 [25]. Similar projections were given in the European Roadmap Smart Systems for Automated Driving (EPOSS). Most car manufacturers claim to be able to build such vehicles within few years' time. In fact, the fast technology evolution during the last two years may prove them right and full automation may be introduced significantly earlier than 2030. But besides the technological capabilities, actual verification of the system robustness is able to slow down the market entrance significantly due to safety issues. In fact, every accident involving self-driving cars (e.g. Uber accident on May 18th 2018, Tesla accident on May 23rd 2018) attract strong media attention and raise demands for higher regulations for self-driving cars.

Prototypes of self-driving cars have been shown by various OEMs, Tier1s, IT giants as well as IC manufacturers. These show continuously better performance in more and more complex traffic scenarios and harder weather conditions. While the first prototypes drove only on sunny days on the highways in California, complex city traffic (e.g. Waymo in Phoenix, San Francisco, Atlanta (USA)) or hard weather conditions (snowy roads in the test area Muonio in Finland) are investigated today and the published results are promising. So far, off-the-shelf-hardware has been used to demonstrate AI capabilities and the focus was on software improvement to verify the proof-of-concept. The results prove that at least certain levels of automation can be realized within a couple of years. Therefore, all major car manufacturers announced the introduction of their first self-driving cars within the next few years. But autonomous capabilities will at first be restricted to certain driving conditions since the traffic complexity differs strongly. For example, Audi and ZF together showed the worldwide first car with level 3 capabilities where Al can take over the car within a traffic jam and steer it up to a speed limit of 60km/h. Baidu and ZF announced autonomous parking in 2018. In both cases the hardware is based on Nvidia's 'DRIVE PX 2' platform. The technology readiness level of autonomous driving can be assessed between level 2 and level 8 depending on the operational and environmental conditions such as traffic or weather. The automotive hardware platform corresponds to a technology readiness level 7. Nevertheless, this hardware consumes still way too much power and there are several optimization approaches under investigation. IC providers already announced the first production of better AI chips in the next years (e.g. Nvidia's 'Xavier' in 2018, MobilEye's 'EyeQ5' in 2018) and the development of a next chip generation (e.g. Nvidia's 'Orin', MobilEye's 'EyeQ6').

There are two different technology paths for the chip development. One approach is to optimize the chip architecture to the arithmetic operations of the ANN. In this case ANNs are implemented in software and conventional von Neumann architectures are used. Here, heterogeneous multiprocessor SoC architectures are used from all IC manufacturers in the automotive segment. Another approach is to implement ANNs directly in hardware by means of neuromorphic chip architectures. This technology is still very experimental and time will tell whether these can play an important role. A possible solution can be a combination of both technology implementations. Neuromorphic chips can be used for object detection and classification tasks while von Neumann architectures will be necessary for precise calculations to assure correct rule-based driving behaviour.

Standardization of an open automotive AI platform can increase competition between IC manufacturers and render OEMs and Tier1s more independent from IC giants. Another possibility is close cooperation between IC manufacturers, OEMs and Tier1s leading to distinct solutions for automotive Al computing platforms. In such a scenario e.g. an ,Intel Inside' label could be a USP similar to laptops if the performance differs significantly between IC manufacturers. Today, Nvidia and Intel/ MobilEye offer hardware as well as software solutions [5]. Such closed system solutions undermine the role of traditional Tier1s, whose software expertise becomes less in demand. But both market leaders offer separate solutions as well what enables module-based hardware integration in open platforms such as 'Apollo' from Baidu. Such solutions are favoured e.g. by NXP. Both approaches can be successful. Today and it is not obvious which approach will be established. Nevertheless, it implies strong changes within the value chain. It should be noted that innovation cycles in the chip industry are much shorter than in the automotive industry. Furthermore, the chip life cycle is significantly shorter than the life cycle of a car. Therefore, a regular hardware upgrade could be necessary. In this case chip providers could sell several chips per car within one car life cycle and improve their position in the value chain. More innovations in electronics are enabled by Moore's law which still predicts a higher grade of integration every other year. There will also be continuous software upgrades increasing the robustness of AI performance and the safety. The corresponding software providers will also benefit from the short innovation cycles. According to this analysis, innovations in automotive could be driven mainly by IC manufacturers and Tier1s.

It should be noted that both market leaders use FinFET technology with the smallest available node sizes of 7nm (Intel/ MobilEye) or 12nm (Nvidia) for their chips. This is important to achieve highest integration as well as highest power efficiencies. The corresponding fabs are located in USA and Asia.

Semiconductor fabs located in Europe are more focused on the SOI technology. Here, the smallest node size of 12nm is currently under investigation by GlobalFoundries in Dresden. Mobil-

Eye used higher evolved technologies for every chip generation of their EyeQ series. For example, the first generations were realized in 180nm-CMOS (EyeQ1), 90nm-CMOS (EyeQ2) and 40nm-CMOS (EyeQ3). The EyeQ4 was built in 28nm-FD-SOI and the new EyeQ5 will be built in 7nm-FinFET. To deal with the intensive computing power, the highest evolved semiconductor technology is necessary. Therefore, only few fabs are able to fabricate these. Such fabs are located in USA and Asia. In Europe, there is a lack of fabs able to manufacture the AI chips with the highest evolved technology.

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2.2 Fuel cell propulsion technology

by Mathias Müller

Fuel cells are electrochemical power devices that directly convert the chemical energy of a fuel into electric power. While fuel cells share principles of operation with batteries, they differ in the way that the electrochemically active materials are stored externally and are continuously supplied to the device and can produce electricity for as long as fuel and oxygen are supplied. With this technology it is possible to build emission free cars if pure hydrogen is used as fuel. The engine is a much simpler construction (60 % fewer parts, 90 % fewer moving parts) and needs a lot less maintenance compared to internal combustion engines (GM 2010). In Europe, all major car manufacturers have been working on fuel cells for many years and all of them have roadmaps that lead to a market introduction in the next few years.

2.2.1 Description of the main concept

Fuel cells are electrochemical power devices that directly convert the chemical energy of a fuel into electric power. They produce electricity by combining hydrogen and air (oxygen) or another oxidizer. While fuel cells have comparable principles to lithium-ion batteries, they differ in the way that the electrochemically active materials are stored externally and are continuously supplied to the device and can therefore produce electricity for as long as fuel and oxygen are supplied.

All types of fuel cells consist of an anode, a cathode and an electrolyte which enables hydrogen ions to move between the electrodes. At the anode a catalyst ionizes the hydrogen. The resulting protons (hydrogen ions) flow to the cathode through the electrolyte and the electrons are drawn to the anode through an external circuit, forming a direct current. At the anode, a different catalyst causes protons, electrons and oxygen to react and form water.

With this technology it is possible to build emission free cars if pure hydrogen is used as fuel. Fuel cell propulsion is a different approach to reduce greenhouse gas emissions from vehicles. Research on this promising technology has been going on for many decades. It picked up momentum in recent years, resulting in announcements of new fuel cell vehicles from Toyota, Honda, and Hyundai for markets with already existing hydrogen infrastructure (i.e. California, Europe, Japan, South Korea). Fuel cell propulsion shares aspects with cars based on internal combustion engines (ICEV) and with battery electric vehicles (BEV). It tries to combine the advantages of both systems. Like electric vehicles, fuel cell propulsion produces zero tailpipe emission if supplied with hydrogen. It only produces water. The environmental impact can be further optimized by the way hydrogen is produced (e.g. through renewable energy). The engine is in general a much simpler construction (60 % fewer parts, 90 % fewer moving parts) and needs a lot less maintenance compared to a traditional ICEV (GM 2010).

On the other hand, the external and continuous supply of fuel to the fuel cell makes higher ranges possible than in BEVs. The achievable range depends mainly on the tank's size and additionally, these tanks can be refuelled as quickly as a petrol tank.

The potential for fuel cell propulsion in general is comparable to that of BEVs, since both are different technological paths for the solution of the same problems. Nevertheless, both have to overcome different technological obstacles which make it hard to predict which technology will be favourable.

Their impact on infrastructure is very different. For refuelling BEVs rely on a network of charging stations with the opportunity to decentralize the process of refuelling, i.e. charging at home, at work, etc. In contrast, fuel cell electric vehicles (FCEVs) use centralized stations like ICEVs. Thus, in order to achieve a successful transition to hydrogen powered vehicles, the automotive market will require complementary and sustainable commitment by hydrogen producers, vehicle manufacturers, transporters and retailers, consumers, and governments. The interaction and coordination of these stakeholders will determine the real costs and benefits of early market transformations policies, and ultimately the success of the transition itself (ORNL 2008).

2.2.2 Analysis & Assessment of the impact on present industry structures

An assessment of the technology readiness level (TRL) has to be segmented for different means of road transport. Fuel cell industrial trucks achieve currently the highest levels, TRL 8 or 9. Especially in North America extensive experience in large numbers is available. The longest and most extensive operational experience is available to fuel cell buses. They are in operation with transit agencies and universities around the world and have reached TRL 7 to 8. First passenger cars with a fuel cell drive are now available as series production vehicles (Honda Clarity Toyota Mirai, Hyundai ix35 Fuel Cell, Hyundai Tucson Fuel Cell) and are at TRL 8. The technology components and operational experience relating to fuel cell buses can in principle be transferred to trucks. Medium duty vehicle classes 4 to 6 (US GVWR classifications) are at an early prototype stage and are in between TRL 6 to 7. For Heavy duty class 7 to 8 first concepts are available (TRL 3). (CaFCP 2016, SHE 2017)

Some of the main technological objectives that need to be achieved by 2020, in order to ensure that its performance will allow for their progressive deployment and integration in the economy up to 2050, are described in the multiannual working plan (MAWP) of the fuel cell and hydrogen joint undertaking (FCH JU). The production costs of fuel cell systems used in transport applications need to be reduced by an order of magnitude (currently 500 €/kW for cars (Nia 2016)). This will be possible through scaling effects of series production as well as scientific and technology progress (DOE 2016). The durability of proton exchange membrane fuel cells (PEMFC), predominantly used in transport applications, needs to be quadrupled from currently 8.000 - 15.000 h. Furthermore, the production of fuel, i.e. hydrogen, from electrolysis needs to become more energy efficient by approx. 10% from currently 67% while reducing the investment cost below 2.000.000 €/t per day capacity (today 3.000.000 - 4.000.000 €/t) (Nia 2016, FCH JU 2014). Today, hydrogen is primarily obtained by steam reforming of natural gas, thus producing greenhouse gases. The most important research topics nowadays include novel materials and fuel cell design concepts to further reduce the usage of precious metals as well as the simulation and understanding of the functionality of 3Dstructured electrochemical interfaces. Last not least, the focus will also be on new concepts and designs to improve the efficiency of the fuel cells (FCH JU 2014).

One important obstacle for a successful market penetration of fuel cell cars which was widely recognized already years ago has still not been overcome yet: The technology for safely storing and using hydrogen on-board of the vehicles is still not in a mature state at present. Despite a plethora of promising lab developments, there has been no practical breakthrough in hydrogen storage and present approaches still have major safety concerns. The new FC vehicles all use high pressure gaseous hydrogen stored in polymer-lined, fibre-wound pressure tanks.

All major car manufacturers have been working on FCEVs in some way. The first concept car was introduced by General Motors back in 1966. It was a van because at that time, vast volumes of available space were necessary to store the fuel cell system in the car.

Competitive situation in Europe:

In Europe, all major car manufacturers have been working on fuel cells for many years and all of them have roadmaps that lead to a market introduction in the next few years. Several times market introduction of FCEVs was announced, but not accomplished. Daimler recently announced a GLC F-Cell plug-in hybrid model which is supposed to be launched in 2018. AUDI introduced a FCEV concept in 2016, announced a cooperation with Ballard to exchange IP, and that it will take the lead for the coming FCEV efforts within the Volkswagen Group. BMW stated the company will enter the FCEV market with small production runs early in the next decade (DOE 2016). Hydrogen was identified as a strategic energy technology to accelerate the development and deployment of low-carbon technologies by the European Union. A huge part of the current activities originated from this classification and correlated policy initiatives (SET 2017). This is consistent with the EU 2020 Strategy (EU2020 2010), the energy 2050 roadmap (EU2050 2012), the white paper on transport (EU-Trans 2011), the strategic transport technology plan (STTP) (EUSTTP 2012), and the FCH JU-2-MAWP 2014.

Competitive situation worldwide:

All big manufacturers have expressed their commitment to the FC technology. 83 % of all patents concerning fuel cells between 2002 and 2012 were issued in the US (47 %), Japan (31 %) and Korea (5 %), the top 5 Companies being Honda, General Motors, Toyota, UTC Power and Samsung. Nevertheless, Japanese (Honda, Toyota) and Korean (Hyundai) companies are the first and until today the only ones to offer FCEVs commercially in small quantities for markets with existing hydrogen infrastructure (i.e. California, Europe, Japan, South Korea).

In principal different types of fuel cells exist and are classified according to their necessity of fuel and electrolyte. The six fuel cell types are alkaline fuel cells (AFC), phosphoric acid fuel cells (PAFC), solid oxide fuel cells (SOFC), molten carbonate fuel cells (MCFC), proton exchange fuel cells (PEMFC), and their subcategory direct methanol fuel cells (DMFC). In automotive applications almost exclusively PEMFCs are used. They offer high power density and bring the advantage of low weight and volume. PEMFCs operate at relatively low temperatures (80°C) which allows a shortened warm-up time and quick starts, resulting in less wear on system components and a better durability (EGG 2004).

The advantages of fuel cells are weight, capital cost and refuelling time/range of operation. In case of FCEVs the range of operation is mainly dependent on the tank's volume and refuelling takes as long as for an ICEV. The fast refuelling – which is a strong unique selling proposition of fuel cells today – might diminish in the near future. Several manufacturers and initiatives are working on fast charging technologies for BEVs enabling a range of 400 km with just 15 minutes charging time (POR 2016). Thus, it is not clear whether fuel cells can outperform BEVs in this regard. Nevertheless, fuel cell systems in vehicles today outperform battery packs in terms of weight significantly (EP 2017) and system price in the future, depending on scaling effects. Both technologies have to overcome significant obstacles, with their development being hard to predict.

