FUTURE MOVE
A review of the main trends in the automotive sector at horizon 2030 in the Great Region

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Contents

Chapter 1

Objective

This white paper is intended to give insights on how the automotive industry can evolve at horizon 2030 under the combined pressure of the COVID-19 crisis, the rising environmental and societal challenges, the new technological changes as well the users' behavior modification, and on how the mobility of people and goods will be redefined accordingly. It also aims at understanding the next opportunities for the automotive industry as it is facing a complete transformation due to revolutions that will impact it broadly, radically, and profoundly.

This work has been carried out in the frame of the Action 7 of the Pôle Automobile Européen (PAE) project funded by the European Commission in the frame of its program INTERREG 5 A Grande-Region and co-funded by the Walloon region of Belgium.

The present document is sourcing several reports from strategy & consulting firms as well as insights from automotive companies. Furthermore, to capture the point of view of the local automotive industry, a High Patronage Committee has been set out, whose members were interviewed during Action 7 by the University of Liège. The striking remarks are embedded in the present report, while the full compilation of the interview reports is gathered in a separate report available on demand.

The composition of the High Patronage Committee was selected to gather a panel of specialists covering all domains of possible evolution of the automotive industry in the next decade. Besides their respective expertise, the members of the High Patronage Committee were selected from all the countries of the Greater Region to embrace the different sensibilities of the partner regions and to gather the visions of the different industrial networks. Moreover, members of different sectors were chosen, universities, research centers, SMEs, start-ups, OEMs, so that there would be opinions and visions from companies all along the value chain. In addition to technological and industrial experts, it seemed appropriate to add a certain number of representatives of civil society and decision-makers to confront the industrial and economic vision with the trends of ecological organizations, sociological evolution, and the vision of the organization of cities and the countryside. Then, the University of Liège got in contact with all proposed members and tried to ensure their participation in a proposed detailed interview.

The content of the interview topics was also a matter of careful consideration. Various topics were approached via targeted questions and the whole spectrum of the current trends in the automotive sector was addressed. Topics indicatively mentioned:

- Electrification
- Autonomous driving
- Digital mobility and data sharing
- Connectivity
- Sustainable propulsion
- Covid-19 consequences
- Brexit
- Industry 4.0
- Shared mobility

The opinion expressed by the experts of the High Patronage Committee offers an opportunity to provide complementary light to the literature review and gives a detailed insight of the experts of what is happening in Europe and more specifically in the Great Region. As we are writing this report (December 2021), large parts of the world are emerging from lockdown and slowly restarting their economy. Opportunities and threats are identified and the Horizon of the next decade is discussed in detail.

In this document, the top Industry Megatrends & Innovations that impact automotive companies worldwide are analyzed and highlighted and a special focus is given to the Grande Region: electrification; autonomous driving; shared mobility; connectivity; Internet of Thing; Industry 4.0; big data; artificial intelligence; block chain; digital twins etc. Some examples of startups are given on these megatrends and depending on the specific needs of each SME in order to highlight the economic development opportunities for the SMEs related to these megatrends. The White paper only scratches the surface of the megatrends identified during the research. It is believed that these megatrends will transform the automotive sector as we know it today. Identifying new opportunities and emerging technologies to implement into the SMEs of the Great Region early on goes a long way in gaining a competitive advantage. The automotive industry is at a turning point in its history. The transition to electro mobility is a key step in maintaining industrial activities and jobs over the long term, and to meet the challenge of a total decarbonization of transport by 2050.

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Table 1.1: Composition of High Patronage Committee

Chapter 2

Introduction

The automotive industry is, without discussion, a key sector of the EU economy, its social life and its environmental impact. 70 percent of the transport made worldwide is done by car and 55 percent of public transport is done by buses. Europe is a leading stakeholder by representing 40 percent of the world automotive industry providing jobs to 12.6 million Europeans representing a significant share of total employment in the European Union (6.6%). With 2.6 million people working in vehicle manufacturing in 185 plants in the EU, the automotive industry accounts for 11,6% of total manufacturing employment in the region [ACEA2020c]. The manufacturing subsector of the automotive industry alone employs 2.6 million people and represents 8.5% of all EU manufacturing jobs. More than 13 million vehicles were "made in Europe" in 2020, representing 18% of global vehicle production. 5.2 million of these vehicles were exported worldwide, generating a trade surplus of 121.2 billion euros for the EU. Today, 278 million vehicles are on Europe's roads. In addition to allowing people and goods to move freely across the continent, these vehicles are an important source of public revenue, bringing in more than €398.4 billion in taxes as stressed by ACEA [ACEA2020c].

