European Commission

October 2020

Advanced Technologies for Industry – Product Watch

IoT components in connected and autonomous vehicles

This report was prepared by Mark Enthoven (Capgemini Invent).

EUROPEAN COMMISSION

Executive Agency for Small and Medium-sized Enterprises (EASME)
Unit A.1.2 — COSME

E-mail: EASME-COSME-ENQUIRIES@ec.europa.eu

Directorate General for Internal Market, Industry, Entrepreneurship and SMEs
Unit F.1 — Industrial Strategy and Value Chains
Unit F.2 — Social Economy

E-mail: GROW-ATI@ec.europa.eu

European Commission
B-1049 Brussels

LEGAL NOTICE

Print	ISBN 978-92-9460-001-1	doi: 10.2826/70918	EA-04-20-320-EN-C
PDF	ISBN 978-92-9460-000-4	doi: 10.2826/640757	EA-04-20-320-EN-N

October 2020

Table of contents

Section 1

1. Background and objectives of the report

Background

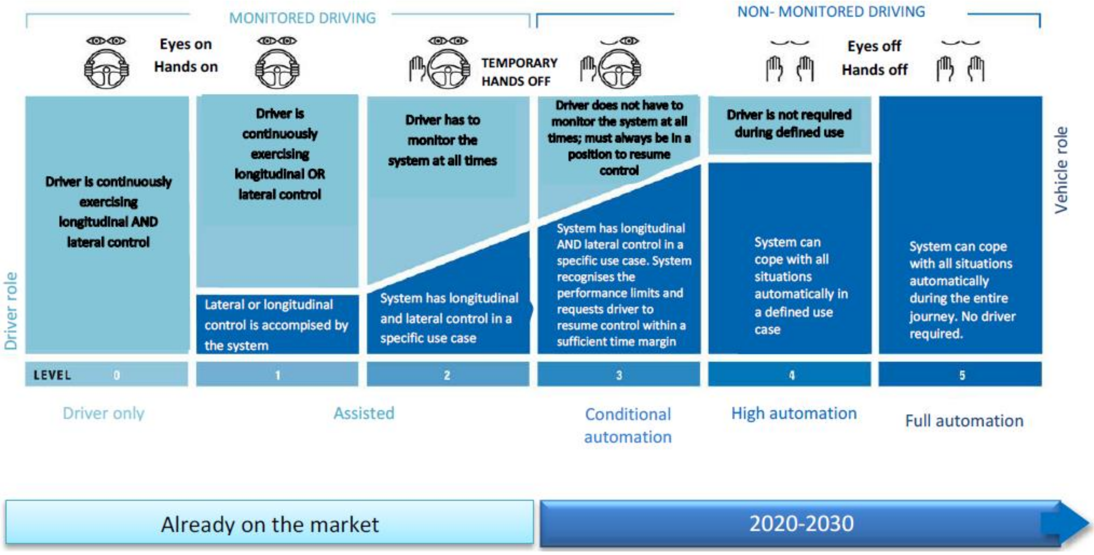
The Product Watch Reports have been developed in the framework of the 'Advanced Technologies for Industry' project and serve to identify and analyse 15 promising advanced technology (AT) based products and their value chains, with an assessment of the strengths and weaknesses of the EU positioning.

Promising AT-based products can be defined as "*enabling products for the development of goods and services enhancing their overall commercial and social value; embedded by constituent parts that are based on AR/VR, Big Data & Analytics, Blockchain, Cloud, Artificial Intelligence, the Internet of Things (IoT), Mobility, Robotics, Security & Connectivity, Nanotechnology, Micro-nanoelectronics, Industrial Biotechnology, Advanced Materials and/or Photonics; and, but not limited to, produced by Advanced Manufacturing Technologies*."

1.1 Background on IoT components in connected and autonomous vehicles

The European automotive industry, representing 6.1% of total EU employment and 7% of EU GDP, is facing a digital revolution in the 21st century in the form of the connected and autonomous vehicle (vehicle to everything – which includes vehicle-to-vehicle, vehicle-to-infrastructure, vehicle-to-network, vehicle-to-cloud, vehicle-to-device and vehicle-to-pedestrian). With the integration of Internet of Things (IoT) components into vehicles, they become part of a network. Vehicles can communicate with each other, with the surrounding infrastructure and with other drivers. Gradually the technologies of IoT for connected and autonomous vehicles (combined with the evolution of Artificial Intelligence and communication networks) support assisted driving (steering, acceleration and brake support), then conditional automation (the system has longitudinal and lateral control in a specific use case), followed by high automation (the system can cope with all situations automatically in a defined use case) and finally full automation (the system is able to drive the vehicle in all conditions; no driver is required) (illustrated below).[1]

Figure 1: Different levels of automation [2]



Source: European Commission (2018)

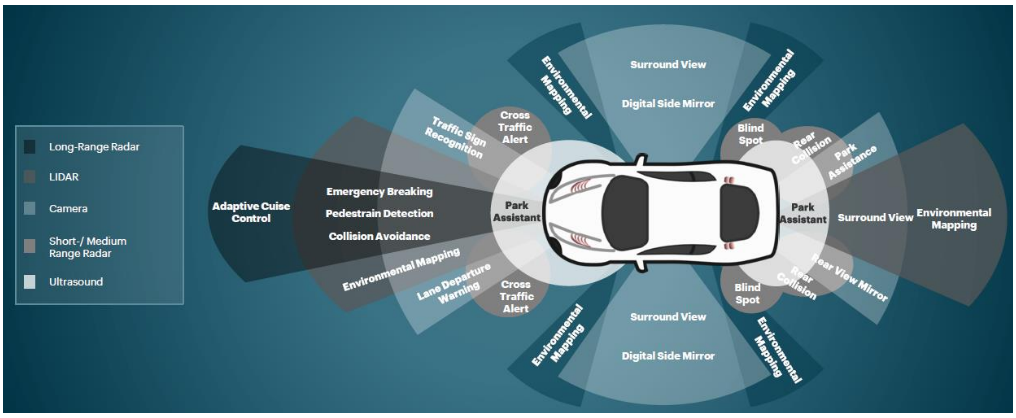
[1] European Automobile Manufacturers Association (2019), Automated driving: Roadmap for the deployment of automated driving in the European Union.
[2] European Commission (2018) On the road to automated mobility: An EU strategy for mobility of the future: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2018:0283:FIN:EN:PDF

The current and future evolution of these connected and autonomous vehicles will have a significant impact on mobility in Europe, as well as on its industry and economy. The benefit of this digital automotive evolution will be mainly safer, more accessible as well as sustainable transport.[3]

First, connected and autonomous vehicles are expected to have a positive impact on road safety. About 90% of the 40,000 yearly road fatalities in the EU are caused by human error.[4] Automotive technologies enabled by connected and autonomous vehicles that can improve safety include:

- eCall: automatically dials the European emergency number 112 in case of a road accident and transmits the vehicle's location to emergency services.[5]
- Connected and autonomous driving technologies will significantly improve traffic flows, reduce the incidence of critical situations, optimise the handling of corresponding scenarios, relieve the pressure on drivers and the environment and support jobs and growth.[6]
- Electronic Stability Control: allows for stabilisation of the vehicle and prevention of skidding. This is estimated to reduce the number of fatalities by 15-20%.[7] Like Electronic Stability Control, several other driver assistance systems (enabled by IoT, depicted in Figure 2 below) aid safety of the driver as well as his surroundings.
- Artificial situational awareness: for a connected and autonomous vehicle, artificial situational awareness can allow for safer traffic decisions. This is, for example, enabled by mental models to predict future states of the driving environment[8], and is further supported by improved connectivity of the vehicle. [9]

Figure 2: Advanced Driver Assistance Systems in the connected Car aiding safety, as enabled by IoT technology



Source: Alonso Raposo M. (2018)

Secondly, connected and autonomous vehicles will make mobility more accessible for elderly people and those with disabilities. This goes especially for people living in areas with dispersed demand for public transport, such as suburbs and rural areas.[10]

Finally, connected and autonomous vehicles can also have a positive impact on sustainability in multiple ways, in the form of reduced emissions and energy savings:

- Decrease of congestion: as congestion leads to a waste of fuels, connected and autonomous vehicles can reduce congestion via improved coordination through their networks.[11]

---

[3] European Commission (2018). On the road to automated mobility: An EU strategy for mobility of the future
[4] European Commission (2020). Mobility and transport: https://ec.europa.eu/transport/themes/its/road_it.
[5] European Commission (2016). The interoperable EU-wide eCall: https://ec.europa.eu/transport/themes/its/road/action_plan/ecall_en
[6] European Commission (2016). A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility.
[7] European Comission (2020). Mobility and transport: https://ec.europa.eu/transport/themes/its/road_it.
[8] McAree (2017) Towards artificial situation awareness by autonomous vehicles
[9] OECD (2018). Safer Roads with Automated vehicles?
[10] European Automobile Manufacturers Association (2019). Automated driving: Roadmap for the deployment of automated driving in the European Union
[11] Anderson, et al. (2016). Autonomous Vehicle Technology A Guide for Policymakers

- Smoother driving: higher levels of automation and driving efficiency will result in an increase in fuel efficiency.[12]`
- Pooled-ride services: the rise of connected and autonomous vehicle technology also allows for the growth of the business of pooled-ride services through services as Uber Pool and Lyft Shared (besides the traditional carpooling), which make use of centralised coordination of fleets to group together travellers moving to and from neighbouring locations[13]. While shared driving as a business model also benefits from the rise of connected and autonomous vehicle technology, in the relation to sustainability it can be stated that, "*Transportation Sustainability follows from more people in fewer vehicles, (and) not necessarily automation*"[14].