In case of a wide deployment of fuel cells for automotive propulsion, the value chain will see only minor changes since the business model is similar to that attributed to ICEVs. Cars will be built by the same manufacturers, possibly with different suppliers. Fuel production will introduce new players like Linde and Air Liquide into the automotive market due to their expertise in gas handling and production. As long as hydrogen is predominantly produced from natural gas, mineral oil companies remain in a strong market position. Fuel stations might be integrated into the existing network of petrol stations.

Advancements in electrolytic production might offer business opportunities for new market entrants, but until today new technologies like steam electrolysis – to reduce production costs significantly – could not be commercialized, slowing down the widespread adoption of electrolyticly produced hydrogen (EP2 2017).

The development of a low-carbon economy with a widespread adoption of hydrogen technologies has to be viewed on the long run with a horizon reaching up to 2050 (Nia 2016, FCH JU 2014). According to the technology roadmaps of the car manufacturers, the introduction of FCEVs will remain slow, only gaining limited market shares – especially with further development of BEVs. For the foreseeable future fuel cells will be more expensive than combustion engines and remain a premium propulsion technology. As described in previous tasks within the SCORE project, mobility demand is highly price sensitive and thus the slow introduction of FCEVs into the market will not have a strong impact on the overall demand. This can, of course, change rapidly in case of spontaneous policy changes concerning taxes or effects of a rising oil price after natural disasters or steaming from authoritarian regimes.

Due to the high complexity of the FC technology, huge investments are required for new entrants which results in very high market entry barriers.

The automotive market is very complex and driven by different factors like customer demand, technological advancements, governmental regulations and environmental issues, all having impacts on each other. A huge driver for FC technology will be the instalment of a sufficiently dense network of fuel stations to maintain the flexibility customers are used to from ICEVs. This USP and the simultaneous addressing of potential safety concerns can position FCEVs as viable alternatives for BEVs and ICEVs in the future. Existing cost issues for fuel cell systems can be compensated by scaling effects and the technology might therefore be comparable to existing solutions.

A main implementation barrier can be a too hesitant policy approach. It comes as no surprise that huge investments in research and development from the industry and the appropriate set-up of a safe and available infrastructure are crucial factors for a successful market uptake. Without them the tipping point of the market introduction might never be achieved.

For a long term success of fuel cell vehicles, an independence from natural gas and thus fossil energy sources should be targeted. Therefore, efforts have to be undertaken to make electrolytic production of hydrogen with electricity from renewable sources more economic. In combination with further advancements in hydrogen storage technologies, a sustainable mobility can be achieved.

Cross sectoral collaborations are not crucial for FC technology but might be highly beneficial. Since heavy investments are necessary on all sides, collaborations are one way to split the necessary efforts between several stakeholders and concentrate on specific core capabilities. Mergers and acquisitions can lead to a pooling of capital and make larger R&D projects feasible. Especially Europe is taking a collaborative approach. The aforementioned FCH JU as a public-private partnership and H2 Mobility (http://h2-mobility.de) as a private partnership are examples for industry-driven collaboration models. Furthermore, worldwide collaborations between different stakeholders are formed at present (e. g. Ballard/Toyota, US Hybrid/Sumitomo, Arcola Energy/IMS ECUBES, Ballard/VW). The European industry is well aware of fuel cell technology and has been investing in research and development for many years, resulting in prototypes and announcements to enter the market in the next years or in the beginning of the next decade. In terms of market readiness European car manufacturers are lacking behind their Asian competitors, where different manufacturers are already selling production vehicles in several markets but comparable small quantities. Thus, the majority of intellectual property for FC propulsion technology lies in Asia and North America, giving those industries a competitive advantage. This already manifests in today's international collaborations of many European manufacturers. For their fuel cell programs they formed cooperations with international partners (e.g. Toyota/ BMW, Ballard/VW, Mercedes/Ford/Automotive Fuel Cell Cooperation) (DOE 2016). Nevertheless, Europe has a fruitful scientific community working on fuel cells (e.g. Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW)).

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2.3 Digitisation in terms of customer interface

by Guido Zinke

The automotive industry - like other industries - is confronted by the countless challenges of sustainable development, global urbanisation and the increasing individualisation of users' preferences. These megatrends shape key socio-economic developments that converge with the technological possibilities of digitisation. This results in new mobility patterns. The central question remains which drive technology will prevail in the future. This is where the technological development of electric drive technology is emerging as the triumphant march of electric drive technology, with bridge technologies such as hybrid drives also playing an important role in the use of combustion engines. Autonomous driving will continue to prevail. Automobile manufacturers have to react to these technological challenges if they want to continue to survive and remain competitive. At the same time, the shift from ownership to sharing creates a fundamental change in user preferences. Instead of owning a car themselves, people want to use distributed systems to meet their mobility needs. As a result, car manufacturers are taking on a new role, increasingly becoming service providers for mobility-as-a-service and sharing concepts of all kinds. Against this backdrop, three major fields of application emerge in which new digital interfaces between drivers and the car of the future emerge: Connected driving, Autonomous driving, New digital ecosystem (digitisation of production and services relating to cars) and Digitally driven mobility services. To be competitive in these areas and ultimately to be competitive requires new demands on business models, competencies, organisational structures and forms of cooperation for the established car manufacturers in Europe, North America and Japan.

2.3.1 Description of the main concept

The future of mobility is determined by the challenges of the megatrends sustainability, urbanisation, individualisation and digitisation. This has a direct impact on mobility and demand patterns in the automotive sector as well. In particular, it leads to new preferences that are reflected in a strengthening of sharing concepts, less ownership and growing service requirements. These innovation paths are primarily autonomous driving, connectivity and networked mobility. These are technological and consumer trends that can be tracked for some time – and they will play an important role in the reformatting of the automobile and will comprehensively reshape the automotive sector. It is still an open question which concrete characteristics and in which combination these mobility trends will prevail in which region of the world. And: Even though these three paths differ a lot, they are closely related to each other.

This technological development radically changes the familiar vehicle and mobility concepts. Less people have the will to own a car while more have the desire to share cars. This is due to clear rational considerations, driven in particular by the desire for more mobility but not just more possessions. The networked and ultimately autonomous driving car also replaces the wellknown driving concept. Instead of concentrating on driving yourself, the ,new drivers' have the opportunity to use their time in a different way. Security also plays a major role. If driving is supplemented by an intelligent assistance system or if the risk factor ,human driver' is replaced, the probability of an accident decreases.

In addition, the manufacturing, distribution and after-sales system we know today will change radically. Vehicles of the future will be manufactured in networked value-added chains according to the customer's wishes. Maintenance is mainly software-based, on-site visits will become less frequent. In addition, a specific automotive data marketplace will be created. In times of self-learning and -training autonomous vehicles, the driving data have a high value in order to improve the driving characteristics. The data is also needed to make the production and dislocation of vehicles more sustainable. Thanks to digital product IDs, it is now possible to track vehicles and their materials throughout their entire lifecycle.

The technological and economic potential of this development is enormous. The US will play a leading role in the introduction of communications and networked automotive applications. This will lead to significant technological developments on the infrastructure and vehicle side. However, Europe and Japan will follow with great effort. China is also playing an increasingly important role in the field of autonomous driving. Much depends on the introduction of 5 and 6G. With the introduction of the first 5G mobile radio networks, a much more efficient usability of connection technologies in traffic is expected. Against this backdrop, it can be assumed that almost all new registrations will be linked to this by 2020. Most of this connectivity is likely to come from embedded systems. The rest is done via integration with the user's smartphone or via connection to other network devices.

Promoted above all by Google, the vision of fully autonomous driving has established itself as an effective model for new mobility. Currently, North American, European and Japanese companies are still leaders in the development of driver assistance systems (ADAS). But the Chinese suppliers are catching up very quickly. Due to this competition, it can be assumed that ADAS features will be used more and more frequently in the coming decades. Fully automatic vehicles are expected to come onto the market initially as low-speed automatic shuttles; pilot tests for automated shuttles are already underway. Many experts expect driverless taxi services to be available in selected urban areas by 2020 while automated vehicles will be available for personal use starting 2030.

The sharing of models for a growing part of the world's population will become a comfortable alternative to vehicle ownership, especially from 2020 onwards (car and bicycle). Riding, tailing and ride-sharing approaches will be increasingly represented in the metropolitan regions by 2030. After 2030, urban areas will largely adopt models for the sharing of vehicles and sustainable new mobility service models will be introduced in rural areas.

The European automotive industry is increasingly confronted with a massive innovation competition, which primarily entails organizational and structural changes. Despite the current positive overall situation, the European automotive industry is confronted with major changes resulting from the mobility trends outlined above.

2.3.2 Analysis & Assessment of the impact on present industry structures:

Sustainability, urbanisation, individualisation and digitisation determine the future technological and social innovation capacity of the automotive industry. (OECD 2015, Roland Berger 2016, ITF/OECD 2017, Arthur D. Little 2015, McKinsey 2016)

- Urbanisation: While about 165 million people lived in cities around 1900, it is predicted that 70 to 80 percent of about 10 to 12 billion people will live in cities in 2050 (UN 2014, World bank 2015). In the 21st century, life in densely populated urban areas will be the typical form of existence for the majority of world's population. The more people have to come to terms with their diverse needs and vital life functions in an increasingly confined space, the scarcer the situation becomes. There is too little space for growing automobile fleets and their external effects (ITF/OECD 2017, Arthur D. Little 2015, McKinsey 2016).
- Sustainability is the way to reduce external effects of industrial and fossil production and consumption. According to the OECD's World Transport Outlook, global traffic will at

least triple by 2050 (OECD 2015). The external effects in the area of mobility are growing rapidly. More regulations are needed to contain the demand for fossil fuels and greenhouse-gas-emissions, air pollutants, noise emissions, accident costs and material and space requirements of mobility. With regard to the automotive industry: The diesel engine is currently being criticised and there is a dilemma between climate protection and health protection within this technology line. The internationally agreed targets for climate protection – far-reaching decarbonisation by 2050 – will only be achievable in the mobility sector if combustion engine drives will no longer be allowed from 2035 onwards (Öko-Institut 2016). At the same time decarbonisation should contribute to social justice and services of general interest, good employment and economic resilience of the places of residence and work. (McKinsey 2016)

Individualisation increases with the level of development of society. This makes mobility needs more specific, flexible and spontaneous and the demand is less able to be bundled. This is one reason why mobility patterns change more quickly and show a less stable and predictable demand pattern than before. Wherever individualisation took place, use of automobiles became more prominent. Until now, passenger cars have been the most functional vehicles to meet this megatrend. At the same time, more and more platform economies are emerging in the urban cultures of the world. Based on the enabling functions of digital technologies but also drawn from the growing complexity, flexibility and changeability of modern lifestyles: where life becomes ever faster, less predictable, spatially and temporally variable, ownership is a brake on flexibility. (ITF/OECD 2017) In mobility, the dynamics of efficient shared products (car sharing) are also strongest at the moment (In Germany, for example, a car is used for an average of one to two hours a day, which means that it remains unused for 22 to 23 hours). (Öko-Institut 2016, Morgan Stanley 2015) The interaction of these subtrends of individualisation leads to changes in urban mobility markets.

A new market is being created: the collaborative transport with relatively stable demand patterns and political regulation in the areas of less space-efficient, less sustainable but highly individualised private transport (private cars, rental cars, taxis) and the very space-efficient, more sustainable but so far less individual collective transport (tram, suburban and underground railways, buses). In the future, the established providers of urban mobility will be faced with the challenge of arranging themselves with old and new players in terms of organisation, technology, finance, business management and branding in order to enable more flexible offers that respond to individualised customer requirements. (ITF/OECD 2017, McKinsey 2016)

Digitisation: Digitisation has disruptive and therefore potentially very powerful innovation effects for established structures and actors due to its inherent exponential development dynamics in digital networking, automation, artificial intelligence and predictive analysis of large amounts of data. Digitisation offers a wide range of approaches and opportunities to cope with the challenges in traffic development resulting from the megatrends outlined above. (McKinsey 2016, ITF/OECD 2017) The expectation of these opportunities is essentially based on three possible effects of digitisation: enormous increase in the efficiency of use of transport infrastructures and vehicle fleets; automation and thus the optimisation of control functions previously performed by people; very effective mediation between supply and demand through networking technology, smart terminals with software applications and new concepts for switching platforms. Each of these partial developments of digitisation would in itself lead to enormous changes. However, in their interaction with each other and with the trends towards electrification and ,benefits instead of possession', they generate the transformative development dynamics for the automotive industry that can be observed right now.

Mobility innovation paths are specific developments that can be even more differentiated spatially and temporally than the megatrends mentioned above. The most discussed new mobility trends in scientific, traffic and automotive policy discourse are currently Automation, Connectivity and networked mobility (ITF/OECD 2017). These are technological and consumer trends that can be tracked for some time – and they will play an important role in the reformatting of the automobile and will comprehensively reshape the automotive sector. It is still an open question which concrete characteristics and in which combination these mobility trends will prevail in which region of the world. (ITF/OECD 2017, Arthur D. Little 2015)

Recently, however, the mobility sector has gained considerable momentum. On the one hand, due to the growing overmodulation of the megatrends and mobility trends mentioned above. On the other hand, new digital application possibilities offer concrete solutions. In the last five years alone in the field of automated driving has experienced unprecedented momentum. Ultimately, this trend should lead to fully automatic vehicles (SAE Level 51). At the same time, driver assistance systems (ADAS) were further and newly developed. (BII 2017) And thanks to a growing number of telematics solutions, infotainment developments and the continuous improvement of vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, significant progress has been made in vehicle connectivity. In addition, hybrid and, above all, electric drive systems are being tested for new drive concepts that can create new, more sustainable mobility. (ACEA 2017) New mobility services triggered by consumers create completely new business models or change existing models with the help of technologies. Such new mobility services are made possible primarily by technology platforms and wireless connectivity that enable more convenient, efficient and flexible travel. And: so far, automobility has been associated with owning a vehicle and the need to control it. (Smith et al. 2017, CAR 2016)

Dieter Zetsche, CEO of the German automotive manufacturing company Daimler, summarizes this development with a view to the challenges facing established car manufacturers in Europe and also in North America and Japan: "Networking, autonomous driving, sharing and electric drives – each of these four trends has the potential to turn our industry upside down. But the real revolution lies in the intelligent combination of the four trends" (Daimler 2017).