Except for the recession in the early 1990s and the financial crisis in 2009, the European automotive industry has continuously been growing since 1980. However, it only (fully) recovered from the financial crisis in 2017, and recovery remains fragile. This growth was enhanced by the development and implementation of technical innovations such as fuel-efficient vehicles and alternative powertrains [McKinsey2019a].

From now on, the auto industry stands on the brink of a revolution. A high level of automation will be needed to produce both electrical and internal combustion engine vehicles, and every process will be affected. The pressure on the workforce will be severe. 11.5% of EU manufacturing employment is in the automotive sector. The industry workforce might be cut by at least 50 percent by 2030 [ACEA2020a], and employees who remain will need quite different skills. Already before the global spread of the COVID-19 pandemic, the automotive industry had to face several challenges related to climate change and a fast changing consumer demand. Major disruptions related to connected, autonomous, shared and electric mobility have been transforming industry, consumer behavior and production facilities and forced industrial players to find new solutions, change production, and initiate new fleets. This challenge has been clearly pointed out by Action 6 of the PAE project that has assessed the future needs of the automotive industry in training and education in Europe.

Alongside the chemical industry and mechanical engineering, the automotive industry is one of the most Rhineland-Palatinate's industrial bases. The core of the industry is formed by the manufacture of motor vehicles and parts and other vehicle manufacturing with a total of 36,400 employees subject to social insurance contributions in 2018 in Rhineland-Palatinate. The main focus in these industries (share of employees in Rhineland-Palatinate 2.6 %, Germany 3.4 %) are the large OEMs (Original Equipment Manufacturer) and system suppliers (Tier1).

The wide variety of small and medium-sized supplier companies at the site is mainly distributed among the metalworking, mechanical engineering, rubber and plastics industry, the chemical industry and the electronics/ICT sectors. The automotive industry, in the broader sense, employs a total of 211,000 people, representing total jobs in Rhineland-Palatinate (Germany 14.6 %).

The upstream automotive industry in France represents approximately 360,000 employees (excluding temporary workers) [AlixPartners2021].

The automotive industry in Germany and Europe is undergoing a significant transformation, which offers considerable potential for innovation and is bringing about economic changes. Key drivers of this development are automated or autonomous driving, changes in the context of drive technology, and a growing importance of digital interfaces, applications and business models. In addition to technological change, the vehicle industry is being influenced not only by technological change, but also by changes in the legal and economic sector, a shift in market demand to other markets and continents. The weight of the global markets is shifting: in the future, emerging markets, particularly in Asia (including China and India) will play an even greater role than in the past. (especially North America, Eastern Europe, Asia/China) [wemoveit].

And then came the COVID-19 (an acronym for ‘ ‘Coronavirus Disease 2019). A game changer: The COVID-19 outbreak is causing widespread concern and economic hardship for consumers, businesses, and communities across the globe. As the pandemic disrupts business as usual and throws the economic outlook into uncertainty, the automotive industry is on the front line. With production shutdowns taking effect, automotive companies need to remain focused and nimble to better navigate this crisis. The high degree of parallelism and simultaneous overlapping of different short-term changes in the economy and global trade (e.g. trade barriers, Brexit, Coronavirus) present the industry with increased uncertainty and significant challenges.

As we live towards a new era of mobility and a carbon-neutral Europe, innovation remains at the core of the automobile industry's DNA (see Figure 2.1). Investing an impressive €62 billion per year, and responsible for a whopping 33% of total EU spending on innovation, the automotive sector has really solidified its position as Europe's number one investor in R&D [ACEA2021c].