On the flipside, the rise of connected and autonomous vehicles also raises concerns regarding cybersecurity, liability, software and hardware reliability and data privacy of these technologies.[15] From the point of view of safety, autonomous vehicles lack human abilities to be able to pick up on subtle signs of other human road users.[16] Furthermore, to fairly measure the environmental impact of connected and autonomous vehicles, their complete lifecycle needs to be taken into account instead of solely fuel consumption.[17]

While vehicle manufacturers are investing heavily in such new technologies (amongst which autonomy and connectivity are major topics), with a yearly spend of €57.4 billion on research and development, the European Commission is acting as a regulator as well as a supporter.[18] It does so by setting up new policies and targets,[19] informing consumers, having proactive discussions with the main stakeholders, and promoting knowledge sharing in the EU.[20] The higher goal therein is reaping the potential benefits of the ongoing connected and autonomous vehicle evolution, while also handling the related challenges and keeping up with the pace of the automotive industry, and finally to support the European automotive industry to remain competitive with those in other parts of the world.

1.2 Objectives of this report

The objectives of this report are to map out the value chain of IoT for connected and autonomous vehicles and the key actors, to provide an analysis of the EU's competitive positioning therein, and to indicate related challenges and opportunities. With an analytical and empirical approach, this report aims to provide relevant stakeholders a clear overview of the current and future landscape of these technologies in the EU. Analyses were based on desk-research and interviews with subject matter experts.

[12] Williams (2020). Assessing the Sustainability Implications of Autonomous Vehicles: Recommendations for Research Community Practice
[13] ITU News (2019). Future Networked Cars: Safe, self-driving and shared
[14] Merlin (2019) Transportation Sustainability follows from more people in fewer vehicles, not necessarily automation
[15] European Comission (2019). Connected and automated mobility in Europe
[16] Müller (2016). The social behavior of autonomous vehicles
[17] Gawron, Keoleian, de Kleine, Wallington, & Kim, 2018). Life cycle assessment of connected and automated vehicles: Sensing and computing subsystem and vehicle level effects
[18] European Automobile Manufacturers Association (2019). Automated driving: Roadmap for the deployment of automated driving in the European Union
[19] European Commission (2018). Europe on the Move: Commission completes its agenda for safe, clean and connected mobility
[20] European Commission (2018). ARCADE - Supporting the CAD Initiative

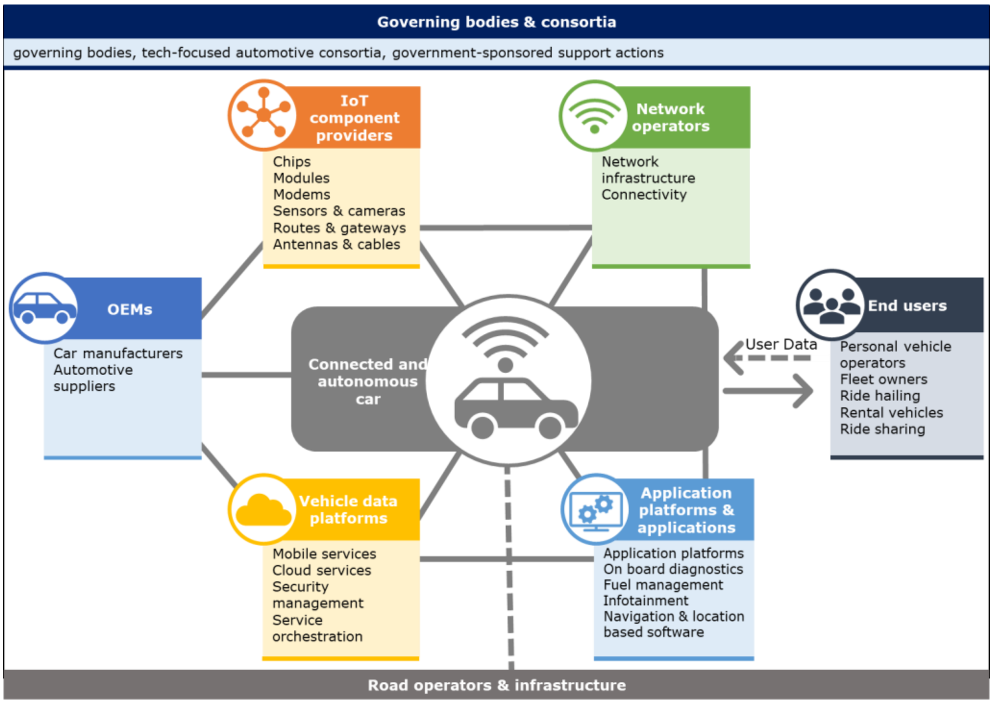
Section 2

2. Value chain analysis

2.1 Value chain structure

The value chain structure for connected and autonomous vehicles in the European landscape is outlined in Figure 3, and allows us to plot the main stakeholder groups and their respective contributions to the chain. The chain consists of parts enabling the connected and autonomous vehicle and supporting the connection of vehicle-to-everything and shows the non-linear cooperation between actors in jointly realising (parts of) the high-level end-product – the connected and autonomous vehicle. Furthermore, the end users, i.e. the various types of customers, facilitate a reverse value stream with their user data, which is then collected by the various stakeholders in the model through vehicle to everything connectivity, rendering the various possible connected services as well as data monetisation. The IoT hardware and software together with connected and autonomous driving software allows a vehicle to sense, plan and act.

Figure 3: High-level connected and autonomous vehicle value chain for the EU



Source: Capgemini Invent

Although traditionally the stakeholders for the automotive industry consisted mainly of Original Equipment Manufacturers (OEMs), it is expected that total revenue in the value stream as well as the number of parties involved will grow, due to the rise of connected and autonomous vehicle related technologies and services. To illustrate: although in 2017, ~€3,000 billion global automotive revenues were mainly generated through traditional businesses (vehicle sales) and aftermarket services, it is expected that in 2030 global automotive revenues will increase to ~€5,500 billion.[21]

These new revenues will mostly originate from disruptive business models such as mobility as a service (MaaS) or data-enabled services. New entrants to the markets capture a part of the increased revenue springing from connected and autonomous technologies. Moreover, OEMs are getting increasingly involved in frameworks such as vehicle data platforms. This causes the blurring of lines between the different actors in the value stream. For example, Alphabet's Waymo shows us that these lines can even

[21] McKinsey & Company (2019). Race 2050 - a vision for the European automotive industry

blur over multiple parts of the value chain (covering every step from IoT components to applications for connected and autonomous vehicles).

Through connected and autonomous vehicle technology, more and more digital technologies are being enabled for vehicles. For example, over the course of 2020, 90% of new car sales are expected to include telematics packages,[22] and 100% of new cars are expected to be connected by 2022.[23] As connected and autonomous vehicle technologies also result in more data and connections from and to vehicles, network operators and data hosting services will also become more and more crucial for vehicles. Subsequently the data is stored on vehicle data platforms, to be utilised through services and applications enabled by application platforms. In the long run, 30%-40% of the value chain will be captured by digital services, through digital platforms.[24] The increase in digital technologies enabled for vehicles can also be explained on the end user side: especially millennials, making up over half of the world's population, expect their mobility experience to be seamlessly integrated.[25]

The road operators and infrastructure act as enablers for the other parts of the value chain and vehicle-to-infrastructure connectivity. A smart infrastructure supporting connected and autonomous vehicles and powered by IoT could consist of, for example, radio transmitters replacing traffic lights, as well as roadside sensors registering real-time data on weather and traffic.[26]

Furthermore, overarching the main part of the connected and autonomous vehicle value chain are the national and international governing bodies (which act as regulators and supporters) and the automotive consortia.