This field of tension between the trajectories has at the same time different future paths for the different regions of the world with different spatial and settlement structural conditions. Particularly in densely populated urban areas, especially robotic electric driving as an efficient service in combination with public transport is an extremely realistic development perspective - provided that the technological feasibility promises can actually be met. It seems to be particularly advantageous in China, where urban settlement structures are still being rebuilt and the space and traffic planning requirements of automatic driving can be taken into account in the sense of an innovation leap (ITF/OECD 2017). On the other hand, passenger car ownership in rural regions of the world is likely to remain relatively stable in the future, but also here with tendencies towards automation, as far as technological developments permit. At the same time, autonomous minibus fleets in rural and suburban regions in particular could enter into a clever alliance with public transport - and thus modernize and make it more attractive. (ITF/ OECD 2017)

The following figure shows the central fields of new digital interfaces between drivers and the car of the future along the four major technological developments

Connected Driving

In the ,Connected driving' application area, the car is increasingly developing into a computer-controlled unit that is ultimately controlled by artificial intelligence (AI). And it is a hub for real-time data transmission with full connectivity to other vehicles, (traffic) devices, databases and objects. This is made possible by sensors on and in roads and other infrastructures (bridges, buildings, traffic lights) as well as by entertainment and navigation services connected to mobile applications (smartphone applications). Over the past few years, networked driving has developed at a very high speed. During the various phases of development, new functions and services were constantly introduced into the technological system and the surrounding eco-system. In addition, there were new players – and last but not least, new business models. It is estimated that this degree of connectivity is expected to be achieved by 2020 in 90% of newly registered cars – and that they are interlinked. (Accenture 2018, WEF 2016)

Infotainment technology in the automotive sector has developed enormously recently. Instead of using proprietary software, more and more OEMs are turning to open source systems and mobile platforms. This also increases



Figure 25: Digital Transformation of customer interfaces, services and products in the automotive sector. Sources: Own illustration based on WEF 2016, Smith et al. 2017

the degree of cooperation with external partners such as Google (USA) or Baidu (China). This makes infotainment more dependent on location and condition. At the same time, systems and platorms can be adjusted to the individual needs of the drivers. Thus, for example, integrated intelligent route planning – even across several modes of transport – is also quite common in luxury class vehicles. While these location- and state-oriented infotainment systems are mostly networked car services of the future due to the more complex implementation requirements, subscription-based services have already arrived. However, they are usually limited to safety features such as breakdown assistance or emergency call systems in the event of accidents, which are also offered by insurance companies. (WEF 2016, Smith et al. 2016)

- In Connected infrastructures the possibilities of connectivity and vehicle-to-vehicle (V2V) communication continue to develop and trigger machine-to-machine communication potentials between vehicles and the roadside infrastructure (vehicle-2-infrastructure communication, V2I). Both - V2V and V2I – are the key factors for intelligent transport. Sensors, transponders and RFID readers in the street, at traffic lights, bridges and car parks are integrated into an integrated communication network of continuously moving digital information in order to increase safety and improve traffic flow. This considerably increases the benefits of onboard infotainment systems in vehicles (see above). In addition, the data obtained from V2V and V2I communication are useful for reducing traffic congestion and improving public safety. At the same time, however, this requires more cooperation and coordination between OEMs and, for example, public institutions. Not only to build up the infrastructure, but also to develop common standards for data exchange and data management. (WEF 2016, Smith et al. 2016)
- Networked driving also allows you to customize insurance offers: usage-based insurance. More and more insurances are moving in this direction, modifying and individualising policies based on individual driving behaviour. Telematic solutions, e.g. on-board sensors that transmit driving information, are still being used for this purpose. In the case of voluntary participation, drivers will be encouraged to generate discounts and other offers through adapted driving. This performance-based or usage-based pricing is a supplement to the emerging peer-to-peer insurance programs and pay-as-you-drive policies. These solutions are already helping to reduce the number of accidents and even lower accident rates will be achieved with a wide range of vehi-

cles equipped with AI systems in the future. (WEF 2016, iii 2016) This development is likely to lead to a shift in liability. Instead of the driver's behaviour, the cover is placed on the manufacturer of a car, the software developer, the device manufacturer, the vehicle owner. (iii 2016) The insurance must be adapted to the circumstances of driving – the specific types of driver, the number of passengers or customers in the car, the purpose of the car (commercial or private), the way in which the passengers are insured. (WEF 2016)

Multi-modal integration connects all forms of individual and public passenger transport on roads, cycle paths, footpaths, railways and waterways to build up seamless connectivity between modes of transport. For some time now, OEMs and suppliers have been working together with other industries as well as planning, tax and supervisory authorities and municipalities worldwide. Comprehensive multimodal integration would bring significant social and environmental benefits. One result would be more efficient traffic management and less congestion. Urban areas would produce better guality of life and urban planning and municipal investments would shift. (WEF 2016, ITF/OECD 2017) Current pilot projects on a small scale have demonstrated the feasibility of the concept, especially in Europe, but further scaling requires new partnerships and the development of advanced application program interfaces (APIs) linking the different operating systems. (WEF 2016)

Expectations for further technological developments in the field of connected driving:

The key question as to how the possibilities of connectivity can be used is to what extent the necessary technologies are available (see the following figure for the USA, Japan and Europe). According to Smith et al. (2017), the USA will play a leading role in the introduction of V2V and V2I security applications. Until 2016, leading automotive and technology companies and governments have committed themselves to making considerable efforts to deploy V2V and V2I applications based on dedicated short-range communication (DSRC) in the 2020s. This will lead to significant technological developments on both infrastructure and vehicle side. Europe and Japan intend to create the necessary legal framework to invest in V2I infrastructure and support the development of V2V applications. Technologically, however, this development will not be limited to DSRC-based connectivity alone. The introduction of the first 5G mobile radio networks is expected to result in a much more efficient usability of connectivity technologies in traffic. (Smith et al. 2017)



Figure 26: Timeline for Vehicle Connectivity Technologies. Sources: Smith et al. 2017

Blackrock (BBI 2017) estimates that approximately 35 % of the vehicles sold in 2015 have connection capacity (see figure below). According to the Blackrock forecast, almost all new registrations will be connected by 2020. Most of this connectivity will presumably come from embedded systems. The rest by integration with the user's smartphone or by tethering with other network devices. (BBI 2017)



Figure 27: New vehicle connectivity estimates, 2015–2020. Sources: BII 2017, Notes: Connected vehicle technology enables wireless communications between vehicles and passengers' personal communication devices, and between vehicles and the infrastructure. Embedded connectivity means that a vehicle has built-in network connectivity capacities and applications. Tethered connectivity means that a vehicle and applications but relies on an external device, such as a cell phone, to get on the Internet. Smartphone integration means that the vehicle relies on a smartphone for services and applications.

Autonomous Driving

The seamless connectivity of millimeter wave radars, cameras, ultrasound sensors, lidar scanners, GPS technology, vehicle-to-vehicle and vehicle-to-infrastructure connectivity, and proprietary algorithms allows an increasing throughput of autonomous vehicles. The expectations in this development are very high. Mobile independence and travel become possible for almost everyone, traffic loads are reduced and road safety increases. The further development of autonomous driving is also subject to various technical constraints and regulatory challenges. At the same time, existing infrastructures must be adapted and supplemented. The biggest challenge, however, is the acceptance of potential users. For car manufacturers, the production of self-driving cars means a complete reorganisation of the automotive industry and its supporting ecosystem. (Roland Berger 2017) And the path to a critical mass adaptation of autonomous vehicles is still unclear. The throughput is conceivable on the one hand with a long-term incremental introduction of discrete autonomous functions, but on the other hand also through direct development and the radical use of new technologies. Both paths are practiced in the automotive sector. For example, Google has produced a completely autonomous vehicle without a steering wheel. In Europe, Japan and the USA, autonomous cars with hands-free car kits are still being tested on public roads for the time being. Many OEMs are investing both in improving the capabilities of assisted driving and in exploring fully self-driving technologies. (Roland Berger 2017, WEF 2016)

Assisted driving is reality and already widely carried out. The use of driver assistance functions in cars is growing from year to year. At the same time, the role of the driver is changing: from an active driver to a rather passive participant in an automated transport process. At present, technological throughput is still hampered by high initial costs, so such systems are still predominantly found in the premium segment. However, with the suitability for mass production, costs will be significantly reduced and assistance systems will also find a broad throughput in the broad production of lower segments. In its study on the digitisation of the automotive sector (WEF 2016), the World Economic Forum assumes that the economic benefits for consumers and society (worldwide) will amount to more than one trillion US dollars by 2026. According to this forecast, improved vehicle safety could reduce potential accidents by 9 % until 2025 thanks to advanced driver assistance systems (ADAS) and avoid 5 % of additional premiums. More importantly, increased security has the potential to save 902,000 lives over the next 10 years by preventing fatal incidents. (BII 2017, WEF 2016)

Assistance systems created the basis for self-driving. Intensive work is being done to develop self-driving vehicles that navigate themselves in mixed traffic conditions on all kinds of roads. The best-known is the Google Auto LLC, which according to Google's own statement should be marketable 2020. (Forbes 2015) At the same time, Tesla is also very strong in the development of electric cars that will drive autonomously, as is Apple. (Roland Berger 2017) But established manufacturers such as Audi, BMW, Mercedes-Benz, Nissan and Toyota are also working on self-driving cars. Volvo, for example, has already tested robot trucks. Self-driving vehicles are therefore already a reality, at least as proof-of-concept tests. However, the extent and number of legislative, infrastructural and technological barriers will drop down while significant questions arise with regard to consumer confidence, data protection and the control of cyber security risks. (Roland Berger 2017)

Expectations for further technological developments in the field of autonomous driving

Promoted above all by Google, the vision of fully autonomous driving has established itself as an effective model of new mobility. However, feasibility and social acceptance are still highly controversial. This is due to the fact that technological development is socially overshaped. From a purely technological point of view, relatively sub-complex, homogeneous and regular driving situations such as driving on roads can already be mastered very well and can contribute to road safety. People are already moving in the area of highly automated driving. It is also undisputed that one of the first applications will be in road freight transport. More controversial is fully automated driving in densely populated urban areas, where the effects would be greatest (e.g. space savings, efficient infrastructure utilization, ecological relief, and new public transport systems). However, the technological implementation is difficult because of complex mixed traffic situations in the cities. Due to the defensive nature of the control algorithms, automated driving has so far only worked reliably and safely in a self-contained homogeneous system - the more homogeneous, the better. This requires better system-accesses and a massive increase in the digital connectivity of infrastructures. (OECD 2015, McKinsey 2016)



Figure 28: Roadmap for Advanced Driver Assistance Systems and Vehicle Automation Technologies. Sources: Smith et al. 2017

Currently, North American, European and Japanese companies are still leaders in the development of advanced driver assistance systems (ADAS). (BII 2017) But Chinese suppliers are catching up very fast. Due to this competition, it can be assumed that ADAS features will be used more and more frequently in the coming decades. (Smith et al. 2017) From CAR's point of view, fully automatic vehicles are likely to be launched on the market initially as low-speed automatic shuttles; pilot tests for automated shuttles are already underway. Many experts predict that driverless taxi services will be available in selected urban areas by 2020, while automated vehicles for personal use will be available from 2030. (Smith et al. 2017, BII 2017)

Smith et al. (2017) believe that this technology path can be used to identify different behaviors of automobile manufacturers, which in turn will form sub-paths. Some manufacturers are developing vehicles with automated drive systems. Others will increasingly rely on the development of conditional automation (SAE J3016 Level 3). And yet other automobile manufacturers want to build vehicles with such a high degree of automation that a human driver is not necessary. These manufacturers justify this with the excessively high complexity of automated systems for humans. From the CAR's point of view, however, it is still unclear whether this will ultimately lead to the development of fully automatic vehicles (SAELevel 5), which is able to operate independently everywhere and in all situations. (Smith et al. 2017)

Digital Ecosystem (Digitisation of production and services relating to cars)

The digitisation of the Automotive Sector is likely to trigger disruptive effects in the value chain. Above all, these are expected to result from increases in efficiency, cost reductions, better cooperation and more innovation. A key factor is the strong transformation of the current B2B approach of the OEMs into B2C-approaches. This provides OEMs with more touchpoints with end user, more communication channels and many approaches to aggregating data. With regard to the development of digital Enterprise and new eco-Systems in the automotive sector, the future design of manufacturing processes in an industry 4.0 will play an important role. (WEF 2017, Smith et al. 2017, Roland Berger 2016, McKinsey 2016, Accenture 2016).