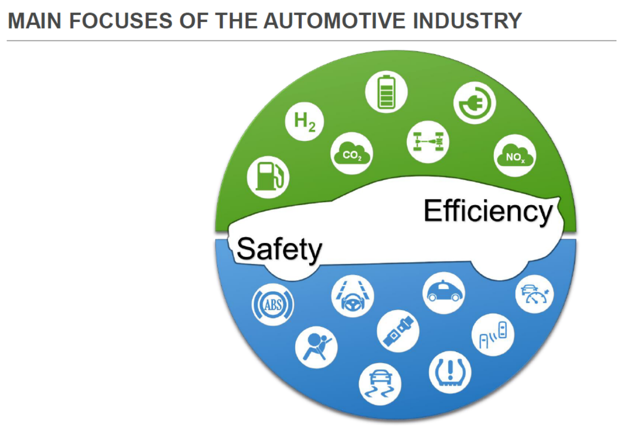


Figure 2.1: Main focuses of the automotive industry. Source: Ford, Overview Driver Assist Technologies & Automated Driving, 14/12/2020, Dr.Ir. Frederic Christen

2.1 The megatrends affecting the automotive sector

The European automotive sector has ascended to the top of the global industry. It has achieved record sales, and—as a major employer and a source of significant grant making—it is an integral part of European society. Beyond the social and economic context, the automotive industry is facing unprecedented challenges, of three kinds:

1. The rapid evolution of technology with increasing robotization supported by artificial intelligence and miniaturization.

2. The digitalization of all areas of everyday life with a change in consumption patterns. Connected objects (such as smartphones, household appliances...) and virtual reality.

3. An aging population bringing new challenges such as access to mobility and security.

The first important change comes from consumer behavior. The automobile is no longer essentially chosen on the technique. The automobile has moved from a technical product to a social product (the focus is on the user and no longer on the technique itself). In the future, mobility will be simpler, more flexible, and more individualized. For the younger generation, mobility must be simple, flexible, and sustainable. In comparison, the generation in their forties is still attached to their cars, but in the future, this will disappear as noticed in [McKinsey2019a]. The demand for vehicles is volatile in the short term, positive in the long term: there are many overlapping and different trends in demand behavior in Germany, Europe and the world. The possible decline in demand for passenger cars in European markets due to an alleged change in mobility behavior among younger people is forecast by industry experts. In the short term, the Corona pandemic will have a noticeable impact on demand in the passenger car/commercial vehicle segment (postponement of purchase, replacement investments, slump in production). In the medium to long term, demand will remain stable to positive, especially in the commercial vehicle segment.

Alongside changes in behavior, population growth will take place in Asia and Africa and mainly in cities. In 2030, 70% of the world's population will live in cities with more than 100,000 inhabitants. These young and urban populations will demand (and accept) innovative and financially accessible solutions in terms of mobility (see Figure 2.2).

The first consequence of these behavioral, demographic, and technological changes is a profound shift in mobility needs towards a sustainable, autonomous and shared model.

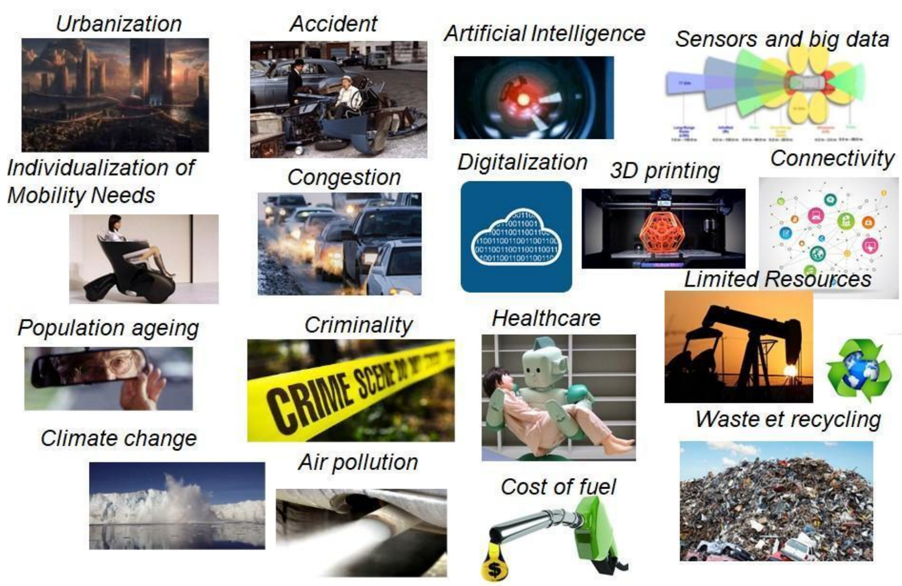


Figure 2.2: Megatrends in action in 2020

The second fundamental consequence is an increase in the urban population until 2050 eager to have access to individual mobility. Autonomous vehicles will increase access to this mobility to 90% as opposed to 60% at present by including adolescents, the elderly and/or disabled.