First, in their role as regulators, the governing bodies develop policies, standards and legislation (for connected and autonomous vehicle technology, for example, this relates to vehicle safety, product liability and data security).[27] [28] Furthermore public bodies provide support by developing roadmaps and strategies together with the industry, and they co-fund projects and set up communication channels as well.[29] These parties, such as the European Parliament, are involved in the value chain in (amongst others) regulations such as those concerning data security and privacy linking to the vehicle's connectivity, driver safety in relation to autonomous technology,[30] as well as providing a supportive testing ground and regulation for vehicle to everything connectivity.[31]

Secondly, encompassing the value chain are automotive consortia, which promote knowledge sharing regarding best practices and strive to steer legislation.[32]

2.2 Key actors in the value chain

With a focus on Europe, the main stakeholders relating to the various groups depicted in the connected and autonomous vehicle value chain are mapped out in the tables below, with the exception of the parts of 'road operators and infrastructure' and 'end users'. Selection of the various parties depicted in these lists is non-exhaustive, and with the aim to provide a general overview of the main parties per stakeholder group on a European as well as global level. And to distinguish between EU and non-EU companies, those with their headquarters located in the EU are indicated in blue.

OEMs

The recently changing business models for vehicles in relation to connected and autonomous technology can be considered challenging to some OEMs. This can be seen in topics such as: the value of the new related services to the customer, as well as data privacy. Some OEMs have already worked out the related business cases, while others are still lagging to some extent.[33]

The main OEMs depicted below, which are working (in greater or lesser extent) with connected and autonomous vehicle technologies, are derived of, amongst others, members of the European Automobile

[22] European Commission (2017). The race for automotive data
[23] Strategy& (2018). Digital Auto Report 2018
[24] European Commission (2017). The race for automotive data
[25] Strategy& (2018). Digital Auto Report 2018
[26] Oliver (2018). To Make Self-Driving Cars Safe, We Also Need Better Roads and Infrastructure
[27] Mcquinn, A., Castro, A. (2018). A Policymaker's Guide to Connected Cars
[28] European Commission (2020). Connected and automated mobility in Europe
[29] European Commission (2017). Automotive industry: Policy and strategy; (UNECE, 2019). Introduction on UNECE
[30] Euopean Parliament, (2019). Self-driving cars in the EU: from science fiction to reality, https://www.europarl.europa.eu
[31] European Union (2016). A European strategy on Cooperative Intelligent Transport Systems
[32] Car Connectivity Consortium (2019). Car Connectivity Consortium, https://carconnectivity.org/
[33] Deloitte (2018). Disruption in the automotive industry

Manufacturers Association;[34] this also consists of several non-EU automotive giants. Additionally, Tesla is added as OEM, being recognised as one of the main global players in connected and autonomous vehicle technology.[35] For each of the OEMs, a link is provided to their webpage on connected and autonomous technology (based on availability).

Table 1: OEMs working with connected and autonomous vehicle technology

Company	Headquarters' location	Website
BMW group	Germany	https://www.bmw.com/en/innovation/connected-car.html and https://www.bmw.com/en/automotive-life/autonomous-driving.html
Daimler	Germany	https://www.daimler.com/innovation/case-2.html
Volkswagen Group	Germany	https://www.volkswagenag.com/en/news/stories/2019/12/the-champions-league-of-autonomous-driving.html and https://www.volkswagenag.com/en/news/stories/2018/10/connected-cars-software-development-at-volkswagen.html
Groupe PSA	France	https://www.groupe-psa.com/en/automotive-group/innovation/connected-car/
Groupe Renault	France	https://group.renault.com/en/innovation-2/
Fiat Chrysler Automobiles	Italy	https://www.fcagroup.com/en-US/innovation/Pages/future_mobility.aspx
Volvo	Sweden	https://www.volvogroup.com/en-en/about-us/organization/other-entities/volvo-group-connected-solutions.html
DAF Trucks	The Netherlands	https://www.daf.com/en/about-daf/innovation
Honda Motor	Japan	https://global.honda/innovation/
Toyota	Japan	https://global.toyota/en/mobility/case/
Hyundai	South Korea	https://www.hyundai.com/worldwide/en/company/news/news-room/news/hyundai-motor-reveals-future-vision-for-connected-cars-0000006598
Jaguar Land Rover	United Kingdom	https://www.jaguar.com/news/connected-autonomous-vehicle-technology.html
Ford	USA	https://corporate.ford.com/company/autonomous-vehicles.html
General Motors	USA	https://www.gm.com/our-stories/self-driving-cars.html
SAIC motor	China	https://saicic.com/our-capabilities/#ADS
Tesla	USA	https://www.tesla.com/autopilot https://www.tesla.com/support/connectivity

Source: Capgemini Invent

IoT component providers

As depicted in Figure 2, IoT components supporting connected and autonomous automotive technology comprise a wide range of technologies, different sensors (such as radar and LIDAR), cameras, modems, chips, semiconductors and antennae. The EU's €1.75 billion sponsoring of joint research projects shows the significance of European market entities for IoT components for connected and autonomous vehicles starting from 2019.[36] Global players are part of the chips and semiconductor market too, which also serve their products as automotive IoT components, such as ASML, Intel, Samsung and the Taiwan Semiconductor Manufacturing Company. Furthermore, other stakeholders have integrated IoT into their business, for example Waymo (formerly known as the Google self-driving car project) and Tesla.[37] Finally, with respect to LIDAR, major global companies Hexagon AB, Velodyne and SICK AG have been added.

[34] ACEA (2019). ACEA's Members, https://www.acea.be/about-acea/acea-members
[35] Forbes (2019). Tesla demonstrates the power of the internet of things
[36] Dahad (2019). EU approves $2 billion for IoT, connected car research
[37] The Economist (2020). How ASML became chipmaking's biggest monopoly

Table 2: Main IoT component providers for automotive

Company	Type of IoT components	Headquarters' location	Website
TTTech	Sensors	Austria	https://www.tttech.com/
Soitec	Chips, compound materials	France	https://www.soitec.com
Valeo	e.g. Sensors, antennae	France	https://www.valeo.com
Carl Zeiss	Optical equipment	Germany	https://www.zeiss.com
Continental	Sensors (e.g. for tires)	Germany	https://www.continental.com/en
Infineon	Semiconductors, sensors	Germany	https://www.infineon.com
HELLA Aglaia	Sensors	Germany	https://hella-aglaia.com/
OSRAM	Optical equipment	Germany	https://www.osram.com/am/
Robert Bosch	Semiconductors, sensors	Germany	https://www.bosch.com
Sick AG	Sensors	Germany	https://www.sick.com/ag
ZF	Sensors	Germany	https://www.zf.com/mobile/en/homepage/homepage.html
ASML	Chips, semiconductors	Netherlands	https://www.asml.com
Hexagon	Sensors	Sweden	https://www.hexagonmi.com/solutions/industries/automotive
Samsung	Chips, semiconductors	South Korea	https://www.samsung.com
ST Microelectronics [38]	Semiconductors	Switzerland	https://www.st.com/content
Taiwan Semiconductor Manufacturing Company	Chips, semiconductors	Taiwan	https://www.taiwansemi.com
Intel	Chips, semiconductors	USA	https://www.intel.com
NVIDIA	Chips	USA	https://www.nvidia.com
Tesla	Various IoT components	USA	https://www.tesla.com
Velodyne	Sensors	USA	https://velodynelidar.com
Waymo	Sensors, chips, optical equipment	USA	https://www.waymo.com

Source: Capgemini Invent

Network operators

The main network operators who facilitate IoT and connected and autonomous vehicles, as listed below, are members of ETNO (European Telecommunications Network Operators), 5GAA (5G Automotive Association), and GSMA (Global System for Mobile Communications Association) with significance in terms of sales in 2019.[39] In 2019, the European Commission indicated 5G as the to-be network supporting its connected mobility roadmap.[40] The networks of these stakeholders facilitate the communication between the connected and autonomous vehicles and its surroundings in a vehicle to everything setting. Since the amount of data a vehicle produces over time is continuously increasing –

[38] ST Microelectronics also has a significant presence in the EU, but has its headquarters located in Switzerland
[39] Forbes (2020). The world's largest public companies
[40] European Commission (2020). Connected and automated mobility in Europe

about 25 gigabytes per hour for modern non-autonomous vehicles, and up to 3600 gigabytes per hour for autonomous vehicles[41] – network providers are challenged to keep up with the capacity of their networks. In support thereof, the Automotive Edge Computing consortium focuses on this challenge to "*drive the evolution of edge network architectures and computing infrastructures to support high volume data services in a smarter, more efficient connected-vehicle future*". [42]

Table 3: Main network operators in the automotive IoT space

Company	Headquarters' location	Website
Proximus	Belgium	https://www.proximus.com
Vivendi	France	https://www.vivendi.com
Orange	France	https://www.orange.com
Deutsche Telekom	Germany	https://www.telekom.com
Telecom Italia	Italy	https://www.telia.com
KPN	Netherlands	https://www.kpn.com
Telefónica	Spain	https://www.telefonica.com
Telia	Sweden	https://www.telia.com
China Mobile	China	https://www.chinamobileltd.com
Softbank	Japan	https://www.softbank.com
Telenor[43]	Norway	https://www.telenor.com
Vodafone[43]	United Kingdom	https://www.vodafone.com
AT&T	USA	https://www.att.com
Verizon	USA	https://www.verizon.com

Source: Capgemini Invent

Vehicle data platforms

In terms of vehicle data platforms, a distinction should be made between vehicle big data marketplaces and central data server platforms:

Vehicle big data marketplaces: The data platforms listed in the table below focus on gathering data from IoT devices, in support of connected and autonomous vehicles and their related applications, instead of brokering gathered data for external analysis. Vehicle data marketplaces such as Caruso from the USA, the Automat project in the EU and Otonomo from Israel are excluded from the overview below.