- A central aspect of digital ecosystems in the automotive sector will be the connected supply chain. Its main advantage is cost reduction through a better managed end-toend process. These national and regional manufacturing and supply relationships that have existed up to now have long lead times and are not very agile because of their highly complex structures. The possibilities of digitisation allow a greater decentralisation and a significant reduction of lead times, of costs and more transparency. For example, certain vehicle components can be monitored in real-time throughout the entire production process thanks to digital product IDs - even during and after use of the vehicle. Thanks to machine learning and predictive analysis, errors can be reduced and the design, manufacture and delivery of components and complete vehicles can be speeded up. This also enables to track vehicle and material usages (circular economy) in an end-to-end orientated manufacturing process. The greatest advantage is to produce vehicles in small quantities, including lot size one. (Roland Berger 2017) The exploding growth of data in an Internet of Things across the supply chain will also require new skills for workers and managers. In the longer term, 3D printing could become one of the most important tools for creating parts either in the main factory. This could lead to the collocation of suppliers and assembly plants and would enable continuous integration across the entire value chain to ensure seamless manufacturing and processing. (WEF 2017, Smith et al. 2017, McKinsey 2016, Accenture 2016)
- Even today, the automotive industry is probably the industry with the highest degree of automation worldwide. In addition to humans, robots have been used in production for decades, and their capabilities have been growing continuously. This means that robots of the new generation are already able to perform a wide range of assembly tasks completely independently of people in a digital manufacturing system. The radical advances in robotics and artificial intelligence, combined with the Internet of Things, will lead to further positive advances in automation especially in China and other locations of the global automotive industry

still catching up in production technology. (ACEA 2017) However, intelligent factories require high investments. Not only internally in the automation of production lines, but also externally to strengthen connectivity in order to be able to aggregate the necessary data. Investments are also needed in technologies that enable virtualization of design and testing to achieve faster time-to-market and lower costs for physical prototypes and testing. Forward-looking plant maintenance will also anticipate and localise machine and component failures more precisely. In the intelligent factory, these networked and intelligent machines speed up operation, create flexibility in adapting or retrofitting a line and improve performance by reducing the error rate. The main obstacle to building an intelligent factory is the massive capital needed to replace existing infrastructure. New business models are also needed. The advantages (quickness, flexibility in adapting, improved operating performance, faster response to customer requirements and cost reductions) should compensate for these obstacles and the necessary investments in the long term. (ACEA 2017, WEF 2017, McKinsey 2016)

- Likewise, the digital transformation will change relations across the entire retail chain to a disrupted retail. Customers increasingly expect a seamless experience across digital and physical touchpoints, no matter who they interact with, and use the manufacturer's digital capabilities (website, online configurator, call center, virtual agent and published online reviews) to inform themselves, configure vehicles individually, compare and test them virtually. (Accenture 2016) This challenges OEMs and dealers to find new ways to stay in touch with customers before and after sales. Some OEMs, such as Tesla, want to avoid middlemen completely in order to establish direct contacts with customers. (Roland Berger 2017)
- In the future, car drivers will benefit from connected service and maintenance systems. Vehicles already remind the driver of necessary for maintenance or repairs. As more and more sensors have been installed in vehicles in recent years, the accuracy of maintenance has improved considerably. Sophisticated, data-driven diagnostic systems (predictive maintenance) in the vehicle together with other intelligent components and data connectivity help to proactively signal when vehicles need to be serviced. This opens up completely new possibilities for preventive maintenance and reduces downtime and recalls. For OEMs are many opportunities to create and maintain touchpoints with the customer. (Roland Berger 2017) Digitisation also changes service



Figure 29: Time indicates full technology maturity and vast industry wide adoption. Sources: WEF 2016

concepts. Instead of mechanical adaptations and repairs, software updates or upgrades are sufficient to optimise the functionality of vehicles. No on-site appointments are necessary for this, but software improvements can be carried out anywhere and at any time, even without direct driver activity. (Roland Berger 2017, WEF 2017)

- A transformation to a digital aftermarket can be expected. Looking at the existing fleet, there may be a medium-term need to upgrade older vehicles for new digital assistance systems. Existing suppliers in the aftermarket will shift their sales and services to meet the growing demand for upgrades that enable consumers to stay connected. (WEF 2016) To facilitate software and hardware upgrades, manufacturers and suppliers are expected to make their systems forward compatible. (Roland Berger 2017)
- With the digitisation in the Automotive Sector, a separate automotive data marketplace is created. After all, the digital approaches primarily cause data-driven business models in which data is collected, aggregated and analyzed on a large scale (bid data) for the purpose of optimizing production, processes and offers. In order to fully exploit the value-added advantages of the generated data, a

secure and robust data market is needed in which they can merge into trading data. (Roland Berger 2017). In this way, companies can make their data capture processes more targeted and efficient, both in support of their own business objectives and for transactions on the data market. (Roland Berger 2017, WEF 2017) This data is not only useful for car manufacturers, also non-manufacturers need the information. For example, TransportAPI consolidates data feeds from British transport services and makes them available to develop applications for local public transport. This combines the usability of individual vehicle data with data from the digital transport infrastructure. (transport API 2018)

In summary, the following diagram shows the complexity of the individual developments and the expected throughput times in the automotive industry.

Digitally driven Mobility Services

The growing clientele, especially the younger population groups, is aimed less and less at the increasingly unelegant, ecologically inefficient and economically irrational ownership of
vehicles in urban traffic situations. Instead, it expects reliable, flexible and at the same time cost-effective access to modern, combinable transport systems including automobile usage concepts. Historically, car sharing – pay per use instead of pay and use – was fed from ecological and moral motives. Today, on the other hand, a very rational mix of cost-consciousness aspects can be observed among younger users in particular, with tight budgets, sustainability motives and functional pragmatism (Deloitte 2017, McKinsey 2016).

Against this background, more and more new mobility concepts are taking shape. New Mobility Services have long since conquered the major cities of North America, Europe and Asia and, with their steadily growing importance, are finding their way into people's working and living environments. (CAR 2016, Deloitte 2017) The origin of its emergence lies in a change in user preferences away from the possibilities of transport towards improved mobility (see above). But there is also a change of system (CAR 2016): user-centered approaches (mobility) are now establishing themselves instead of system-centered approaches (mobility). The cities around the world are working very actively on this, and carmakers are also becoming increasingly involved in establishing a wide range of new mobility services. (ITF/OECD 2017) Both want to meet the needs of all users for movement and access to places, goods and people as far as possible in a holistic and systemic way. These include car sharing, ride sharing, ridesharing, ridesharing, microtransit, bike sharing and mobility as a service. They all follow the concept of ,shared-use mobility', enables users to access the transport modes (vehicle, bicycle, motorcycle, etc.) at short notice and in line with their needs and increasingly blurring boundaries between public and private transport, between what is shared and what is property. (CAR 2016, Morgan Stanley 2015)

Ridehailing services, established around 2000, connect users and drivers (often also taxis, such as in Germany) via smartphones, who use their private vehicles for a fee. This resulted in a large number of Transportation Network Companies worldwide, implement matching via their own platform. The best known is Uber, followed by Lyft (USA), Didi (China), Ola (India), Haxi (Europe) and Gett (Europe). (CAR 2016) In the meantime, Ridehailing has been supplemented by further services. So it is now also possible to share rides with others, so-called 'ride splitting' services (UberPOOL, LyftLine). Nevertheless, this is not a car pool, as the driver still does not share a destination with his passengers and operates like a taxi driver. The TNCs are also experimenting with real car pooling services (e.g. UberCOMMUTE, Uber's Destinations Feature, Lyft Driver Destination, Lyft Carpool), which enable drivers to enter their journeys in the time-tables and then receive requests for journeys from people who want to travel on the same route. (CAR 2016)

- ▶ For some time now, ride sharing concepts have been establishing as opportunities for private vehicles to travel to common destinations. Travellers share their travel expenses via specially provided passenger platforms and charge a fee for using the connection. (CAR 2016) The trend began around the mid-2000s. So far, the concept has been most successful in Europe. The largest operator is BlaBlaCar, mainly active in Europe and South America. In the United States, mainly smaller platforms allow peer-to-peer ride sharing (usually for short distances), real-time carpooling or vanpooling. These services include vRide and Commutr. Waze (a subsidiary of Google) took a new step. The ridesharing pilot project launched in May 2016 with several companies in the Bay Area currently offers around 25,000 employees a ride with other Waze users use similar shuttle lines. Drivers can choose whether or not to accept this request. Users pay drivers a recommended amount based on the standard fare set by the Internal Revenue Service (IRS) – 54 cents per mile. (CAR 2016) Ridesharing is worldwide on the forefront. It is particularly established in Asia. In 2015, more than EUR 5 billion invested there in corresponding start-ups and structures. (Bll 2017)
- Car sharing is a short-term also hourly car rental. Customers have access to the vehicles via various electronic systems. Petrol and insurance are included. In recent years, however, the distinction between the two models has become increasingly blurred, especially as car rental is moving closer and closer to car sharing. (CAR 2016, Deloitte 2017) Car sharing is currently available in more than 25 countries in North and South America, Europe, Asia and Oceania. The largest car sharing market is Europe with more than two million members and a good 60,000 vehicles. North America ranks second with more than 1.6 million members and over 25,000 vehicles. (CAR 2016)
- Microtransit is a new concept private transit services offer via minibuses flexible routes or timetables (or both) based on customer demand. This closes the gap between individual and public transport. (CAR 2016)
- In the case of Mobility as a Service (MaaS) approaches, mobility needs are met via an interface with offers of different service providers. The bundling of several transport options (local traffic, car sharing, ride hailing, etc.) is thereby inte-

grated in an integrated solution for the user via a smartphone application and payment of the service. for a single account. This combination is intended to create a universal mobility offer. Mobility-as-a-Service was first conceived in Europe. (CAR 2016)

Shared autonomous vehicles are fully automatic or autonomous without human drivers. Information on the origin and destination of the trip is also recorded automatically. Shared Autonomous Vehicles are to be commissioned by customers with the help of mobile phone applications. Various automobile manufacturers (Volvo, GM, Ford, Mercedes, etc.), technology companies (Google, EasyMile, Apple) and mobility companies (Uber, Lyft, Zipcar) are already working on the development of shared services. (CAR 2016)

Expectations for further technological development in the field of new mobility services

In the cities of the future, mobility services will become more diversified and the trend shift from owning to sharing will become increasingly pronounced. From the point of view of Smith et al. 2017, these developments will certainly converge with other trends. Especially with the increasing automation of vehicles and connectivity of vehicles and infrastructures. (CAR 2016, Smith et al. 2017)

Sharing models for a growing proportion of the world's population will become a convenient alternative to owning a vehicle, especially from 2020 (car and bicycle). Until 2030, riding tailing and ride sharing approaches will be increasingly represented in the metropolitan regions (Smith et al. 2017). After 2030, urban areas will largely adopt models for the sharing of vehicles, and sustainable new mobility service models will be introduced in rural areas. (Smith et al. 2017)

Increasingly, the European automotive industry is facing a massive innovation competition, which primarily entails organizational and structural changes. Despite the current positive overall situation, the European automotive industry is facing major changes resulting from the mobility trends outlined above (ACEA 2017, Accenture 2018, Ramsauer et al. 2017). The following explanation identifies challenges and possible



Figure 30: Roadmap for New Mobility Services and Vehicle Automation Technologies. Sources: Smith et al. 2017



Figure 31: Growth of Car sharing worldwide and North-America. Sources: on illustration based on Smith et al. 2017

solutions for car manufacturers and the European industry resulting from the digitization of the automotive industry – with relevant policy implications.

ICT competencies

ICT plays a key role in the future success of European automobile manufacturers. (Smith et al. 2017, Accenture 2018, Ramsauer et al. 2017).

- The integration of different development cycles of software and automotive manufacturers as well as connectivity solution providers has to be mastered successfully. An agile software development during the vehicle development is by a release comparison with the "Quality Gates" and the increasing maturity during the pattern development quite compatible. (McKinsey 2016, Ramsauer et al. 2017)
- Different software versions and bug fixes during the serial production of a series are currently common. In addition, the integration of software and service changes in automotive after-sale will also be available in the future through OTA ("over the air") updates. Safety-relevant functions play a special role and are discussed separately below. (McKinsey 2016, Accenture 2018)
- The increasing complexity of electrical and software-controlled vehicle components increases the risk of malfunc-

tions. The safety integrity of a system must be guaranteed for every possible operating state (also in the event of misconduct). While compliance with functional safety for ECUs with embedded software in the vehicle is already standard, this will also apply to all relevant systems from the vehicle to the back end in future. The more the newly developed driver assistance systems actively intervene in safety-relevant driving functions, the higher the classification within the framework of the Automotive Safety Integrity Levels and the associated system, software and hardware requirements. (Accenture 2018, McKinsey 2016)

The integration of back-end-based IT systems into the vehicle's safety-related functional chains brings completely new challenges of functional safety and for ICT solution design, development, validation and verification. Potential malfunctions must be counteracted by a solid automotive ICT security concept. A cross-system safety concept from the backend to the vehicle ultimately implies that the vehicle must continue to be equipped with sufficient intelligence and sensors in the future in order to validate driving interventions independently and without permanent Backend-interaction. Last but not least, automotive manufacturers and suppliers are called upon to push the expansion and safeguarding of the ISO 26262 standard for functional safety in the automotive industry towards ICT. (Smith et al. 2017, Accenture 2018, McKinsey 2016)

Collaboration between OEMs and more cross-industry-cooperation

In order to survive in international competition, the digital networking competence of the automotive industry will be crucial. As a base for new services and operating concepts, it guarantees the absorption of automotive and automotive-related value creation while the pure production of vehicles will earn less and less money in the future. It can be observed that the IT industry – in particular the globally operating companies from Silicon Valley, but also the corresponding Chinese IT companies - has been crossing industry boundaries for some years and attacking established automotive industry with new concepts of driving and using automobiles on the basis of their digital competence directly, visionarily, financially and aggressively. In addition, there are the diverse and guite aggressive activities of companies with a lot of venture capital, such as Lyft, Didi Chungxing or Uber. They do not want to develop new vehicles, but rather establish a new culture of using automobiles on the basis of digital networking and operating platforms (mobility services). Finally, the LeEco group of companies, Baidu, China's largest Internet company Tencent or the trading platform Alibaba, which are preparing to enter this market, should be mentioned in this context. They are investing in linking online user data, electromobility and automation technology for mobility services in Chinese conurbations. (McKinsey 2016)

The shift in the structures of mobility demand necessitates new competence mixes in order to be able to offer adequate services and products. It is hardly to be expected that this can be done fully within a company. In this respect, more cooperative value creation models will emerge that are flexible enough to meet such demands. In any case, a 'lot size one' requires the reduction of value added depths while at the same time strengthening the value added widths in networks. In addition, the development of intermodal and multimodal transport systems requires more cooperation with manufacturers of other modes of transport.