The third consequence is an intensification of vehicle use thanks to autonomous and shared vehicles. At the end of the day, this will reduce the lifespan of vehicles even if their reliability increases.

Over the past 50 years, the automotive sector has invested billions of euros in enterprise systems, automation solutions and advanced product technologies. Nonetheless, in some respects, automotive companies remain a slow follower to data and technology companies that are defining the competitive landscape of the Fourth into speed connectivity, and machine learning that have enabled the digitalization of the physical world.

But while industry evolutions in the past served as accelerators to create an innovative economy (See Figure 2.3), the European automotive industry is now at a tipping point. The disruptive path ahead includes value pools shifting dramatically to new business models and present market leaders having to redefine their role in the newly created ecosystem, not least because their technological leadership is at risk in these new business models. In other words, the success story of the European automotive industry is challenged by the combination of two revolutionary forces that together are fundamentally changing the industry: the current momentum beyond the traditional set of players and regions, and disruptive megatrends.

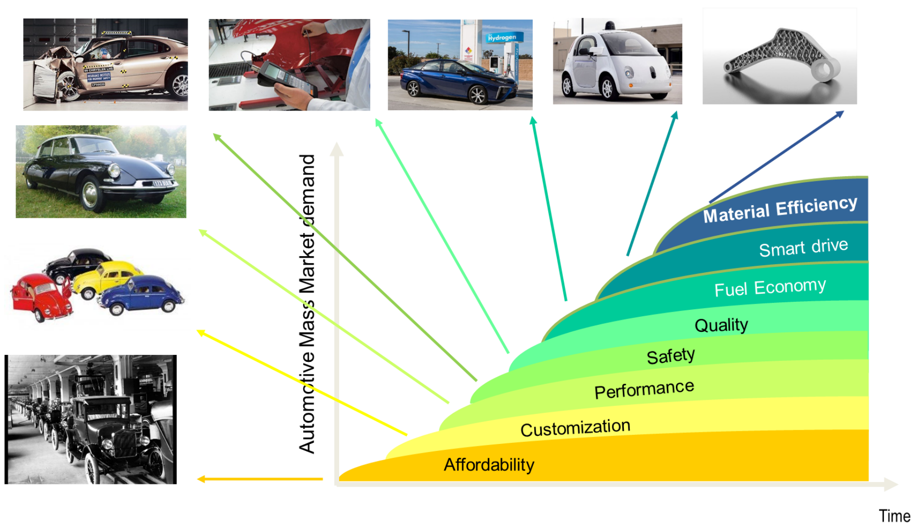


Figure 2.3: Historical perspective of technological challenges in the automotive industry (source: Ford - Low-cost carbon fibers for Automotive Applications conference. Liege, 2012-11-22)

The European automotive industry continues to be a huge success story but is currently facing strong headwinds: customer trust in the industry has recently suffered in light of the Diesel scandal, revenue pools are shifting strongly towards Asia, new players are entering the market, and the industry is facing disruptive megatrends of a new magnitude. Four technology driven megatrends are disrupting the industry (McKinsey, CASE, 2019): **C**onnectivity (e.g., the number of customers ready to change vehicle brand for better connectivity has doubled during the last 2 years), **A**utonomous driving (e.g., 80% of the OEMs are planning to build highly autonomous vehicles), **S**hared mobility, **E**lectrification (e.g., more than 40% of the new vehicle models developed for 2021 will be based on EV powertrain).

Besides these technological changes and the demand for sustainable mobility, customers are beginning to demand individualized products, such as pay-per-use mobility packages or mobility as a service (MaaS), that integrate different modes of mobility according to individual needs and circumstances.

Vehicles are increasingly becoming a platform for data, services and interfaces, creating new value chains. In addition, the automotive industry is becoming interesting for newcomers from the software industry, which means that new partners must be integrated into the value chain. We must not neglect the risk of dependency on service providers from outside the industry at the expense of established companies in the automotive industry. Markets and revenue pools are shifting to new business models and new technologies, such as data-enabled services, advanced driver assistance systems (ADAS) technologies, and alternative powertrains. This development results in the emergence of new competitors such as tech players, and start-ups, whereas digital/e-commerce companies can be expected to grow rapidly.

However, for established players this presents not only new threats but also new opportunities. To successfully shape these disruptive technologies, the industry will have to manage a significant employment transition, with accelerated importance of software and electronic engineering skills. Furthermore, industry collaborations are becoming increasingly relevant not only to gaining critical market shares, but also to shaping the necessary infrastructure.