Central data server platforms: IBM Cloud, Microsoft Connected Vehicle, Alibaba Cloud and other such central data server platforms collect data from the internal vehicle network and store it on a server, which is often controlled by the OEM.[44] Furthermore, in the recent years a platform such as GM's OnStar has transformed from an IoT platform only focussing on driver safety into a platform offering a broader range of services on the basis of vehicular data.[45]

A number of these platforms are developed by OEMs such as BMW CarData and Hyundai Blue Link. Other platforms are developed by companies operating mainly in the digital space such as Amazon Web Services and Alibaba Cloud which are used in partnerships with OEMs, for example the collaboration between Microsoft and Volkswagen.[46] Besides gathering and hosting data, all the providers mentioned below also offer data analytics services.

[41] Fleutiaux (2018). Vehicle data is more profitable than the car itself
[42] AECC. Mission Statement
[43] Both Telenor and Vodafone also have a significant presence in the EU
[44] European Commission (2018). Access to digital car data and competition in aftersales services
[45] Dix (2017). 12M connected cars gives General Motors a massive IoT fleet
[46] Volkswagen (2019). Microsoft and Volkswagen jointly develop the Automotive Cloud

Table 4: Vehicle data platforms

Vehicle data platform (OEM)	Headquarters' location	Website
BMW Car Data	Germany	https://www.bmwgroup.com/en/innovation/technologies-and-mobility/cardata.html
Ericsson Connected Vehicle Cloud	Sweden	https://www.ericsson.com/en/portfolio/iot-and-new-business/iot-solutions/iot-for-automotive/connected-vehicle-cloud
Alibaba Cloud	China	https://www.alibabacloud.com/
Mobility Service Platform (Toyota)	Japan	https://www.toyotaconnected.co.jp/en/service/connectedplatform.html
Hyundai Blue Link	South Korea	https://www.hyundai.com/in/en/hyundai-story/technology/blue-link
Amazon Web Services	USA	https://aws.amazon.com/automotive/
IBM Cloud	USA	https://www.ibm.com/internet-of-things/explore-iot/vehicles/automobiles
Microsoft Connected Vehicle	USA	https://www.microsoft.com/en-us/industry/automotive/connected-vehicles
OnStar (General Motors)	USA	https://www.onstar.com
Tesla (Tesla)	USA	https://www.tesla.com

Source: Capgemini Invent

Application platforms and applications

Application platforms: Applications for automotive fuelled by a vehicle's data, as obtained through IoT components, are hosted either on a third-party platform (e.g. Apple Carplay, Android Auto, Blackberry's QNX; on the basis of data requirements of the installed applications on these platforms), or on an OEMs software platform (such as General Motors' OnStar or Ford Sync, which coincidentally both make use of QNX).[47] These platforms allow developers to develop applications through developer kits, and let their applications utilise APIs to access the data hosted on the vehicle data platforms. Their respective applications are in turn available on dedicated application stores and can link to their respective mobile applications as well.[48] Connection between a phone and the vehicle's API can otherwise also be established through apps dedicated to creating such a connection, such as the 3rd party app Mirrorlink, or those from OEMs such as Renault's R-LINK. While most major OEMs have their own application platform, they often also support the two main platforms being Android Auto and Carplay.

Table 5: Application platforms

Application platform (company)	Application / application platform	Headquarters' location	Website
Mercedes me	OEM application platform	Germany	https://www.mercedes-benz.com/en/mercedes-me/
Volkswagen Car-Net	OEM application platform	Germany	https://www.vwcarnetconnect.com
AliOS	3rd party application platform	China	https://www.alibaba.com
T-connect (Toyota)	OEM application platform	Japan	https://www.toyota-connect.com
Android Auto (Google)	3rd party application platform	USA	https://www.android.com/auto/
Carplay (Apple)	3rd party application platform	USA	https://www.apple.com/ios/carplay/
Ford Sync	OEM application platform	USA	https://www.ford.com/technology/sync/

47 David (2016). 4 mobile platforms for the auto industry: Get up to speed!
48 European Commission (2018). Access to digital car data and competition in aftersales services

Microsoft Connected Vehicle	3rd party application platform	USA	https://www.microsoft.com/en-us/industry/automotive/connected-vehicles
OnStar (General Motors)	OEM application platform	USA	https://www.onstar.com
QNX (Blackberry)	3rd party application platform	USA	https://blackberry.qnx.com/

Source: Capgemini Invent

Applications: vehicle applications cover a broad range of uses. Amongst those are the following main categories, with some examples:

- On-board diagnostics: myCARFAX, Drivvo
- Navigation: Google Maps, TomTom
- Fuel prices: Fuelio, Gasbuddy
- Infotainment: YouTube and Netflix for videos, Spotify for music
- Ride hailing and car sharing: Uber and Lyft for ride-hailing, and car2go for carsharing
- Parking: Parkify to find parking spots, and Car Finder AR for finding your car

Governing and supporting bodies

Governing Bodies: On a European level, the European Commission regulates and supports the automotive industry in the EU, and the European Council for Automotive R&D coordinates proposals for EU funded research.[49] On a global level, the United Nations regulates and supports the automotive industry in its member countries through the World Forum for the Harmonization of Vehicle Regulations.[50]

Consortia: Industry consortia in the table below consist of those encompassing solely automotive OEMs, and those spanning across industries. Indicated in light blue are the global consortia, which also cover Europe.

Table 6: Automotive industry and cross-industry consortia

Consortium (abbreviation)	Goal	Website
CAR 2 CAR	The CAR 2 CAR Communication Consortium (C2C-CC) towards accident free traffic (vision zero) at the earliest possible date	https://www.car-2-car.org/
C-Roads	A joint initiative of European Member States and road operators for testing and implementing C-ITS services in light of cross-border harmonisation and interoperability	https://www.c-roads.eu/platform.html
European Association of Automotive Suppliers (CLEPA)	The main lobbying and standards group of the automobile parts industry in the European Union	https://clepa.eu
European Automobile Manufacturers Association (ACEA)	The main lobbying and standards group of the automobile industry in the European Union	https://www.acea.be/
European Automotive and Telecoms Alliance (EATA)	Cooperation between Europe's automotive and telecom sectors, to jointly explore how to best accelerate the deployment of autonomous mobility	https://eata.be/
European Road Transport Research Advisory Council (ERTRAC)	European technology platform which brings together road transport stakeholders to develop a common vision for road transport research in Europe	https://www.ertrac.org/

[49] European Commission (2017). Automotive industry: Policy and strategy
[50] UNECE (2019). Vehicle Regulations

Consortium (abbreviation)	Goal	Website
European Road Transport Telematics Implementation Co-ordination Organisation (ERTICO)	Intelligent Transportation System organisation in Europe that promotes research and defines ITS industry standards. It is a network of ITS and Services stakeholders in Europe.	https://ertico.com/
5G Automotive Association (5GAA)	Cooperation between the telecom industry and car manufacturers to develop end-to-end solutions for future mobility and transportation services	https://5gaa.org/
Car Connectivity Consortium (CCC)	An organisation driving global technologies for smartphone-centric car connectivity solutions	https://carconnectivity.org/
Open Automotive Alliance (OAA)	The OAA is a global alliance of technology and auto industry leaders committed to bringing the Android platform to cars	https://www.openautoalliance.net/

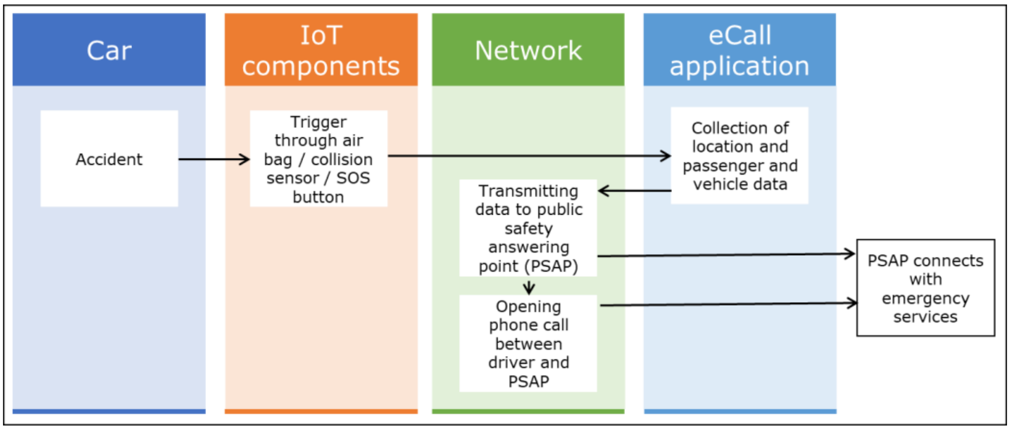
Source: Capgemini Invent

2.3 Linkages along the value chain

Stakeholders which are part of the automotive industry initially consisted mainly of OEMs. Separate streams within the value chain existed. Nowadays, the lines distinguishing the various steps in the value chain are blurring. In effect, some companies are active in two or more of the value stream steps or operate in cross-industry consortia. Shifts take place too, for example traditional OEMs are becoming more active in the field of data platforms, and technology firms are shifting from providing hardware IoT components towards full applications for connected and autonomous vehicles.