ICT companies are already the most important partners and at the same time competitors of car manufacturers. It is becoming apparent that these companies will not build their own vehicles, but instead want to create digital platforms for autonomous driving and networked services. As a result of this development, established car manufacturers could run the risk of becoming just suppliers of vehicles. Examples of this are the cooperations between Google and Fiat-Chrysler or Daimler and Uber. In both cooperations, it is conceivable that a great added value for both partners will be offset by a loss of importance for the established carmaker. (Accenture 2018, Ramsauer et al. 2017)

Various car manufacturers have already reacted. For example, VW and 'Mobility Asia' are looking for clearly defined partnerships with Chinese IT companies, as well as BMW, which recently entered into collaborations with the Israeli start-up company Mobileye and Intel. At the same time, value-added cooperations are developing between carmakers, as the example here shows. Daimler, BMW and Audi participated in the production of digital maps and navigation systems. In other words, the automotive industry also wants to compete with Google or Apple with independent business models. In particular, the formulation of technological standards should be prevented without the involvement of the established automotive industry. However, technological competition remains. The Chinese Smart-SUV Roewe RX-5 from SAIC is equipped with YunOS, a proprietary operating system with navigation, entertainment and Alipay from Alibaba. Until now, such solutions have not been found in vehicles of US and European manufacturers. (KPMG 2017, Accenture 2018)

Organizational structures and -cultures

Against the backdrop of current developments, three organizational models in the automotive sector will develop in the future (Ramsauer et al. 2017, Accenture 2018):

- B2C (Business to Consumer) is the existing organizational model of established manufacturers. The core content of the company's activities remains R&D, production and sales of vehicles for the private and commercial fleet market, supplemented by a range of services. By offering services, product and service packages are developed around owned vehicles and thus the own ecosystem is built up. The central customer benefit is the brand experience and mobility offer from a single source in the areas of automotive-related services (parking, refuelling, insurance, health, personal assistance).
- B2B vehicle manufacturer (Business to Business) concentrates on production of vehicles for mobility service providers. A B2B manufacturer has no direct contact with end customers, so only becomes a supplier for the mobility service provider. It is probable that the vehicles will be completed by mobility service providers with their own relationships to other suppliers. This is because data acquisition from the mobility services is necessary to achieve

the desired technical and functional design of the vehicles. In particular, the presumably increasing market volume of mobility services (ride and car sharing) will lead to a new vehicle market segment in the area of fleet-managed vehicles. This ideal type is currently being implemented by the Italian-American company Fiat-Chrysler, for example, as part of its cooperation with Google.

Mobility service providers offer mobility services. Their key customer benefit aspects are an integrated, intermodal mobility offer with a high convenience factor (Seamless Mobility) and a high process flexibility in the areas of availability, processing and payment transactions. This organizational model follows software- and internet-based structures with a focus on the operation of digital networks. Direct digital customer access via smartphone applications and web portals enables the rapid retrieval of customer data and thus opens up the targeted offer of highly customer-value services.

Decisive for the question of the organizational model is the way a change in one of the types can and should succeed. In addition, the different resource, process and competence requirements are points in need of clarification. An important aspect remains - the organizational culture. If non-material products and services are to be increasingly generated, it may be necessary to change from hierarchical decision-making processes and focus on the corporate goal of organizing production processes to clearly more agile structures. In any case, the challenge here is digital transformation. And also dealing with partners in new networks, which can differ from the actual manufacturer in mentality, speed, flexibility, capital strength, understanding of customer experience and risk affinity. From today's perspective, the foundations of the Daimler subsidiary Moovel or the Volkswagen subsidiary Moia can be seen as positive examples of the creation of the necessary agility. (Ramsauer et al. 2017)

Norms, standards and connectivity

Another aspect for the digitalised car of the future is to provide broader connectivity. In this context, global Permanent Roaming agreements may be an important factor for best coverage provisioning. This is a solution that keeps the costs of data communication between vehicle and backend within bounds through global contracts. But also in order to keep the activation and maintenance of (eSIM-based) connectivity in the vehicle as uncomplicated as possible across national borders. Special attention must be paid to the legal and regulatory framework of certain countries (e.g. Brazil, China, India). If necessary, special provisions must be made there. This is primarily a challenge for the telecommunications industry. (McKinsey 2016)

In addition, compatibility with various network technologies is required, expected to be available over the average life of a car, to be ensured by software updates and multi-technology design. The manufacturers' task will be to work towards new communication standards (protocols, interfaces, technologies). With the increasing functional integration of back ends into grey and colorful services and into partially and fully automated assistance systems, new demands are increasingly being made on mobile communications. In this case, it is advisable for car manufacturers to enter into appropriate cooperations with the ECU suppliers with at least one of the four major telecommunications alliances. (Ramsauer et al. 2017)

Data protection and legal frameworks

One of the key challenges for the digitalisation of the automotive industry is the correct handling of data, data ownership and globally heterogeneous legal requirements. Drivers' concerns about the use of data in particular can become a stumbling block for customer acceptance. The current uncertainty in data handling also offers car manufacturers the opportunity to generate a unique selling point through a transparent and secure approach. Two basic data classes can be identified in the context of automotive digitalization: Vehicle-related data (data that originates in and through communication with the vehicle and the outside world, e.g. performance data) and Customer-specific data (data that is generated in the car as well as input from external and customer-specific data sources that is directly related to the driver). (McKinsey 2016)

The difficulty with these data is that they contain personal data, which – at least in Europe – can be subject to data protection. As a rule, such data must be made anonymous or at least pseudonymised if it is to be made available to the manufacturers. In addition, there are requirements in the appropriate encryption of data transmission. An important part of future business models in the automotive industry will continue to be data commercialization by OEMs and third-party suppliers. (Accenture 2018)

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2.4 Smart systems for automotive manufacturing

by Leo Wangler

Industry 4.0 is a topic with high relevance for industrial production today and in the future. Different European countries (e.g. Germany, Sweden, or Austria) are in leading positions with respect to the implementation of smart systems. The automotive value chain is highly integrated across different European member states. This might facilitate spillovers among European countries and help to raise the Industry 4.0 readiness level in those countries that stay currently behind those who are leading. Industry 4.0 will change future production processes significantly.

The transformation of industries towards more digitalization is still ongoing. CEOs along the value chain have to be aware that this increasing digitalization has a large impact on the future competitiveness of firms. The topic is of high relevance for SMEs as well as OEMs. Many processes that are linked with the further implementation of the internet of things (IoT) have a high potential to foster the dynamics of industrial production. The impact of the IoT on future production processes is currently discussed under the notion 'Industry 4.0' which describes the use of digital and often interconnected technologies in industrial production (compare OECD 2017).

2.4.1 Analysis & Assessment of the impact on present industry structures

Different studies have analyzed the impact of Industry 4.0 on future industry production. There is the general finding that industry 4.0 leads to growth in productivity. The following list highlights some of the main findings:

- Output and productivity in firms that adopt data-driven decision making is 5–6% higher compared to the output and productivity of firms with conventional investments in information and communication technology (ICT) (Brynjolfsson et al. 2011).
- Improved data quality and access by 10% results in an increase in labor productivity by 14% on average. However, there are significant cross-industry variations (Barua et al. 2013).
- Average expected cost reductions connected to the IoT are 18 % (Vodafone 2015).
- Autonomous mine haulage trucks have the potential to increase output by 15–20 %, lower fuel consumption by 10–15 %, and reduce maintenance costs by 8 % (Berger and Frey 2015).
- The internet of things is related to high energy consumption. For example, Google data centres use approximately 0.01 % of the world's electricity (Koomey 2011). In 2016 it was reported that AI has the potential to reduce energy consumption by up to 40 %.



Figure 32: IoT devices online, top OECD countries. Source: (OECD 2017), p. 86.



Figure 33: Industry 4.0 Readiness Index. Source: (EU 2017a)

Even though from an economic perspective high expectations are related to future growth within the industrial sector (BCG 2015), the empirical evidence about completion of implementation processes of industry 4.0 within countries is rather weak. The reason behind this is that the number of IoT devices connected to the internet is difficult to measure. Countries are now just at the beginning to collect data.

One data-source (Shodan⁷, a search engine for Internet-connected devices) allows to measure the use of IoT. The sample consists of 363 million observations about IoT devices. From those devices, 84 million are registered to China and 78 million to the United States. Korea, Brazil and Germany follow with 18 million connected devices, and Japan, Spain, the United Kingdom and Mexico make up the rest of the top ten countries, with 8 million to 10 million devices each. As the countries differ in country size, the counts of IoT per capita is used as a measure. The top ten countries based on the described IoT-data are depicted in Figure 32. Except the first rank – Korea – and the fourth rank – the United States – all countries among the top ten are European countries. From this perspective it seems that the European industry is well prepared for the fourth industrial revolution.

On the European level differences between countries can be observed. There are 'frontrunners' like Germany, Sweden, Ireland and Austria, 'potentialists' like Belgium, Denmark, Netherlands, UK und France, 'traditionalists' like Czech Republic, Slovakia, Slovenia, Hungary and Lithaunia and 'hesitators' like Italy, Spain, Estonia, Portugal, Poland, Croatia an Bulgaria (EU 2017a).

Major driver for this success are national initiatives accompanied by European initiatives, supporting the implementation of Industry 4.0 on the state level. For this reason the political initiatives within the three core regions of the SCORE-project (Europe, US and China) are looked at in more detail.

Europe

There are different policy measures within European countries, supporting the digital transformation towards Industry 4.0 in the private economic sector. For European member states, the exchange of ideas and best-practices is of high relevance. For this reason, representatives of different national initiatives meet at the European level twice a year to discuss Industry 4.0 at the High-Level Roundtable of the European Commission in Brussels. As Figure 34 shows, within Europe more than 30 national initiatives are set to push Industry 4.0 within the member state economies. Especially the exchange of best-practices from 'frontrunners' to countries which are behind in implementing Industry 4.0 bears high potential.

Industry 4.0 is of high strategic relevance for the European Union. One important strategic aspect is Industry 4.0 for developing an integrated digital European market. In addition, fostering Industry 4.0 comes along with an increase in competitiveness.

The exchange of virtual products comes along with an intensified European market integration. So far, this European market integration is mainly focused on the exchange of physical products with respect to goods services and migration of labor forces. For the time being framework-conditions for virtual products are not in the main focus. To exchange virtual products, there are still a lot of barriers. Only 7 % of small and medium enterprises within the EU offer their goods and services in other European member countries (Plattform Industrie 4.0 2017).

One major challenge with a significant innovation potential is related to the implementation of industry 4.0 within SMEs. For this reason the European Commission initiated I4MS to help



Figure 34: Overview of European Initiatives on Digitising Industry. Source: (EU 2017a)

smaller companies to implement ICT-technologies across the entire value chain. The knowledge necessary to improve the skills in this direction is provided as part of the funding scheme.

For the European Union the automotive sector has a high priority (EU 2018). Since October 2015 the High Level Group GEAR 2030 has analysed and discussed key trends and challenges which will affect the automotive industry over the next 15 years.

As an outcome, GEAR 2030 produced jointly agreed roadmaps that set objectives, specified milestones and clearly defined the responsibilities of different stakeholders (EU 2017b). Current policies are part of the CARS 2020 Action Plan established in 2012. Its aim is to reinforce the industry's competitiveness and address current challenges related to climate, environment and society. The following four areas built the core of the strategy:

- financing innovations,
- improving market conditions,
- facilitating internationalization,
- responding to change.

Additional initiatives to foster competitiveness of the EU's automotive industry are related to improvements in the following four main areas:

- smart regulation,
- international harmonization,
- bilateral regulatory dialogues,
- access to finance and market access support for small and medium-sized enterprises.

Automotive products are regulated by EU laws for vehicle type-approval. The area of smart regulation aims to improve the level playing field for approval of vehicle parts. Its aim is to increase the trust of consumers and reduce administrative burden related to competitiveness proofing.

The international technical harmonisation is a second key factor with high potentials to strengthen the competitiveness of the EU's automotive industry. The major focus is on common technical requirements (e.g. under the UNECE framework). Such initiatives have the potential to reduce development costs and avoid the duplication of administrative procedures. The aim of bilateral regulatory dialogues is to ensure a coherent regulation between European and non-EU countries. The addressed core topics are energy saving, emission reduction and mitigation for the burdens related to certification. Access to finance is one topic of particular relevance for SMEs. There are two major initiatives addressing the needs of SMEs and larger firms:

- COSME: the focus of COSME is on improved access to debt and equity finance;
- SME instrument: the focus is on finance for research undertaken by highly innovative automotive SMEs.

United States

The US government has its own initiatives in order to support digitisation within industries. The initiatives are summarized in the report 'A Snapshot of Priority Technology Areas Across the Federal Government'. Part of the initiative are the following core topics, with relevance for the automotive sector within the US (NSTC 2016):

- Manufacturing technology areas of emerging importance:
- advanced materials manufacturing
- Manufacturing technology areas of established importance, including the mission themes of the US National Manufacturing Innovation Institutes:
 - additive manufacturing
 - advanced composites
 - digital manufacturing and design
 - flexible hybrid electronics
 - integrated photonics
 - lightweight metals
 - smart manufacturing
 - revolutionary fibres and textiles
 - wide bandgap electronics.
- Further technical areas of interest identified by the US Department of Defense include:
 - advanced machine tools and control systems
 - assistive and soft robotics
 - bioprinting across technology sectors
 - certification, assessment and qualification
 - securing the manufacturing digital thread cybersecurity for manufacturing.
- Technical areas identified as being of interest by the US Department of Energy include:
 - chemical and thermal process intensification
 - sustainability in manufacturing
 - high-value roll-to-roll manufacturing
 - materials for harsh service conditions.

Part of the strategy is to regain international competitiveness and to reshore US manufacturing. For this reason companies are asked to adopt a more comprehensive total cost analysis. The guess is that many offshoring strategies will not pay off. The major reason behind is related to rising offshore labor rates and 'hidden costs' that in many cases counterbalance any remaining savings from cheap price or labor abroad (RI 2017).

Another relevant argument is that separating R&D from manufacturing has a negative impact on the strength of the innovation system (e.g. ITIF 2012). For those reasons Industry 4.0 is a strategy which is connected to the expectation of industrial recovering of the US Economy.