Furthermore, in the meanwhile, customer demand for sustainable mobility products is rapidly increasing. Environmental concern is getting strong in the public opinion and global warming and air pollution becomes a major criterion for many people in their buying choices.

Finally, the weight of the global markets is shifting: in the future, emerging markets, particularly in Asia (including China and India) will play an even greater role than in the past. This applies both to the sales market and to production and development. Global supply chains bring together parts from production sites on different continents and enable production and value creation based on the division of labor. The trend towards global supply chains and the growing importance of emerging markets and in particular the Chinese market for established OEMs is leading to a relocation of production sites. On the one hand, this is due to the fact that new production sites are being established in markets of growing importance. Volkswagen Group China alone, for example, employed more than 95,000 people in eleven Chinese production facilities [wemoveit]. On the other hand the establishment of global supply chains means that components can now be produced on different continents and brought together in a single production plant. Thus, geographic location advantages such as proximity to a production site are disappearing or integration into a technological cluster becomes less important when comparable quality can be purchased elsewhere at a lower price. Suppliers are also increasingly outsourcing their production to countries with lower production costs.

These disruptive megatrends require new core competencies, new actions, and a new way of thinking which will be discussed in more detail below in this White Paper. It should be noted that these trends are being highlighted primarily for the passenger car market and the framework conditions of the global vehicle industry, with which **the Great Region vehicle industry will have to deal with in the future.**

2.2 COVID19 Crisis - The challenge

COVID-19 interrupted the status quo of mobility practices worldwide. The immediate human and economic costs of COVID-19 are severe. They threaten to scale back years of progress on reducing global poverty and inequality and further damage social cohesion and global cooperation, which were already weakening before the virus struck. While the current crisis has led to an overall drop in vehicle sales worldwide, electric cars have fared relatively well, with sales expected to increase from 2 million cars in 2019 to almost 2.5 million in 2020, or 3% of global car sales. Electrification in the transport sector is even more significant, with the sector accounting for almost 11% of global demand by 2040 [ACEA2020a].

In the meanwhile, new individual mobility systems like e-bikes and e-scooters have boomed up, while shared vehicles, to which a promising bright expansion was promised, have been slowly postponed in the agenda. At the same time, new ideas have made breakthroughs and are showing up at the window like robotaxi, autonomous drones for parcel delivery or even flying cars. For sure the new decade will be exciting and will change the deal that looked to be firmly established for individual passenger cars powered by internal combustion engines fueled with petrol.

New barriers to individual and collective advancement will likely result from the pandemic as the world faces the sudden disruption of social interactions, a widening digital divide, abrupt shifts in markets and consumer behavior, loss of education and jobs, and challenges to democracy and international relations. “Digital inequality”, “youth disillusionment” and “social cohesion erosion” were all identified by respondents as critical short-term threats. A digital leap forward—disrupting industry, education, labor markets, and the balance of power between nations—risks widening the gap between the technological “haves” and “have-nots”. All generations and groups have been affected by the crisis: older populations are the most vulnerable to the pandemic itself, and youth face new barriers to social mobility, strains on mental health, uncertain economic prospects and the continued degradation of the planet. Climate change—to which no one is immune, nor can the world vaccinate against it—continues to be catastrophic: “climate action failure” is the most impactful and second most likely long-term risk identified in the World Economic Forum

[WEF2021].

Billions of people worldwide are at heightened risk of missing out on future economic opportunities, and the benefits of a resilient global community. The crisis has also challenged national policy-making and international relations in ways that threaten lasting impacts. Institutions and policies to support international coordination were already in decline, and responses to the pandemic have caused new geopolitical tensions (Figure 2.4).