Due to this hybridity, the value chain streams are highly interrelated. An illustrated example of linkages along the value chain is pictured below in the form of a process diagram for the eCall application, which activates in case of a registered accident.

Figure 4: Process diagram of eCall, displaying linkages over the value chain



Source: Capgemini Invent

Section 3

3. Analysis of EU competitive positioning

Overall, the EU's position on connected and autonomous vehicles differs from that of other significant regions in this industry such as USA, Japan and China.[51] The EU shows its strength in regulating security and privacy of data, and vehicle and driver safety and security in connected and autonomous vehicles and benefits from a strong and diverse European automotive industry. On the other hand, foreign competition and public trust and acceptance of autonomous driving could also be seen as a hurdle for its further evolution.[52] The EU can be considered to face risks in terms of the spread of funding (which spreads assets amongst developing technologies instead of focusing on a few). Also, there is a risk of relative gap in IT skills. Opportunities for all regions with a focus on connected and autonomous vehicles are the ongoing deployment of 5G networks, as well as big data and digital platforms.
The main strengths, opportunities, challenges and risks for the EU in connected and autonomous vehicles are depicted in Figure 5 and described in further detail in this section.

Figure 5: Strengths, opportunities, challenges and risks for the EU in connected and autonomous vehicles

Source: Capgemini Invent

3.1 Strengths

Security, safety and privacy

With the ongoing automotive digitalisation as well as automation, topics as security and privacy of data, as well as vehicle and driver security and safety in connected and autonomous vehicles can be seen as key requirements for the EU for further development and deployment.[53] Due to its highly democratic approach and development of policies on national as well as European level, a combined automotive strategy, and a strong striving for harmonisation and standardisation, the EU has strong standards on the pillars of driver security and safety, as well as for data security and privacy. The USA works under decentralised legislation regarding these topics, as these are regulated on a state level, whereas mainly highway rulings are being established on a national level (by the National Traffic Safety Administration). The USA is known to have a relatively low level of legal predictability due to its system's setup.[54]

On the side of driver and vehicle safety and security regulations, the lines between rules for drivers (mainly ruled nationally in EU countries) and those for vehicles (mainly harmonised EU vehicle approval legislation) will blur with the rise of connected and autonomous vehicles; a harmonised approach for these two is therefore essential.[55] Consequently, on both the national and European level, legislation on these different aspects of connected and autonomous vehicles has been developed.[56] On a national level there are examples such as Germany's Autonomous Vehicle Bill (2017), and the legislative framework for testing autonomous vehicles in countries such as France, Spain, Italy, the Netherlands and Germany.[57] On a European level, legislation has been approved, depicting that as of mid-2022 motor vehicles will have to be equipped with a number of safety features enabled by IoT technology, such as advanced driver distraction warning systems and advanced emergency braking systems.[58] Finally, on

[51] McKinsey & Company (2019). Race 2050 - a vision for the European automotive industry
[52] McKinsey & Company (2016). Advanced driver-assistance systems: Challenges and opportunities ahead
[53] European Commission (2018). On the road to automated mobility: An EU strategy for mobility of the future
[54] Carp (2018). Autonomous vehicles: problems and principles for future regulation
[55] European Commission (2017). GEAR 2030
[56] European Commission (2018). Autonomous Vehicles & Traffic Safety summary 2018
[57] Autovista Group (2019). The state of autonomous legislation in Europe
[58] Council of the European Union (2019). Safer cars in the EU

the side of data privacy and security, the EU published its guidelines on processing personal data in the context of connected and autonomous vehicles and mobility-related applications.[59]

Strong and diverse European automotive industry

The EU has a strong automotive industry and its potential is unique compared to the Chinese and American automotive industry. While in China big-city mobility solutions are dominant and suburban traffic represent the majority of the automotive mobility in the USA, the EU has the strength of diversity. The European automotive industry is characterised by a strong network of global leaders in the automotive industry serving a very diverse set of mobility needs. This is a strength compared to the automotive industry in the USA and China.[62]

The European diversity is manifested in its people, economies, technologies and mobility solutions. The diversity of the people living in the EU27 in distinct regions makes available a large pool of profiles and eventually a rich pool of data. Regarding the economic diversity, the automotive industry has a strong role in connecting the diverse economies. It has contributed to an integrated manufacturing industry by connecting plants in Eastern Europe with consumer market in Western Europe. The European automotive industry focuses on different segments with their specific technologies which requires a high level of innovation power. The innovation power is illustrated by the 60% share of global patents in autonomous driving filed by the European automotive industry. Last but not least, the diversity strength is manifested by the diverse set of mobility solutions which is required to service the different mobility systems in Europe ranging from narrow street in Medieval city centres to congested traffic in large cities, and from rural areas to (high and low income) cities.[62]

Having such a strong basis and such a diverse breeding ground is a strength which enables learning and the development of solutions that will fit in other regions that are as diverse as Europe. The European automotive industry is therefore well positioned to optimise future mobility solutions locally and scale these globally. [60]

3.2 Opportunities

5G network

With a continuously increasing demand for network capacity to carry the increasing amount of data being communicated through vehicle to everything, the industry could be considered to have two options for supporting this: 5G and wireless local area networks (w-lan). For that matter 5G acts as a stronger enabler than 4G in the future of cellular vehicle-to-everything,[61] on the basis of its higher speed and lower latency compared to 4G.[62] In comparison to w-lan, 5G can be considered to have technical benefits in terms of speed, latency, security and reliability, as well as the ability for partners to participate in application development via APIs.[63] While 5G is currently not yet available in the whole EU to secure this coverage, by 2025 the EU plans to provide uninterrupted 5G coverage in urban areas and along main transport paths.[64] The ongoing roll-out of the 5G network over Europe, as well as countries such as USA, China and Japan, is seen as a major enabler for connected and autonomous vehicles – the strongly-advocated new standard per major players in the value chain.[65]

In terms of commercial value, the automotive industry is expected to become the largest market opportunity for 5G IoT solutions, as it is forecasted to represent 53% of the overall 5G IoT commercial endpoint opportunity in 2023. Furthermore, the percentage of 5G connected vehicles is expected to increase from 15% in 2020 to 74% in 2023.[66] Cooperation between various parties in the value chain is therefore expected to evolve with the rollout of 5G, as network operators will need contracts with OEMs to justify their investments into the new network. The European Commission devised an action plan for a funded Europe-wide rollout in cooperation with network operators of 5G networks; it offered 5G services starting from 2020, up to a broader coverage over urban areas and main transport paths by 2025, at the latest.[67]

---

[59] European Data Protection Board (2020). Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications
[60] McKinsey and Company (2019). Race 2050 - A vision for the European automotive industry.
[61] McKinsey & Company (2019). Development in the mobility technology ecosystem—how can 5G help?
[62] Zubel (2017). How will 5G revolutionise the European automotive industry?
[63] Capgemini (2019). Connected Vehicle Trend Radar
[64] European Commission (2020) Towards 5G
[65] 5GAA (2020). Experience the Future of Mobility
[66] Gartner (2019). Gartner predicts outdoor surveillance cameras will be largest market for 5G Internet of Things solutions over next three years
[67] European Commission (2020). Towards 5G

Big data and digital platforms

With the rise of IoT, connected and autonomous vehicles and 5G networks, the commercial opportunities of big data and digital platforms for automotive are growing too. It results in an estimated revenue pool on a global scale of between $450-750 billion.[68] In a questionnaire, 83% of automotive executives think it is extremely or somewhat likely that there will be a major business model disruption in the automotive industry.[69] In the long run it is expected that 30-40% of the value in the automotive value chain will be captured in this digital space.[70] The key to commercial success in this space can be described as the combination of premium products, vehicle connectivity and a user interface platform.[71] As a result of this potential, European OEMs that invest in big data and digital platforms highlight it as part of their strategy, and integrate its potential in their value chain. While a great opportunity lies ahead for the European automotive industry, the European digital automotive platforms and big data utilisation is currently not at scale as compared to those of the digital giants in the USA, such as Google, Amazon and IBM, as well as those in China, such as Alibaba.[72]

3.3 Risks

Spread of funding

The EU funds technological advancements in the automotive industry through initiatives such as its Horizon 2020 (and in the future Horizon Europe) programme. It spreads available funding over a multitude of related topics such as big data, electric driving and connected and autonomous driving.[73] Therein it differs from the USA and China, which are more capable of focusing efforts on certain technological development themes for automotive. In the USA, due to a relatively high valuation at capital markets, new business models (including those for automotive) can be developed without the immediate need for profitability.[74] Furthermore, the USA has a much more advanced culture in venture capital (as well as the risks taken therein) as compared to the EU, boosting technology start-ups in the automotive scene. In China, the government is pushing its domestic companies to lead in internet technologies.[75] As a number of companies are state-owned, the government is able to steer their efforts in the same direction,[76] in the last year, for example, they bet heavily on electric vehicles.[77] The spread in automotive funding in the EU can lead to the risk of USA and China making bigger developments in the same timeframe.