Parts of the strategy might already show some results. According to current studies the degradation of jobs within industry has stopped. In 2014 and 2015 there was already a reshoring of US industrial manufacturing employment. Due to offshoring in 2000–2007 the United States lost net about 200.000 manufacturing jobs per year. Within the last seven years about 265.000 manufacturing jobs have been brought back to the US (RI 2015). Industry 4.0 can be considered as a strategy to strengthen this development.

China

In order to push industry 4.0 within the national economy, the Chinese government recently released implementation guidelines for the "Made in China 2025" strategy. Based on the 'Made in China 2025' initiative, it is the aim to lift the country into a higher value-added economy (OECD 2017) (Euromonitor International 2017).

China has priority funding for many R&D projects with a special focus on digitizing the economy. This will impact the competitiveness of the manufacturing sector in the next years. R&D funding with close connection to the automotive sector are the following:

- New energy and energy-saving vehicles:
 - energy-saving vehicles
 - new energy vehicles, including batteries and motors
- intelligent vehicles.New materials:
 - advanced basic materials, e.g. textiles and steel
 - essential strategic materials, e.g. special alloys and high-performance fibres and composites
 - cutting-edge new materials, e.g. 3D printing materials and metamaterials.





Figure 36: Top 25 Countries with Largest Manufacturing Share and Readiness to Adopt Industry 4.0 Solutions. Source: (Euromonitor International 2017)

The 'Made in China 2025'-Initiative is one response to current slowdown of the Chinese economic growth. From 2006–2016 the Chinese manufacturing turnover in real terms grew by 10%. Part of this growth was an increase in production in intermediate and high-tech goods. In the last years a slowdown in growth could be observed. In 2016 the rate decelerated to just 5%, compared to more than 20% per year a decade ago. The reasons for this observable slowdown are rising wages in China, coupled with maturing domestic market and limited global economic expansion. (Euromonitor International 2017)

The 'Made in China' strategy is of high relevance for the Chines economy (e.g. UK Trade and Invest 2016). A failure might lead to the so-called 'middle income trap', characterizes by high production costs without enough growth to ensure sustainable development. This could lead to unemployment or inflation (Euromonitor International 2017). One weakness of the Chinese innovation system is the low share of higher value production. Even though China has a high share in industrial production, core design centers for products are usually located within the developed countries. For this reason China connects the 'Made in China 2025' strategy to the foundation of 40 new R&D centers (USITC 2017), with the aim to boost innovations in the manufacturing sector. The R&D centers shall be able to compete with those located within developed countries. The future success is still an open question, as developed countries have well-established R&D capabilities.

From a macroeconomic perspective two major risks are related to the future development of the Chinese economy. Low-cost countries try to take advantage of the increased wages in China in order to attract additional value added and other developed countries try to increase the competitiveness related to higher value added products (e.g. Europe and the U.S. economy) (USITC 2017). When Chinese strategy pays off, foreign companies will keep being attracted by the Chinese market. As a consequence the argument of increasing labor costs gets less important for industries when considering leaving the country. One major concern of foreign investors is that the Chinese strategy includes prioritisation of domestic products. This comes along with the risk of foreign investors reducing their activities within China. The threat is that FDIs in China are reduced as one response to the protectionism (Euromonitor International 2017).

One further problem is related to the specialization of Chinese firms on lower value added products. When China changes the production output to higher value added products this might come along with an increase in unemployment with the related social consequences. Additional important topics are problems in data protection, cyber security and net neutrality. As these topics are not so well elaborated, this might be a barrier for the expansion of Industry 4.0 within China. The reason is that Industry 4.0 comes along with massive amounts of data, which buyers, suppliers, manufacturers, logistic-service-providers and others agree to share, in order to achieve efficiency gains. If this agreement is not settled among the stakeholders, Industry 4.0 might not work properly.

2.4.2 Analysis and assessment of the impact of Disruptive Technologies on the value chain

When it comes to the concrete channels through which Industry 4.0 changes productivity within industry, different relations and interconnections have to be taken into account (OECD 2017). For example:

- Based on new sensors, control devices, data analytics, cloud computing and the IoT machines and systems are getting increasingly intelligent and autonomous.
- More intelligent production processes offer opportunities to eliminate production errors. Items can be monitored by making use of sensors and actors and drawing samples from batches is getting less relevant. The real time monitoring offers opportunities to reduce machine downtime and repairing costs, as intelligent systems are able to predict maintenance needs.
- Another important factor for an increase in cost-effectiveness is that products and processes can be simulated more easily, what helps to save money and to increase product quality.
- The time to deliver orders can be reduced by the data gathered along the entire supply chain. Based on digital technologies it gets easier to reduce the quantitative outcome of cost efficient production processes, what helps to meet

current demand. The whole production gets more efficient. Firms benefit from getting rid of the necessity to hold high quantities of inventories by becoming more flexible. Costs savings come along with reduced failure rates for new product launches.

- The IoT allows to increase the integration of robots in the production processes. As robots are faster, stronger, more precise and consistent than workers, robots especially in the automotive sector have contributed to an increase in productivity. The major focus so far was on stationary robots automating processes along the assembly-line. In the future there are new opportunities to make use of robots interacting with workers within the factories.
- Industry 4.0 goes hand in hand with additive manufacturing. The use of 3D printing offers opens up additional opportunities for disruptive cost savings within production processes.
- The advances in materials, science, and computation allow for an improved simulation-driven approach to develop new materials and processes. This reduces time and costs, as companies will be able to build the desired qualities into materials from the beginning, instead of searching for materials with the desired qualities by making costly and time consuming experiments.
- Nanotechnology offers new possibilities to make plastics electrically conductive. This comes along with new opportunities for more efficient processes. There are predictions which come to the result that the automotive industry is able to remove the need for a separate spray painting process for plastics, which allows to reduce production costs by USD 100 per vehicle.

The automotive industry is a sector for which Industry 4.0 has a high priority. This sector is characterized by strong OEMs as well as TIER1 suppliers and an overall value chain which is internationally diversified. Because Industry 4.0 allows to connect suppliers and customers along the value chain, new opportunities to reorganize production processes occur. There is the occasion to restructure relations from hierarchically top-down control systems to more self-organized bottom-up systems between suppliers and customers. This comes along with new opportunities for subcontractors offering products and services.

Due to Industry 4.0 especially SMEs have new opportunities to increase revenues by providing products and services to other firms being part of the automotive innovation system. This market potential increases opportunities especially for SMEs as



Figure 37: Scenario about interaction along the value chain without industry 4.0. Source: Own presentation oriented on (Wischmann/Wangler/ Botthof 2015, p. 39)

well as TIER1 suppliers. But also OEMs can cooperate more easily with each other. The related dynamic has high potential for future innovations. New opportunities for economic value creation arise. Especially on the base of the interconnected production data firms have the opportunity to create new revenues, by offering additional goods and services (e.g. Wischmann/ Wangler/Botthof 2015).

Furthermore, the IoT will raise productivity by generating synergies among technologies (due to the increased interoperability of machines). Industry 4.0 allows automotive companies to use 'generative' software algorithms to create industrial designs which optimize product weight and strength in completely new ways that are not evident to human designers. Such new methods allow simulating the evolution of multiple variants on an initial design by eliminating the least fit designs in successive stages. This allows to increase significantly the fit of (industrial) designs. For example, the so-called 'Dreamcatcher software' was used in order to optimize the chassis of the world's fastest motorbike, the so-called 'Lightning Electric Motorcycle' (Kinkead 2014).

This shows that data-driven optimisation processes offer many opportunities for the automotive sector. Based on these software algorithms new highly complex designs are generated.

Interaction between SMEs and OEMs with lindustry 4.0



Figure 38: Scenario about interaction along the value chain without industry 4.0. Source: Own presentation oriented on (Wischmann/Wangler/ Botthof 2015, p.41)

Very likely the new designs can only be manufactured in an economic way by using new additive manufacturing tools like 3D printing. Industry 4.0 generates new requirements for the combination of different technologies. Augmented reality (AR) is one example. AR allows engineers to see in real-time projections of the inner working of machines. This feature can be used to train employees and/or to give guidance for maintenance. AR can be considered as a core technology which has to potential to make production processes more cost efficient.

How fundamentally the automotive supply chain will change can also be demonstrated by taking into account the platform economy (Engelhardt/Wangler/Wischmann 2017). For instance, firms can send the data for 3D-printed prototypes to potential suppliers and receive the printed products from retailers. The transaction happens by the mediation of an online marketplace where manufacturers compete for the contracts to print the prototype.

One further relevant aspect changing the whole future industry-production is the topic of artificial intelligence (AI). For example, the use of AI allows to make use of machine-learning algorithms in order to find out which combination of robots and tools is the most efficient in assembling the device. Based on these set initiatives it is an interesting question to discuss what production in the automotive industry will look like in 2030. The following scenario gives a first impression on automotive production will in the year 2030.

Automotive production in 2030

The following description tries to give an impression on what future production processes may look like (please also compare OECD 2017, pp. 78). Some components, such as systems-ona-chip and sensors, are still produced by the existing manufacturers. For other devices new supply-structures become relevant. The mass production of the components will mainly be executed by autonomous robots. The produced components and the associated data are then sent to the assembly facility of the OEM. Blockchain is one core technology to allow for automatized transactions between firms. In order to integrate the different automotive parts, the robots along the assembly line retool and arrange themselves. Robots will move the components and assemble the devices. When robots assemble a device, computers make use of the machine-data in order to control for the efficiency of the production process. The calculation gives information whether the process still fits the parameters and whether there is potential for further optimization.

When the product is finished it is boxed by a robot, and the box is loaded by another robot into a self-driving truck. This autonomous vehicle brings it to the retailer. The loading is also done by robots who automatically place the product in the correct warehouse storage location. The order for the product is made automatically. When an order comes in, robots transport goods all the way to the customer's front- door.

For the case that sales exceed expectations and orders increase from around the world, it becomes necessary to increase the production capacity. The OEM will then enter the market, which means contacting manufacturers in the region via an online-platform. Those manufacturers will compete with each other in order to get the contract that allows them to produce larger or smaller batches of the product. When the subcontractor gets the assignment, he will also get access to the machine-learning algorithms from the previous production processes, which allows him to immediately start with an efficient production. After the factory has finished producing its order, reorganization and retooling is done automated by the robots. The transaction between contractor and subcontractor is monitored automatically via a block chain. In 2030 an automotive will mainly be produced by robots. After the car is designed, significantly less workers will be employed within the factory itself. The major task which is left to employees is related to monitor the production process. For many processes like plastics moulding, assembly or the logistics, the need for workers within the production process will be reduced significantly. Automotive production is highly flexible and OEMs are able to fulfill individual needs and wishes of their customers. Many of the car-features are produced individually for the particular customer.

Success factors for implementing new technologies, products and innovative concepts and strategies into present value chains

As mentioned above Industry 4.0 comes along with a 'creative destruction' of established businesses, markets and value networks within the automotive industry. In the future many current organisational structures and many business processes will be affected by this development (Wischmann/Wangler/Botthof 2015). Existing business models involve costs that cannot be recovered (so-called sunk costs). Employees working within these industries are anxious about the consequences that might result in job losses. This fear causes resistance against too disruptive changes (Christensen 1997). Especially with regard to big OEMs like Volkswagen, General Motors, or PSG, it is an interesting question how these big companies are able to deal with the disruptive changes of Industry 4.0.

From a firm level perspective it is obvious that an organisational culture which is mainly characterized by resistance among management and their employees against the Industry 4.0 related changes can be a threat for the consequent future competitiveness of the firm (Christensen 1997). Such developments come along with the so-called 'innovator's dilemma', meaning that companies might fail to innovate in the long run because they are currently successful and fail to put enough emphasis on current changes related to Industry 4.0. One major reason is the 'fear of change' which bears the risk that the management acts too conservative, meaning that it sticks to the established business model. As governments are aware of existing barriers and the economic relevance for implementation of Industry 4.0, many R&D funding schemes have been implemented to support innovation and digitisation within the automotive sector.

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3 Demand scenarios until 2030

The main objective of this chapter is to identify relevant trends and future perspectives that will affect the demand for the automotive manufacturing industry and derive upcoming challenges and opportunities. Likely market developments of present and upcoming markets are forecast and future customer requirements and mobility demands including aspects like demographic trends, GHD reduction targets affecting business models of the automotive industries are analysed. This way a comprehensive picture of (interdependent and interplaying) trends and their complex impact on the competitive position of the European transport automotive industry is created by characterizing anticipated future competition arenas.

The report assesses how future developments and trends will shape the demand and in turn will shape the requirements of the automotive manufacturing industry. Overall six research topics for the automotive industry were identified and elaborated in interactive workshops with industry experts. For each topic, a plausible use case scenario was defined and implications and conclusions for the present value chain were derived. Three of these topics have been analysed and are reported in the following chapters. The full analysis with all six topics for the automotive industry (e.g. energy infrastructure for electric vehicles, recycling of lithium-ion batteries, mixed platooning of passenger and freight vehicles) and additional topics for other transport industries are available online via the project SCORE-BOARD. The following three topics are analysed in depth within the next chapters:

Flying taxis

Congested roads in big cities could be improved by the automation of cars but only up to certain limits. New trends in electrification and automation enable self-flying, vertical take-off and landing vehicles at low energy consumption. What are demand-side requirements to a safe and regulated usage of flying taxis?

Mobilitiy-as-a-Service

How will the shift from traditional car ownership models to mobility on demand reshape mobility patterns of young and adult urbanites and what are the effects on the automotive value chain?

Autonomous driving

With the evolution of automation capabilities, technology providers will struggle with traditional car manufacturers and ride-sharing/ride-hailing companies for the leadership and value added along the value chain. How will autonomous driving change our mobility demands and which stakeholder has the best prospects to win the race?

3.1 Flying Taxis

by Jakob Michelmann, Konstantin Konrad

With rising population of cities and increased road congestion, vertical take-off and landing flying taxies (VTOL – which are autonomous passenger drones) are being explored in a few major cities worldwide. Both, the aeronautic and automotive sectors have complementary competences to react to the increasing demand for VTOLs and both industries will rely on cooperation in the market ramp-up phase. Looking at the urban aviation market today, the EU is on a level-playing field with the US and China with a comparable amount of players, gaining competences in automation and electrification.