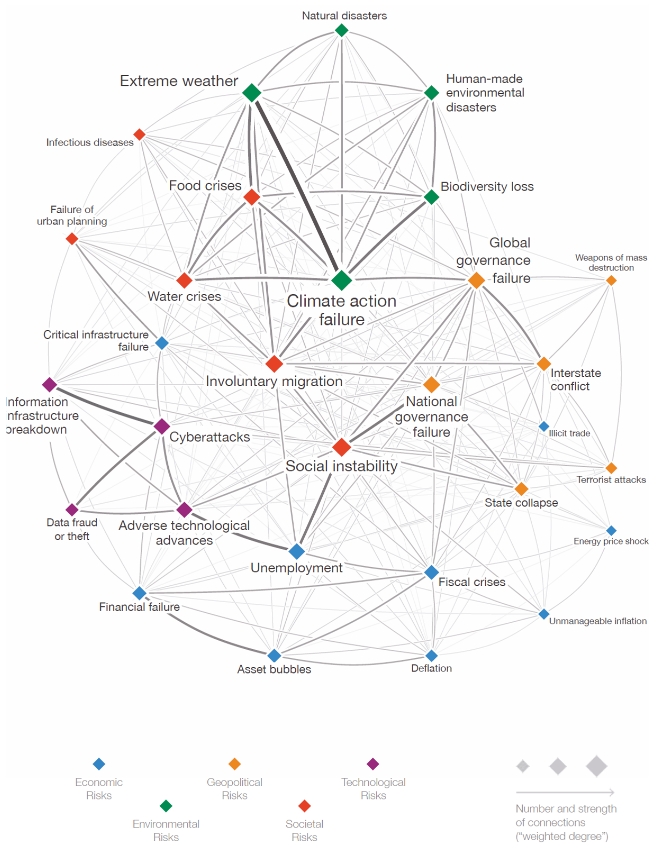


Figure 2.4: Source: `https://www.weforum.org/reports/the-global-risks-report-2020`.

The automotive industry belongs to the industries that have been hardly hit by COVID-19. Most car manufacturers have had to shut down their development and production sites for several weeks or even months during the year 2020. The impact of the coronavirus on automotive production and employment is at the height of the crisis. **The jobs of more than 1.1 million Europeans working in automotive manufacturing were directly affected by plant**

closures during the closure period. EU-wide production losses amounted to more than 2.4 million motor vehicles [ACEA2020b]. Since EU policy makers and national governments have not urgently increased their political and economic support, for example by implementing fleet renewal programs, 2020 year's total car sales (15.3 million) have been reduced by about 25%, seriously threatening future employment, production, and investment.

The European Union recorded a higher number of COVID-19 deaths per million people than the global trend and much higher than the reported cases in China, for instance. The numbers in the EU are currently lower than in the United States (US). However, in terms of vaccinations, the EU is currently lagging behind the US (as shown in Figure 2.5 below).

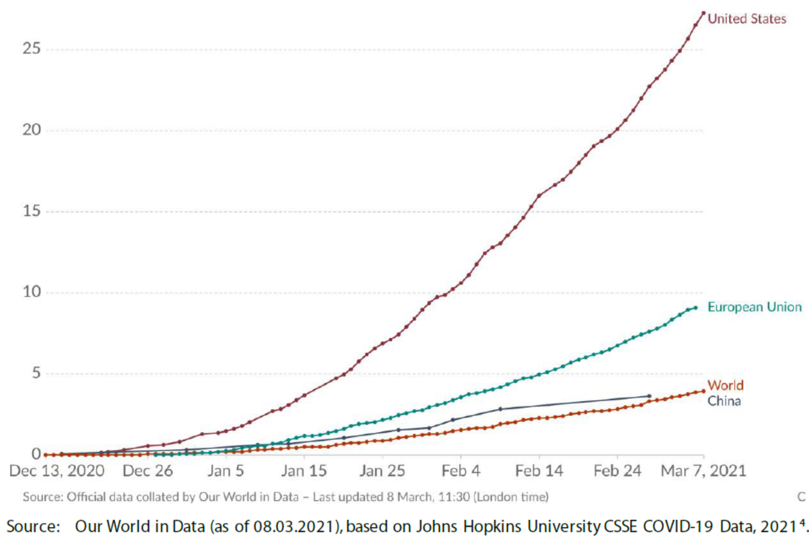


Figure 2.5: European Parliament, Think Tank, Impacts of the COVID-19 pandemic on EU industries.

The supply chains of the European automotive industries were disrupted from the first shutdowns of Chinese factories. Across the EU Member States, automotive factories were closed for an average of 30 days, with the shortest downtime in Sweden (15 days) and the longest in Italy (41 days). In the first half of 2020, the EU automotive industry suffered production losses of 3.6 million vehicles, which reflects a loss of €100 billion. Until the end of September 2020, this number increased to 4,024,036 motor vehicles, representing 22.3% of the EU total production in 2020 [ACEA2021g].