Potential challenges in IT skill capacity

The ongoing digitalisation of the automotive industry results in a heavily increasing demand for IT skills. The EU is putting effort into developing these on different job levels with its New Pact for Skills Agenda[78] (which, amongst others, brought forward project DRIVES, and which specifically focuses on the automotive industry)[79] to strengthen its position therein, now and in the future, but should stay alert for a potential skills gap (as indicated in the European Commission's report on The Digital Skills Gap in Europe,[80] amongst others).[81] Therefore, IT skills in the automotive industry should be regarded with care, before it could turn into a competitive disadvantage over the coming decade.[82]

3.4 Challenge

Foreign competition

Foreign competition for the European industry is spread over the various stakeholder groups, and the gravity of competition varies in each of them compared to those with their headquarters in the EU. To pick an example illustrative of autonomous driving technology advancement, foreign companies can be considered to lead in terms of autonomous driving kilometres. As autonomous driving technology runs

[68] McKinsey & Company (2019). Race 2050 - a vision for the European automotive industry
[69] KPMG (2017). Global automotive executive survey 2017
[70] European Commission (2017). The race for automotive data
[71] Lynch (2017). The Big Bang – the Second Coming … could it even be the next Amazon?
[72] European Commission (2017). The race for automotive data
[73] EUcar (2015). Horizon 2020, https://www.eucar.be/horizon2020/
[74] McKinsey & Company (2019). Race 2050 - a vision for the European automotive industry
[75] Accenture (2018). Data driven business models in connected cars, mobility services & beyond
[76] Chen Y. L. (2017). The Chinese Automobile Industry and Government Policy
[77] McDonald (2019). China powers up electric car market
[78] European Commission (2016). New Skills Agenda for Europe
[79] DRIVES (2020), https://www.project-drives.eu/en/background
[80] European Commission (2017). The Digital skills Gap in Europe
[81] European Centre for the Development of Vocational Training (2016). Digitalisation and digital skill gaps in the EU workforce
[82] McKinsey & Company (2019). Race 2050 - a vision for the European automotive industry

on machine learning (among other technologies), the number of kilometres driven can be considered to result in a better-trained autonomous driving machine learning model. Globally, Tesla can be considered to be ahead of its competition therein, as they had registered up to 3.2 billion driving kilometres in their more than 600,000 vehicles globally by March 2020, next up Waymo registered 32 million kilometres[83], while, for example, European Daimler registered 10 million test kilometres up to 2020[84].

Public trust and acceptance of connected and autonomous driving

For increasing levels of connected and autonomous driving as well as digitalisation to be successful in automotive, public acceptance is seen as a barrier.[85] For example in polls in the USA and Germany it became apparent that the public associated this new technology with a loss of freedom and a fear of negative social consequences.[86] In 2017, 61% of Europeans indicated not feeling completely or fairly comfortable traveling in a driverless vehicle.[87] These factors are expected to be barriers in the market.[88] Situations wherein people would be more likely to adopt connected and autonomous driving include closed environments (such as a university campus), finding a carpark and public transport with a chaperone.[89] The EU aims to increase consumer confidence through for example their TRUSTVEHICLE project with the use of reassuring software.[90]

[83] Lambert (2020) 5 top autonomous vehicle companies to watch in 2020
[84] Daimler (2020) Automated driving
[85] McKinsey & Company (2016). Advanced driver-assistance systems: Challenges and opportunities ahead
[86] Fraedrich (2016). Societal and individual acceptance of autonomous driving
[87] Fortunati (2019). European Perceptions of Autonomous and Robotized Cars
[88] Zubel (2017). How will 5G revolutionise the European automotive industry?
[89] Kaur (2018). Trust in driverless cars: Investigating key factors influencing the
[90] European Commission (2019). Creating trust in driverless cars

Section 4

4. Conclusions and outlook

4.1 Conclusions

The ongoing trend of digitalisation in the automotive industry, powered by IoT in connected and autonomous vehicles, is undeniable. And it will result in, amongst others, safer, more accessible and more sustainable transport. Although the traditional automotive value chain consisted mainly of OEMs and their component providers, other stakeholders now claim an increasing part of the automotive market value: IoT component providers, network operators, vehicle data platforms and application platforms. The key players have been listed in section 2. The value chain consists of enabling and supporting parts and has a non-linear cooperation between the stakeholders. Digitalisation causes lines between these parties to blur.

Facing this ongoing evolution in the automotive industry, one of the key strengths of the EU is the European standardisation of security and privacy of data. The EU has strong standards for security, safety and privacy on both national and European level. Examples are the European legislation regarding the IoT enabled safety measures that vehicles must be equipped with as of 2022 (including driver distraction warning and advanced emergency braking systems) and the EU guidelines on processing personal data related to connected and autonomous vehicles.

The strong basis of the European automotive industry and its diversity are other key strengths for the European automotive industry. The diversity of people, economies, technologies and the diversity of mobility services offered to service customers enables learning and the development of solutions that will fit in other regions. This positions the European automotive industry well to optimise future mobility solutions locally and scale them globally.

The European Commission action plan for a funded Europe-wide rollout in cooperation with 5G network operators is a key opportunity for connected and autonomous vehicles in the EU. The EU plans to provide uninterrupted 5G coverage in urban areas and along main transport paths by 2025. The 5G networks will be the key carriers for IoT solutions related to connected and autonomous vehicles and the automotive industry is expected to become the largest market opportunity for 5G IoT solutions.

With the rise of connected and autonomous vehicles, the commercial value of big data and digital platforms for automotive represent another key opportunity. A major business model disruption is expected in the automotive industry. European OEMs that invest in big data and digital platforms highlight it as part of their strategy and are integrating its potential in their value chain.

EU funding for technological advancement in the automotive industry (Horizon 2020, Horizon Europe) is spread over related topics (such as big data, electric driving). Such spread in funding in the EU may be a risk if USA and China focus their funding for developments in the same timeframe.

Another risk to be considered is the IT skill gap. The digitisation in the automotive industry results in an increasing demand for IT skills. To mitigate this risk, the EU is putting effort into development of these skills with its New Pact for Skills Agenda.

The challenges of (the level of) foreign competition and social acceptance of connected and autonomous vehicles have also been identified. The fierceness of foreign competition varies in the different elements of the value chain. Comparing the autonomous driving distance as an indicator (important for the development of machine learning models for connected and autonomous driving) Tesla and Waymo are ahead of European players.

Another challenge to overcome – globally – is the public acceptance regarding connected and autonomous driving and the level of feeling comfortable traveling in a connected and autonomous vehicle. The EU aims to increase consumer confidence through for example their TRUSTVEHICLE project.

4.2 Outlook

Connected and autonomous vehicle technologies and the applications they enable will further evolve over the coming century. This will result in, amongst others: the evolution of vehicle to everything connectivity, further blurring lines between stakeholders in the value chain[91] and the rise of mobility as a service[92] (instead of the traditional vehicle ownership model). Furthermore, it will also lead to a rise of the digital platform economy in automotive, mobility as an experience (wherein passengers no longer drive but can enjoy benefits such as infotainment applications), further growth of shared mobility, and it will impact areas including employment, insurance, public transport, and regulations.[93]

4.3 COVID-19 – impact on the automotive sector

During the current and ongoing COVID-19 crisis, the automotive industry in general is seeing significant impact on various fronts.