3.1.1 Description of the future use case scenario

With rising population of cities and increased road congestion, in 2030 vertical take-off and landing flying taxies (VTOL) are currently being explored in a few major cities in the US, Europe and China besides Saudi Arabia. VTOL-vehicles are autonomous passenger drones that can take off vertically and then accelerate horizontally with high energy efficiency in cities using their (all-in-one) electric propulsion system for vertical and horizontal aviation compared to a conventional jet-engine, where two drive trains would be required (Uber 2016). Though, automated cars will ease the traffic flow in 2030, traffic jams cannot be eliminated by 2030 yet due to mixed traffic situations and rising individual transport necessities. Although private car ownership has decreased over the last decade, a majority of people still owns a private car (ECF 2016). The usage of individual on-demand transport with automated shared cars has increased, that is why roads remain congested (Wang 2017). Moving on-demand transport from road to air space is a solution of choice in order to meet climate protection goals and ease road traffic. Thanks to the efficient electric propulsion, automated urban air taxis vertically take off and land on 'vertiports' based within the city. Thus, smart charging infrastructure with higher energy capacity as well as security measures has been installed, that allow an efficient application. Legal restrictions only permit the employment of fleets in certain corridors to ensure citizen's privacy and public safety. Most routes connect airports located out of cities with central mobility mega-hubs within the city to shrink commuting times.

Until 2030 the vision of individual transport by flying cars for both, air and land, has been driven by smaller startups and a few premium OEMs. The dominant technical path of flying cars utilizes advances in vertical take-off and landing instead of horizontal take-off (as is it is today, referring to Aeromobil 2017; Pal-V 2017). The shape and configuration of flying cars can be transformed to meet requirements for road and air transport. Due to legal restrictions regarding public roads, flying cars remain a niche application in motor sports and leisure with exclusive flying zones. Only specialist vehicles, such as emergency vehicles or VIP-transport vehicles for public authorities, could be permitted on the road and air to facilitate their service under any circumstances.

While the urban air taxi service will have started as a premium service for managers and officials with dense schedules due to the simple fact that vertiports (urban air taxi hubs) are easier to facilitate on privately owned buildings, the clients in 2030 are working commuters between economic centers of towns or airports into the city center with high affinity to intermodal-mobility solutions, since the services got more reasonably priced.

3.1.2 Analysis and assessment of the impact on present industry structures

Around the world, the main players actively developing in the field of urban air taxis already follow the vision of automated passenger drones. Today is a tipping point in history, where automation technologies and machine vision are far advanced, battery costs shrink at high pace and IT-based on-demand business models are starting to be accepted by clients who realize the vision of automated (and thus safer) passenger transport in cities.

The technical paths differ in the way of aviation and purposeful design (size, function, etc.). One of the biggest challenges of today is the navigation in 3D-space in complex urban environments, noise reduction and increasing the range while lowering the weight (Uber 2016).

Regarding personal flying cars (roadable aircrafts) many startups are active in developing high cost products. They fly with conventional fuel, but drive on electricity (Aeromobil 2017; Terrafugia 2017).

 In Europe: Speaking of urban air taxis (VTOL), the European industry is pioneering different technological paths for aviation. Volocopter is embracing a multi-copter approach whereas Airbus and Lilium follow a multi-jet-engine approach (Lilium 2017; Airbus 2016). The players at present move from the demonstrator phase to the prototype phase and real-world tests (Spiegel-Online 2017).

Worldwide: Mobility service startups like Zee.Aero or Uber and aircraft building companies like Boieng in the US focus on both jet-engines as well as rotors (business-insider 2017; Uber 2016). Ehang in China develops an automated passenger drone with highest range of 20min flight time known to the public today (Ehang 2017). Uber announced plans to run a commercial route in 2020 in Dubai and Dallas (Aviationweek 2017).

The value chain to mass-produce light-weight electric automated passenger drones does not exist so far. In the future, the value chains of aeronautic and automotive sectors would need interfaces, benefiting from trackable goods with innovations alongside the automated factory. For the infrastructure and its security completely new business models have to be launched.

The on-demand business model for urban air taxis is not launched. Airlines today work with long-term booking systems. Together with airports they run a quiet efficient passenger handling. The automotive industry on the other hand has no experience in deploying and maintaining aircrafts, but some OEMs and mobility services have set up on-demand business models with ride-sharing or ride-hailing capabilities. Thus, they already have the connection to on-demand users and the direct user interface. A future challenge will be to run a business model with efficiency in digital-based on-demand services, passenger handling on the one other hand and on the other an Artificial Intelligence-based routing of flights and an efficient fleet management.

Both the aeronautic and automotive sectors have complementary competences to react to the increasing demand for VTOL's. While aeronautic suppliers have capabilities in aviation, navigation, automation, safety standards, the automotive industry has most experience in electrification and IT-based business models as well as experience with on-demand-mobility clients. Volocopter and Daimler as well as Airbus and Italdesign (New Atlas 2017) are pioneering aeronautic and automotive collaborations. Probably, both industries will rely on cooperation in the market ramp-up phase to meet the demand in 2030. Later on, each industry will gain competences in the other's field to deploy services on their own. Looking at the urban aviation market today, the EU is on a level-playing field with the US and China with similar amount of players, gaining competences in automation and electrification. Huge investments are done either in-house, such as Airbus (Airbus 2016), by mergers and acquisition such as with Boeing and Aurora (Lavars 2017) or with external investments such as from Daimler into Volocopter (Volocopter 2017). None of the players is at the stage of technical development at which on-demand-mobility services are integrated. Thus it is difficult to say which country holds an advantage there. The competences for this could be acquired from existing on-demand-mobility services that each market already provides. That is why collaboration is one crucial strategic factor for increasing competitiveness for the new market.

Regarding the path of horizontal starting roadable aircrafts (flying cars) it can be stated that the EU has two more known players than the US engaging in the field. All countries would find resources and competences to build products for the niche market as fast followers.

Global trends and technology developments facilitating a realization of the Use Case

Societal trends facilitating a realization of the described scenario:

- Increasing population size from 2015 until 2030 in urban areas (e.g. Paris from 10,8m up to 11,8m; New York 18,6 up to 19.9m; Shanghai from 23,7m up to 30,8m) (UN 2015)
- Traffic: Europe's countries with highest congestion (Inrix 2016)
- Private Car Ownership: may drop by 80% but will be replaced by shared cars, causing the same road occupancy (Business-Insider 2017b);

Political activities facilitating a realization of the described scenario:

 Congestion taxes and other instruments reduce traffic in metropole city centers slightly (Transport of London 2006, p. 3)

Technology developments facilitating a realisation of the scenario:

 Horizontal acceleration (Flying cars): Aeromobil (Slowakia); Pal-V (Netherlands); Terrafugia (US); Vertical take-off & landing: Airbus (France); Lilium Avaition (Germany), Volocopter (Germany); Boing (US), Zee Aero (US); Ehang (China);

Range: 20min range, 200kg (Ehang 2017)

IT-Platform technologies offering on-demand mobility (ride-sharing/ ride hailing/ carpooling services): Uber, Didi, Gett, Lyft, Grab Carma (Techworld 2017).

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3.2 Mobility as a service applications reshape mobility patters of young and adult urbanites

by Jakob Michaelmann, Konstantin Konrad

Mobility-as-a-Service (MaaS) is a widespread on-demand mobility concept that supports and utilizes the inter-modality of transport in the year 2030 providing sustainable and affordable long-distance journeys in combination with first/last mile solutions. Traditional business models, vehicle designs as well as the value chain will change radically. To realize MaaS business models, collaborations are essential. With new technologies like automated shared vehicles, intelligent algorithms and block chain, all partners of a platform together can achieve that objective.

In Europe MaaS-business models and pilot implementations are currently run in middle-sized cities such as Hanover or Leipzig, mainly driven by the public transport services. Though, there are no real MaaS-applications in the US and China known by today, these countries have the potential to become full MaaS-providers because they have the IT expertise for the development of an MaaS-platform and with already established service providers (Uber, Lyft, Didi Chuxing...) an enormous potential.

3.2.1 Description of the Future Use Case Scenario

Mobility-as-a-Service (MaaS) is a widespread concept that does both, it supports and utilizes the inter-modality of transport in the year 2030 providing sustainable and affordable long-distance journeys in combination with first/last mile solutions. To offer seamless door-to-door journeys, public and private transport providers are integrated into digital platforms and thus become part of a comprehensive service. MaaS offers its users an intelligent journey planner optimising the travel schedule according to individual needs (transfer time, preferred modes of transport, etc.) and providing real-time information on delays and alternative routes (Catapult 2016). Very attractive to most user groups appears the comfortable all-in-one ticket and payment system with transparent bill-per-use or with flat rates (VCD 2017). Blockchain-based ticketing allows the exact and secure tracking and payment of inter-modal vehicle usage (Burgwinkel 2016). Not all companies are using this due to development and implementation costs.

While MaaS-implementation in bigger cities are mainly driven by fast-growing start-ups, because of their competences in scaling up IT-platforms and collaborations and because of their understanding of younger user groups, local and regional public transport providers are driving the change in small municipals. This is due to the fact that they have experience in operation of local solutions on tight budgets and their already built-up ties with customers. Some cities have used co-creation-approaches to merge ideas of different user groups in order to implement intermodal-transport solutions successfully, overcoming barriers through dialogues with the society. This way, the high investments were allocated effectively (for the potential of co-creation refer to Mobility4EU 2017).

On the one hand, a positive effect of MaaS for the livability of urban areas is that more people leave their cars at home or do not buy a car at all. Further, users get in touch with CO₂ emission-free transport solutions and spread the word attracting more people to join platforms. Due to increasing interconnectivity and data for user statistics time tables can be optimized based on big data and by the help of intelligent algorithms. On the other hand, the existence of several new platforms in bigger cities with different approaches still makes it hard for potential users to decide which service to follow. They doubt some of them will be still relevant a few months later. Some users are expected wait before they adopt a new solution, once a platform seems to be established. This economic betting process as well as mergers and acquisition activities lead to the breakthrough of one or two incumbents per area (comparable to the intercity bus market developments, cf. Doll 2017).

The outlook of cities has changed as well. Mobility hubs are spread across the city at frequented places in quartiers. This has architectural impact, since space for bike and car parking is required, as well as more dedicated bike roads are built. The new space around the mobility station is partly used for leisure activities in green spaces and shopping. Though, more traffic occurs around these spaces, the noise and emissions are significantly lower than before due to the combination of low-emission transport modes.

Hence, logistic companies develop platforms for a flexible logistic online- and offline infrastructure, where free capacity for freight transport is marketed. The transport on ship, rail, trucks and busses is organized in a modular way by the help of algorithms. Block chain is helping to stay on track with the location of goods (Mattke 2017). The transportation of goods is partly organized in fusion with passenger transport, where it is effective, e.g. with long-distance busses.

More and more young people and young to middle-aged adults find MaaS attractive because it gives them the freedom to leave their car at home or not even want to buy a car at all.

Younger people and adults without cars get used to planning journeys on the go. There is no need for a car even for a longer trip out of town, because car rental companies are part of the service portfolio providing discounts on cars. Older people also adopt the solution. However, companies fail to offer offline-solutions. Thereby, they exclude users who avoid digital-only services. In the segment of middle-aged people, there are different usage patterns, but usually they keep a private car even though they use MaaS from time to time. But there are many people who will not be reached by those offers. They want to keep their cars to remain independent. Especially people living out of cities tend to keep their cars since MaaS is not available in their particular region.

Nevertheless, not all car drivers gave up their private car in order to get to destinations in and out the city whenever they want, especially if there is either no interface of their service with the service at the destination or no MaaS at all.

There are certain logistics-as-a-service users ranging from startups with upscaling, but unstable good deliveries like new online fashion or electronic stores, but also bigger companies experiment with new kinds of service, especially if they have free capacity in their own logistic chain.

Fruitful cooperation between passenger and freight transport, where parcels are delivered into shared vehicles for the driver that is picking it up.

3.2.2 Analysis and assessment of the impact on present industry structures

At present, there are a lot of companies with different approaches and pilot applications/services entering the market.

In Europe: Compared to other solutions, small-scale MaaS-business models are currently run in middle-sized cities such as Hanover or Leipzig, driven by the public transport services, using one electronic card to track the usage of services. They provide mobility hubs across the city with secure bicycle parking spaces as well as parking lots for cars requiring electric charging infrastructure. This way, sustainable modes of transport can be combined (VCD 2017). The Finnish company PaylQ offers smart city payment solutions, e.g. contactless cards to pay different cross-modal transport with one solution (PaylQ 2017). Startups like Moovel or MaaS Global (App: Whim) undertake trials for MaaS in Hamburg, Helsinki and London (Whim 2017; Moovel 2017). Various pricing schemes are already offered today (pay-per-use vs. flat rate packages). Furthermore, some transport providers joined with one or two partners to offer interlinked transport, like DB does with a car sharing and bike sharing. This is a good foundation to lay out largescale intermodal transport solutions.

Worldwide: In the US, companies like Uber or Lyft built up ride-hailing and ride-sharing services. Didi Chuxing, a Chinese ride-hailing service, is investing in emerging markets like India or Brazil. The mobility startups foster cooperation with OEMs to provide automated driving. Further, bike sharing services are established across the US and in major cities in China (Wikipedia 2017). Though, there are no MaaS-applications in the US and China known by today, these countries have the potential to become full MaaS-providers, if they reach out to other partners, because they have the IT-expertise for the development of a MaaS-platform.

The implementation of MaaS into the transport system has a very high impact. Traditional business models, vehicles designs as well as value chain will change radically. MaaS would require incremental innovation in existing fleets in terms of connectivity, but rather radical innovation in terms of vehicle design: To fit the needs of differently sized cities and purposes, vehicles should be designed with universal design principles to include vulnerable groups and or citizens with impairment. Therefore, they should be easy-to access, easy to drive and park. These vehicles should do not need much space on roads. This way, they need active safety-mechanisms preventing accidents. Such vehicles should have easy-to-use HMIs with self-explaining functionalities. Electrified, automated, connected vehicles can fulfill these requirements (Meyer 2015).