The shift in the pandemic's epicenter to Europe and North America underscores the need for automotive companies to remain nimble in their responses to the crisis. Supply chain disruptions combined with the significant - and growing - macroeconomic uncertainty fueled by COVID-19's global spread can make formulating the right response a moving target.

Unfortunately, January 2021 was the worst start of the year for the EU's automobile industry. Only 726,491 new cars were sold, which is an almost 25% drop compared to January 2020, with a 956,447 record, the latest data by the European Automobile Manufacturers Association [ACEA2021c]; France and Sweden were the only two countries in which sales went up, according to the data, with some other markets dropping by more than 50% as Spain, Romania, and Slovakia. In Belgium, the number dropped by 27.2%, which is a bigger loss than the EU average.

In some ways, the pandemic made the situation worse, as it hit an industry that was already adjusting. However, the impact of the economic downturn is not affecting the industry uniformly. Automakers and large subcontractors are relatively well prepared, as global automotive markets begin to recover. The situation is different for smaller suppliers, who are often highly specialized. For them, the negative consequences of the economic downturn, technological change and the pandemic are cumulative [AWEXMunich2021].

The numbers may seem to contrast ACEA's prediction in early February that "2021 will mark a first step on the path to recovery, with sales rising by about 10% compared to 2020," but they specified that "the car market should pick up in the second half of the year as vaccination programs progress." The pandemic and extensive lockdowns took a heavy toll on both transport activities and the pace of new car sales. The latest mobility data show that transport activities recover quite fast as countries relax their initial broad lockdown measures, but they fall back when restrictive measures are reintroduced to contain new virus variant outbreaks.

Even if the number of cars sold globally over the first half of 2020 dropped by nearly 30% compared to the same period in 2019, the impact on sales has not affected different powertrains equally. Sales of electric cars have been relatively resilient during the pandemic, helped by strong policy support in many countries, and the share of EVs in total car sales rises to over 3% in 2020 from around 2.5% in 2019. (European Parliament, Think Tank, Impacts of the COVID-19 pandemic on EU industries). As of September, the demand for cars in the EU decreased by 28.8% compared to the previous year (see Figure 2.6 **New car registrations in EU**).

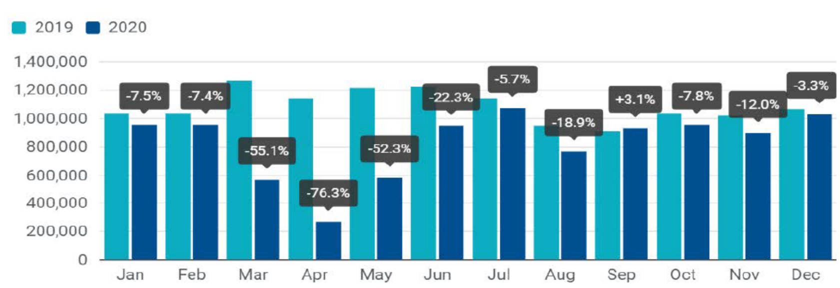


Figure 2.6: New car registrations in EU (Source : ACEA January 2021

Additionally, to comply with hygiene, distance, and security measures, and due to reduced performance and demand drops, the number of people actively working in the factories was substantially reduced. In addition to workers who were laid off, many were re-employed on short-term contracts: in Germany 95% of all companies in the automotive sector set their workforce on short-term working during the first lockdowns [McKinsey2020h].

Both production and demand in the passenger car and commercial vehicle segments experience a considerable slump and the outlook remains highly volatile in the short term. In addition to the temporary downtime (lockdown) and the scaling back of production capacities, increased uncertainty on the demand side will shift purchasing and replacement investments. In the medium to long term demand in the commercial vehicle sector will remain positive and tends to be more stable than demand for passenger cars. The longer-term economic consequences for the vehicle industry as a result of the pandemic / Covid-19 crisis can only be indicated in rudimentary form at the time of this study. The re-evaluation with regard to the robustness of international supply chains, the global division of labor, and the resilience of production and business locations will be relevant future topics for the automotive industry in Germany and in Germany and Rhineland-Palatinate [wemoveit]. Based on market forecasts and manufacturer announcements, production in France in 2025-30 will be down more or less 14% compared to 2019 [AlixPartners2021].