As a result of COVID-19, deteriorating market conditions and a potential global recession has led to widespread loss of consumer confidence, which has a significant impact on the automotive industry's revenue and profit[94]. The financial impact thereof also impacts suppliers, potentially resulting in downstream supply chain disruptions. However, as measured in April 2020, Chinese vehicle sales already saw a recovered trend in line with the diminishing of COVID-19.[95]

An expected shift in mobility behaviour after lockdown shows a higher expected usage of private vehicles and less so of public transport in China, the USA and the EU. But, only for China there exists a significantly higher likelihood for an individual to buy or own a car post COVID-19[96]. Overall, 58% of customers intended to postpone the planned purchase of a car (of which 40% due to financial uncertainty), but 89% of hesitant customers would be convinced to buy with great offers or on the basis of a good customer experience.[97]

Another shift in consumer behaviour due to COVID-19 risks, is that 60% of potential car buyers would now be more likely to buy a car online (given the scenario that dealerships are open again).[98]

Specifically regarding the development of connected and autonomous vehicles, companies in the connected and autonomous vehicle value chain are heavily financially impacted by COVID-19 and might have to divert capital from research and development to keep operations active, slowing down the technological advancement.[99]

In Europe, the first indications of the COVID-19 impact on the car sales and registrations are visible. Car registrations in the EU27 over the first 7 months of 2020 have decreased with 35% compared to the same period last year. There are also signs of recovery: July has shown the highest number of registrations in Europa since September 2019.[100]

[91] Accenture (2018). Data driven business models in connected cars, mobility services & beyond
[92] Strategy& (2018). Digital Auto Report 2018
[93] PWC (2020). The future of mobility
[94] Deloitte (2020). Understanding of the impact of COVID-19: automotive sector
[95] BCG (2020). COVID-19's Impact on the Automotive Industry
[96] BCG (2020). COVID-19's Impact on the Automotive Industry
[97] Capgemini Invent (2020). How COVID-19 is affecting car sales and consumer attitudes
[98] Capgemini Invent (2020). How COVID-19 is affecting car sales and consumer attitudes
[99] Deloitte (2020). Understanding of the impact of COVID-19: automotive sector
[100] Jato (2020), JATO European Press Release – July 2020

Section 5

5. Annexes

5.1 List of interviewees

Figure 6: List of internal and external interviewees

Interviewee	Company / association	Country
Maxime Filament	5GAA	Belgium
Joost Vantomme and Mohit Tyagi	ACEA	Belgium
Andreas Kaselowsky, Laura Kussl and Philipp Meissner	Capgemini Invent	Germany
Robbert Janssen	TNO	The Netherlands

5.2 Bibliography

5GAA. (2020). *Experience the Future of Mobility*. Retrieved from 5GAA: https://5gaa.org/5g-technology/experience-the-future/

Accenture. (2018). *Data driven business models in connected cars, mobility services & beyond.* Accenture & BVDW.

ACEA. (2019). *ACEA's Members*. Retrieved from ACEA: https://www.acea.be/about-acea/acea-members

ACEA. (2020). *Cooperated, connected and automated mobility.* Brussels: ACEA.

AECC. (n.d.). *Mission Statement*. Retrieved from AECC: https://aecc.org/about/

Alonso Raposo M., G. M. (2018). *An analysis of possible socio-economic effects of a Cooperative, Connected and Automated Mobility (CCAM) in Europe.* European Commission.

Anderson, J., Kalra, N., Stanley, K., Sorensen, P., Samaras, C., & Oluwatola, O. (2016). *Autonomous Vehicle Technology A Guide for Policymakers.* Santa Monica: RAND Corporation.

Automat. (2015). *Vehicle Big Data Marketplace*. Retrieved from Automat: https://automat-project.eu/content/vehicle-big-data-marketplace-vbmp

Autovista Group. (2019, February 28). *The state of autonomous legislation in Europe*. Retrieved from Autovista Group: https://autovistagroup.com/news-and-insights/state-autonomous-legislation-europe

BCG. (2020). *COVID-19's Impact on the Automotive Industry.* BCG.

Capgemini. (2019). *Connected Vehicle Trend Radar.*

Capgemini Invent. (2020). *How COVID-19 is affecting car sales and consumer attitudes.* Capgemini Invent.

Car Connectivity Consortium. (2019, August 10). *Car Connectivity Consortium*. Retrieved from Car Connectivity Consortium: https://carconnectivity.org/

Carp, J. (2018). Autonomous vehicles: problems and principles for future regulation. *Journal of Law & Public Affairs*.

Chee, F. (2019, July 4). *EU opens road to 5G connected cars in boost to BMW, Qualcomm*. Retrieved from Reuters: https://www.reuters.com/article/us-eu-autos-tech/eu-opens-road-to-5g-connected-cars-in-boost-to-bmw-qualcomm-idUSKCN1TZ11F

Chen, S. (2017). 5G, Vehicle-to-Everything (v2x) Services Supported by LTE-Based Systems and 5G. *IEEE Communications Standards Magazine*, 70-76.

Chen, Y. L. (2017). *The Chinese Automobile Industry and Government Policy.* University of California at Davis Working paper.

Council of the European Union. (2019, November 8). *Safer cars in the EU*. Retrieved from Council of the European Union: https://www.consilium.europa.eu/en/press/press-releases/2019/11/08/safer-cars-in-the-eu/
Dahad, N. (2019, January 16). *EU Approves $2 Billion for IoT, Connected Car Research*. Retrieved from Electronic Engineering Times: https://www.eetimes.com/eu-approves-2-billion-for-iot-connected-car-research/#
Daimler. (2020). *Automated driving*. Retrieved from Daimler: https://www.daimler.com/sustainability/safety/automated-driving.html
David, M. (2016, May 19). *4 mobile platforms for the auto industry: Get up to speed!* . Retrieved from Tech Beacon: https://techbeacon.com/app-dev-testing/4-mobile-platforms-auto-industry-get-speed
Davis, F. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, 319-340.
Deloitte. (2018). *Disruption in the automotive industry.* Retrieved from Deloitte: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Consumer-Business/gx-deloitte-uk-disruption-in-the-automotive-industry.pdf
Deloitte. (2020). *Understanding the impact of COVID-19: automotive sector.* Deloitte.
Dix, J. (2017, March 21). *12M connected cars gives General Motors a massive IoT fleet*. Retrieved from Network World: https://www.networkworld.com/article/3183090/12m-connected-cars-gives-general-motors-a-massive-iot-fleet.html
DRIVES. (2020). *About*. Retrieved from project DRIVES: https://www.project-drives.eu/en/background
EUcar. (2015, January 1). *Horizon 2020*. Retrieved from EUcar: https://www.eucar.be/horizon2020/
Euopean Parliament. (2019). *Self-driving cars in the EU: from science fiction to reality*. Retrieved from Euopean Parliament: https://www.europarl.europa.eu/news/en/headlines/economy/20190110STO23102/self-driving-cars-in-the-eu-from-science-fiction-to-reality
European Automobile Manufacturers Association. (2019). *Automated driving: Roadmap for the deployment of automated driving in the European Union.* European Automobile Manufacturers Association.
European Centre for the Development of Vocational Training. (2016). *Digitalisation and digital skill gaps in the EU workforce.*
European Comission. (2016, September 22). *The interoperable EU-wide eCall*. Retrieved from 2016-09-22: https://ec.europa.eu/transport/themes/its/road/action_plan/ecall_en
European Comission. (2017, July 6). *Automotive industry*. Retrieved from European Comission: https://ec.europa.eu/growth/sectors/automotive_en
European Comission. (2019, September 25). *Connected and automated mobility in Europe*. Retrieved from Shaping Europe’s digital future: https://ec.europa.eu/digital-single-market/en/connected-and-automated-mobility-europe
European Comission. (2020, March 4). *Intelligent transport systems*. Retrieved from Mobility and transport: https://ec.europa.eu/transport/themes/its/road_it
European Commission. (2016, June 10). *New Skills Agenda for Europe*. Retrieved from European Commission: https://ec.europa.eu/social/main.jsp?catId=1223
European Commission. (2017, August 30). *Automotive industry: Policy and strategy*. Retrieved from European Commission: https://ec.europa.eu/growth/sectors/automotive/policy-strategy_en
European Commission. (2017, January). *Digital Transformation Monitor*. Retrieved from The race for automotive data: https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_The%20race%20for%20automotive%20data%20v1.pdf
European Commission. (2017). *GEAR 2030.* European Commission.
European Commission. (2017). *The Digital Skills Gap in Europe.*
European Commission. (2017). *The race for automotive data.* European Commission.
European Commission. (2018). *Access to digital car data and competition in aftersales services.* European Commission.
European Commission. (2018, October 1). *ARCADE - Supporting the CAD Initiative*. Retrieved from connected automated driving: https://connectedautomateddriving.eu/about/arcade-project/
European Commission. (2018, February). *Autonomous Vehicles & Traffic Safety summary 2018*. Retrieved from European Commission:

https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/ersosynthesis2018-autonomoussafety-summary.pdf
European Commission. (2018). *Europe on the Move: Commission completes its agenda for safe, clean and connected mobility.* European Commission.
European Commission. (2018). *On the road to automated mobility: An EU strategy for mobility of the future.* Brussels: European Commission.
European Commission. (2019). *Creating trust in driverless cars* . Retrieved from European Commission: https://ec.europa.eu/research/infocentre/article_en.cfm?&artid=50268&caller=other
European Commission. (2020, March 8). *Connected and automated mobility in Europe*. Retrieved from European Commission: https://ec.europa.eu/digital-single-market/en/connected-and-automated-mobility-europe
European Commission. (2020, March). *connected-and-automated-mobility-europe*. Retrieved from Shaping Europe's digital future: https://ec.europa.eu/digital-single-market/en/connected-and-automated-mobility-europe
European Commission. (2020, March 8). *Towards 5G*. Retrieved from European Commission: https://ec.europa.eu/digital-single-market/en/towards-5g
European Commission. (2020, April). *Towards 5G*. Retrieved from European Commission: https://ec.europa.eu/digital-single-market/en/towards-5g
European Data Protection Board. (2020, January 28). *Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications*. Retrieved from European Data Protection Board: https://edpb.europa.eu/sites/edpb/files/consultation/edpb_guidelines_202001_connectedvehicles.pdf
European Union. (2016). *A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility*. Retrieved from European Union Law: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016DC0766
Fleutiaux, F. (2018). *Vehicle data is more profitable than the car itself*. Retrieved from Telekom: https://www.telekom.com/en/company/management-unplugged/francois-fleutiaux/details/vehicle-data-is-more-profitable-than-the-car-itself-516208
Forbes. (2019, October 30). *Tesla Demonstrates The Power Of The Internet Of Things*. Retrieved from https://www.forbes.com: https://www.forbes.com/sites/miriamtuerk/2019/10/30/tesla-demonstrates-the-power-of-the-internet-of-things/#4c4389e410b7
Forbes. (2020). *The World's Largest Public Companies*. Retrieved from Forbes: https://www.forbes.com/global2000/list/#industry:Telecommunications%20services
Fortunati, L. G. (2019). European Perceptions of Autonomous and Robotized Cars. *International Journal of Communication*, 2728-2747.
Fraedrich, E. &. (2016). Societal and individual acceptance of autonomous driving. *Autonomous driving* , 621-640.
Gartner. (2019, October 17). *Gartner Predicts Outdoor Surveillance Cameras Will Be Largest Market for 5G Internet of Things Solutions Over Next Three Years* . Retrieved from Gartner: https://www.gartner.com/en/newsroom/press-releases/2019-10-17-gartner-predicts-outdoor-surveillance-cameras-will-be
Gawron, J., Keoleian, G., de Kleine, R., Wallington, T., & Kim, H. (2018). Life cycle assessment of connected and automated vehicles: Sensing and computing subsystem and vehicle level effects. *Environmental Science & Technology*.
Hobert, L. e. (2015). Enhancements of V2X communication in support of cooperative autonomous driving. *IEEE communications magazine*, 64-70.
ITU News. (2019, August 15). *Future Networked Cars: Safe, self-driving and shared*. Retrieved from ITU News: https://news.itu.int/future-networked-cars-safe-self-driving-shared/
Kaur, K. R. (2018). Trust in driverless cars: Investigating key factors influencing the. *Journal of Engineering and Technology Management*, 87-96.
KPMG. (2017). *Global automotive executive survey 2017.* KPMG.
Lambert, S. &. (2020, March 25). *5 top Autonomous Vehicle Companies to watch in 2020* . Retrieved from MES Insights: https://www.mes-insights.com/5-top-autonomous-vehicle-companies-to-watch-in-2020-a-910825/
Liberatore, F. K. (2019, September 23). *Industrials Insight : The eCall Technology Dilemma Facing OEMs and M2M Providers* . Retrieved from Lexology: https://www.lexology.com/library/detail.aspx?g=d5599192-6179-4cd7-a436-e8a085dc34e1

Lynch, M. (2017). *The Big Bang – the Second Coming … could it even be the next Amazon?* Princeton.
McAree. (2017). Towards artificial situation awareness by autonomous vehicles. *20th IFAC World Congress.*
McDonald, T. (2019, January 11). *China powers up electric car market*. Retrieved from BBC: https://www.bbc.com/news/business-46745472
McKinsey & Company. (2016, February). *Advanced driver-assistance systems: Challenges and opportunities ahead* . Retrieved from McKinsey & Company: https://www.mckinsey.com/industries/semiconductors/our-insights/advanced-driver-assistance-systems-challenges-and-opportunities-ahead
McKinsey & Company. (2016). *Monetizing car data.* McKinsey & Company. Retrieved from https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive%20and%20Assembly/Our%20Insights/Monetizing%20car%20data/Monetizing-car-data.ashx
McKinsey & Company. (2019, June). *Development in the mobility technology ecosystem—how can 5G help?* . Retrieved from McKinsey & Company: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/development-in-the-mobility-technology-ecosystem-how-can-5g-help
McKinsey & Company. (2019). *Race 2050 - a vision for the european automotive industry.* McKinsey & Company.
Mcquinn, A., Castro, A. (2018). *A Policymaker's Guide to Connected Cars.* Information Technology & Innovation Foundation.
Merlin, L. A. (2019). Transportation Sustainability Follows From More People in Fewer Vehicles, Not Necessarily Automation. *Journal of the American Planning Association*.
Müller, L. ,. (2016). *The social behavior of autonomous vehicles.* ResearchGate.
OECD. (2018). *Safer Roads with Automated vehicles?* Paris: International Transport Forum's Corporate Partnership Board.
Oliver, N. P. (2018, August 14). *To Make Self-Driving Cars Safe, We Also Need Better Roads and Infrastructure*. Retrieved from Harvard Business Review: https://hbr.org/2018/08/to-make-self-driving-cars-safe-we-also-need-better-roads-and-infrastructure
PWC. (2020). *The future of mobility*. Retrieved from PWC: https://www.pwc.nl/en/industries/automotive/the-future-of-mobility.html
Russon, M. (2018, September 27). *Will 5G be necessary for self-driving cars?* Retrieved from BBC: https://www.bbc.com/news/business-45048264
SCORE. (2018, March 3). *Mapping of future perspectives and challenges for the value chain of European transport manufacturing industry*. Retrieved from Scoreboard of Competitiveness of the European Transport Manufacturing Industry: http://transport-scoreboard.eu/site/assets/files/1206/score_d3_1_mapping_of_future_perspectives_and_challenges_for_the_value_c.pdf
Strategy&. (2018). *Digital Auto Report 2018.* Strategy &.
The Economist. (2020, February 29). *How ASML became chipmaking's biggest monopoly*. Retrieved from The Economist: https://www.economist.com/business/2020/02/29/how-asml-became-chipmakings-biggest-monopoly
UNECE. (2019). *Introduction on UNECE*. Retrieved from UNECE: https://www.unece.org/trans/main/wp29/meeting_docs_wp29.html
UNECE. (2019). *Vehicle Regulations* . Retrieved from UNECE: https://www.unece.org/fr/transport/areas-of-work/vehicle-regulations/reglementation-des-vehicules-accueil.html
Venkatesh, V. M. (2003). User acceptance of information technology: toward a unified view. *MIS Quarterly*, 425–478.
Volkswagen. (2019, February). *Microsoft and Volkswagen jointly develop the Automotive Cloud*. Retrieved from Volkswagenag: https://www.volkswagenag.com/en/news/stories/2019/02/microsoft-and-volkswagen-jointly-develop-software.html
Williams, E. ,. (2020). Assessing the Sustainability Implications of Autonomous Vehicles: Recommendations for Research Community Practice. *Sustainability*, 3.
Zubel, K. (2017, September 1). *How will 5G revolutionise the European automotive industry?* Retrieved from Impact research hub: https://impactcee.com/wp-content/uploads/2017/09/Raport.pdf

About the 'Advanced Technologies for Industry' project

The EU's industrial policy strategy promotes the creation of a competitive European industry. In order to properly support the implementation of policies and initiatives, a systematic monitoring of technological trends and reliable, up-to-date data on advanced technologies is needed. To this end, the Advanced Technologies for Industry (ATI) project has been set up. It provides policymakers, industry representatives and academia with:

- Statistical data on the production and use of advanced technologies including enabling conditions such as skills, investment or entrepreneurship;
- Analytical reports such as on technological trends, sectoral insights and products;
- Analyses of policy measures and policy tools related to the uptake of advanced technologies;
- Analysis of technological trends in competing economies such as in the USA, China or Japan;
- Access to technology centres and innovation hubs across EU countries.

You may find more information about the 16 technologies here: https://ati.ec.europa.eu.

The project is undertaken on behalf of the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and the Executive Agency for Small and Medium-sized Enterprises (EASME) by IDC, Technopolis Group, Capgemini, Fraunhofer, IDEA Consult and NESTA.

EA-04-20-320-EN-N

Publications Office
of the European Union