In terms of infrastructure, it is important that high-speed secure connectivity is ensured for real-time data exchange, not only for the fleet, but also between the platform and each affiliated service. The topic of transaction decryption through block chain requires new IT-competences, probably supplied by the platform provider. For the traffic management, big data analytics will be run in order to adapt schedules of each affiliated transport provider.

Probably, transport providers like car rentals or bike sharing services will work with different platforms and more or less standardized interfaces in the beginning, since it is not clear, which platform will have a breakthrough and later a dominant market position. In the ramp-up-phase within the next years, it is important to stay agile regarding cooperation and ready to advance related product and service innovation demanded by the platform. Another strategy could be to build an own platform. Especially in smaller cities, this could be the only way of introducing MaaS e.g. by local transport with appropriate functionality, since local transport providers know their clients and have already set up basic infrastructure.

Currently, many transport providers run collaborations with one or more partners, e.g. to show connections (Google Maps, DB AG, etc.). They usually do neither offer booking services nor show the prices for the complete journey. Though, some basic structures of possible MaaS business model are on the market, e.g. ticketing through app, the intermodal journey planner as well as intermodal hubs are being installed, a MaaS business model requires more functional diversity than that. There a few startups like MaaSGlobal or Moovel with different pricing schemes according to transport needs.

To realize MaaS business models, collaborations are essential. In order to provide transport to a high variety of destinations, it is necessary to build a network of different transport solutions and use the benefits of each mode. To follow the user need for seamless transport and on-demand availability (Mobility4EU 2017) the optimization of the interconnection between each travel step is a difficult task. With new technologies like automated shared vehicles, intelligent algorithms and blockchain, the joint partners of a platform can achieve that objective.

The EU transportation industry is in a competitive position with the US and China from today's perspective, since all MaaS-platforms known to this study, being tested today, come from Europe. With a very good transport network and already existing intermodal links, the provider-side is in a good position to extent inter-modality. China has a very good network as well, whereas road and air transport dominate the US transportation market. But, the US and China could utilize their strong investment companies helping existing mobility services to extend their service portfolio and scale up their market volume immensely. Previous market entries of Uber and Didi Chuxing show how quick they built up services in other geographic markets. The necessary AI-competences are rather located in the US and China than in Europe. So in the future, Europe could lose its competitive position if there are no EU-based platforms established by 2030. Thus Europe needs to support companies with IT-know-how engaging in the field to stay competitive within the future.

3.2.3 Global trends and technology developments facilitating a realization of the Use Case

Societal trends facilitating a realization of the scenario:

- Last-Mile: public transport network is impractical for certain destinations due to last-mile problems (still cars are needed) (Catapult 2017)
- Increasing urbanization: leads to less space (to park own car), usually public transport has faster connections compared to driving in bigger cities
- Increasing user belief: Travelling time should be quality time (Mobility4EU 2017)
- Increasing demand in sharing-solutions (bike, car) (CarIT 2016)
- Disinclination to give up freedom with cars (ORB 2017)

Economic trends facilitating a realization of the scenario:

- Digital platform-based business models are easier to scale up (Investopedia 2017)
- Increasing cost-efficiency in connectivity, sensor-based and automation, electrification technologies for earlier return on investments

Political trends facilitating a realization of the scenario:

- Promotion of sustainable transport solution across EU (Horizon 2020)
- Increasing cross-border inter-modality (Mobility4EU 2017)

Technology trends facilitating a realization of the scenario:

- Intelligent matching and route optimization, journey planning algorithms
- Connected, automated & electrified driving technologies are advanced (Mobility4EU 2017)
- Connectivity
- Big data analytics for traffic and network management
- Block chain

3.2.4 References

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3.3 Autonomous Driving

by Mathias Müller, Jakob Michelmann

Within this future scenario autonomous driving is in the phase of deployment. Approx. 30 % of all vehicles sold will have autonomous driving capabilities (level 4–5). This results in tremendous shifts for the value chain. Technology providers will struggle with traditional car manufacturers and ride-sharing/ ride-hailing companies for the leadership and value added along the value chain. At present a lot of alliances are formed amongst the stakeholders and the future value chain is not decided yet.

3.3.1 Description of the Future Use Case Scenario

In 2030, autonomous driving is technologically well established in all driving scenarios for passenger and freight transport. Approximately 30 % of all vehicles sold have autonomous driving capabilities (level 4–5) (VTPI 2017), i. e. the vehicles are able to handle all aspects of dynamic driving situations without any manual intervention. The huge requirements regarding sensors and electronics for level 3 autonomy could partially already be handled in 2017 (Audi 2017, Tesla 2017). Level 4 autonomy and upwards require an upgrade of infrastructure concerning information and communications technology (5G networks) which will be available between 2020 and 2025.

All major car manufacturers are present in the market with more than one model. Deployment of the new technology into the car fleet is slow. In 2030 only 15% of the vehicle fleet will have it installed, since autonomous driving is, at least in the private sector, at present not sufficiently deployed to replace an old vehicle (VTPI 2017).

Software will be the biggest differentiator for OEMs, which gives the opportunity for companies new to the vehicle market to enter as service providers, technology suppliers, or challenge established manufacturers with complete cars. By 2030 first market consolidations will have happened in the field of autonomous taxis and micro-driving.

Although the majority of people will still own a private car, their number is expected to decrease over the 2020s (ECF 2016). Especially in urban areas autonomous taxis and micro-driving are a cost-efficient alternative. Nevertheless, the vehicle market will not shrink at first, due to the increased demand for individual on-demand transport. Still, in less congested areas people unable to drive - like adolescents and disabled people - benefit tremendously from better mobility with an increased participation in social and economic life. Another aspect in this sector is the free time gained during longer road trips or commuting. This time span can be used either for productive work or personal relaxation which is another entry point for service providers into the market. Utilizing autonomous driving helps to optimize traffic flow, which leads to increased road capacity, reduced fuel consumption and therefore reduced costs and pollution. The community and the individuals will benefit strongly from increased safety standards. Despite a growing traffic density fewer people get injured in car accidents (VDA 2015). Self-driving cars will have proven to be at least as reliable as and much safer than manually driven cars. For commercial freight transport the cost advantage of not having to rely on a driver is substantial. Thus, adaption in this segment is even higher than in the private sector (ITF 2017).

In private passenger transport autonomous driving will have trickled down into midsize vehicles but remains a moderate premium feature. In this case Level 4 autonomy will dominate since a considerable amount of drivers still wants to ride manually on occasion.

For commercial applications, either freight transport or passenger transport, level 5 autonomy will be established. The first to adopt are trucks for long distance routes due to their relatively simple road conditions. For urban purposes the scenario is more complex and therefore adoption is slower. Nevertheless, level 5 vehicles will be available on a large scale and used for delivery, taxi services, and micro-driving services.

3.3.2 Analysis and assessment of the impact on present industry structures

All major industry players have been actively working in the field of autonomous driving for many years. Most car vendors, e.g. Mercedes, BMW, Audi (VW), PSA, Lexus (Toyota), Infinity (Nissan), Cadillac (General Motors), Volvo, Ford, Hyundai, Tesla, have level 2 autonomy systems commercially available. AUDI recently introduced the first production car with level 3 autonomy for driving in traffic jams on highways up to a speed of 60 km/h (AUDI 2017). All competitors announced comparable systems for the next two years. The industry expects full autonomy around 2021. First, it will be deployed on highways and

later during the decade in urban areas due to its more complex environment (VB 2017). Prototypes of level 4 cars are being extensively tested on public roads.

The current market is characterized by a network of strong strategic and technological collaborations. Electronics companies like NVIDIA and Intel are investing heavily into spreading their technology across the automotive industry. They supply the technology for artificial intelligence and machine learning, which is necessary to handle all the sensor input and navigation in a self-driving car.

Additionally, new players are entering the market. These include Software companies like Waymo (Alphabet/Google), Baidu and Apple, start-ups like nuTonomy, suppliers like ZF and Delphi or service providers like UBER and Lyft. They are either supplying software solutions or developing complete system platforms in cooperation with car manufacturers or on their own.

- European car manufacturers are investing heavily to be able to deploy autonomous driving into their fleet, starting with premium passenger cars and trucks. The companies are beginning to sell cars with level 3 capabilities and cars of higher levels of autonomy being already tested. In Germany several public test fields exist or are under development. Recently an international collaboration for a public test area was announced between Germany, France, and Luxemburg (BMVI 2017). The landscape of self-driving cars in Europe is dominated by the big manufacturers and suppliers.
- Worldwide there are different approaches to the topic. Japanese companies like Toyota and Honda took a very conservative one but their efforts are increasing. Toyota announced an investment of \$1 billion into their Toyota Research Institute in 2016 (BI 2016). In the United States the market is more diverse. It is a mixture of long established car manufacturers (GM, Ford, Chrysler), established software/technology companies (Apple, Waymo, NVIDIA, Intel), and start-ups (Lyft, UBER). Autonomous cars are being tested on public roads in several states (California, Arizona, Michigan, Nevada). The market in China is comparably diverse. Legislation regarding testing and deployment is not yet in place, but politics gave strong signals, that they are willing to push the technology (20AD 2017).

The value chain will see significant changes. A large scale deployment of car sharing/pooling with automated taxis would change the ownership model, as people might not need a car of their own anymore. To a certain degree this can already be observed in a lot of urban areas with car sharing solutions in place. An increase in road safety and decrease in severe injuries will lead to dropping insurance rates or premiums for cars without certain autonomy features.

The freed up time will further increase targeted in-car advertising and sales of CRM data (B2B revenue streams). In addition to this, new in-car content services, both work and entertainment related, will increase. This might be an opportunity for consumer electronics to expand their reach (McK 2014). Concerning the handling of data streams a division is imaginable. The large amount of data generated by the cars (upstream) will stay under the sovereignty of car companies, whereas the downstream will be handled by technology companies with their content services. This is comparable to the computer industry with its division between hardware suppliers and software companies.

In the field of logistics and industry services lots of applications are imaginable in urban areas and on long distance routes. Most of them lead to a considerably reduced demand in truck drivers. The lack of drivers hampers the growth of logistics at the moment. Thus, self-driving trucks could give new impulses for the industry on the one hand but will lead to job losses on the other (ITF 2017).

Fully autonomous vehicles rely heavily on infrastructure, i. e. digitalization of roads for car2x communication or capable mobile networks. It is not clear how this will be handled. In case of subscription models the introduction of new market participants is possible.

Business models will shift further towards car sharing, autonomous taxi services, and micro driving services. The market already responds to that in form of development of own car sharing services (e.g. Car2Go by Daimler, Maven by GM) and alliances to new ride sharing solutions (e.g. Lyft, UBER) are formed. Not to forget, established car rental companies (e.g. Hertz, Avis, Sixt), which are experienced in handling large fleets, are eager to form alliances with car manufacturers (e.g. Sixt/ BMW with DriveNow) or with technology companies like Apple (Hertz) and Waymo (Avis) (Jal 2017). This in part might lead to OEMs becoming white label manufactures and providing engines, chassis – up to complete vehicles (Del 2017). Thus, the industry is well aware of the upcoming changes. The widespread introduction of autonomous driving makes the work on new highly sophisticated technologies (digitalisation, mobility services, artificial intelligence/deep learning, and many more) necessary. All these technology fields are more or less completely new to car manufacturers and pose tremendous challenges for them. Thus, partnerships with technology companies are vital. All players identified these necessities and are involved in a large amount of collaborations in all directions. In the future a division, comparable to the computer industry, is highly possible with hardware suppliers on one side and software companies on the other. In that way software becomes a main differentiator.

European car manufacturers and in particular German manufacturers today are technologically well established since they are dominantly based in and more or less form most of the premium segment, where technology is a main differentiator. This makes them attractive employers who attract many skilled workers and talents. Additionally, they are well funded.

In the future the competition is going to see significant shifts. The 15 biggest technology companies today already have a bigger market capitalization than the 25 biggest car companies (KPMG 2018). The vast majority of those tech companies are based in the US and China and they are investing heavily in autonomous driving. Both governments set up well financed funding programs (BI 2017, for 2016). The mindset of competition purely between car companies has to change. This is especially true for the Chinese market where 47 % of customers rank technology companies as most trustworthy regarding to autonomous driving (KPMG 2018).

3.3.3 Global trends and technology developments facilitating a realization of the Use Case

The worldwide population in urban areas is going to grow considerably (e. g. Paris from 10.8m up to 11.8m; New York 18.6 up to 19.9m; Shanghai from 23.7m up to 30.8m) (UN 2015) and the annual number of cars sold remains growing as well (McK 2017). This combination leads inevitably to more congested roads unless new mobility concepts are developed and is fertile ground for new mobility services. Beyond that, autonomous driving will help to make the traffic more efficient and will counteract the increasing congestion. Due to an increase in car sharing services the rate of car ownership might drop by 80 % but will be replaced by those shared cars (Business-Insider 2017b) leading to the same or even more congestion (BI 2017b). Politics starts to act in dense urban areas. One approach is the establishment of congestion taxes and other instruments to reduce traffic in metropole city centers (ToL 2006)

The bulk of the technology required for self-driving cars is not futuristic, but it is the combination of different sensors with advanced computer vision systems that makes it work. Many of the vehicles use Lidar (Light Detection and Ranging) – a rotating laser, that continually scans the environment around the car. Traditional radar is also used for detecting distances to objects and cars, as are various cameras, accelerometers, gyroscopes and GPS, which are all used in conjunction to build a 3D picture of the environment around the vehicle.

The most complex part of an autonomous car is the software that collects the data, analyses it and actually drives the vehicle. It has to be capable of recognizing and differentiating between cars, bikes, people, animals and other objects as well as the road surface, where the car is in relation to built-in maps and be able to react to the environment. As in many areas the systems have to shrink further in physical size and costs to get widespread deployment. On a positive note, hardware capabilities regarding artificial intelligence and deep learning made big leaps in recent years (TD 2017).

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