Overall in 2021, commercial vehicle registrations in the European Union **increased by 9.6% to reach 1,880,682 units,** largely thanks to the low base recorded during the first half of 2020. Nevertheless, this full-year result remains far below the 2.1 million units registered in 2019, the year before the pandemic. With the exception of Spain (-2.8%), all major EU markets posted growth last year. Italy saw the highest percentage gain (+15.5%) followed by France (+7.8%), while registrations increased by only a modest 0.6% in Germany[1].

2.3 Impact on strategic value chains

The impact on value chains has been more short-lived than the initial expectations. While global trade slowed down in the first and second quarter of 2020, it started recovering in the third quarter, and the subsequent outbreaks seemed to have less of an effect [2].

In the EU and across the world, borders have remained largely open for the circulation of goods with fewer interruptions to supply. Moreover, there has not been a big reshuffling of value chains as a result of the COVID-19 pandemic, but it is much more that underlying economics have been changing, which affects global value chains in the longer term. Overall, while the initial shock uncovered

[1] https://www.acea.auto/cv-registrations/commercial-vehicle-registrations-9-6-in-2021-8-4-in-december/

[2] UNCTAD, 2020, Global Trade Update: a frail recovery in the second half of 2020, https://unctad.org/system/files/official-document/ditcinf2020d4_en.pdf

weak spots in supply chains, EU industries showed a great deal of resilience in adjusting to it.

Containment in parts of China or border closures in Europe have largely paralyzed global supply chains, which is why almost **all vehicle production in Germany was halted in April 2020**. Exports were also virtually halted. The automotive industry was hit harder than the manufacturing industry as a whole. Towards the end of April, assembly plants were able to restart and the supply shock is now largely over, with supply chains fully established again [AWEXMunich2021].

As a result of the pandemic, there is likely to be an increasing tendency to locate the most important subcontractors close to the assembly plants. In addition, manufacturers and major subcontractors are increasing the monitoring of their supply chains. Internalisation is also increasingly considered by manufacturers.

The European battery value chain is seen as strategic for the EU because the production of batteries within the EU is expected to be a key driver for the EU's future industrial competitiveness. Batteries are an indispensable component in the decarbonisation of the European mobility sector and the EU's shift towards a circular and sustainable economy. Lithium-ion (Li-ion) batteries are the main type of batteries used for electric vehicle battery packs. The Li-ion battery value chain extends from raw material extraction to battery recycling, with China being the major supplier along the whole value chain. In terms of processed materials and components for Li-ion batteries, China, Japan, and South Korea account for 86% of the global supply, while European firms are producing less than 20 % of the global quantity. This is seen as insufficient to satisfy European demand for Li-ion batteries. Concerning the processes of cell assembling and battery pack manufacturing, China accounts for 66 % of global cell production [EU2019]. In contrast, Europe is almost fully dependent on imports of battery cells, exposing the industry to supply unpredictability and potentially higher costs. The COVID-19 pandemic initially had a disruptive effect on the battery value chain. During the first months of the pandemic, China endured complete shutdowns, and as a consequence, the global Li-ion value chain was put on hold. Additionally, large mining centers in Africa and Latin America limited the movement of personnel, and international travel restrictions limited the labor supply needed for full operation. This led to decreases in the extraction of cobalt and lithium needed for battery production [EU2021c].

The sub-sectors most affected would be screw-cutting (-47%), gravitational aluminum foundry (-45%), cast iron foundry (-42%), metal processing (-29%), rubber (-27%) and forging (-25%). Stamping is also impacted (-19%) for reasons of re-internalisation by manufacturers [AlixPartners2021].

The impact of the pandemic on global supply and value chains (supply shortages in intermediate inputs, dependencies in production on other nations and continents, large inventories of passenger cars) may lead to possible **relocation of production processes** and supply chains. While companies are thus faced with the question of where they want to produce in the future and whether existing production capacities abroad Rhineland-Palatinate, for example, has a general opportunity to make itself visible and attractive at an early stage. and to attract value-added processes. Especially the logistics location Rhineland-Palatinate, which has a strong position in the automotive industry, can be of great help in the context of the relocation. It has a strong position in the automotive industry, can be an attractive location in the context of its central location in Central Europe (Western/Southern Germany, Benelux, France), the good transport links (shipping and transport corridors) and the existing commercial and logistics commercial and logistics areas in this context and, within the framework of new supply and value-added structures, it will be able to maintain, defend and neighboring countries [wemoveit].

2.4 Impact on semiconductors

At the height of the pandemic, corona measures shut down nearly 90 percent of vehicle and component plants in China, North America and Europe. At the same time, automakers sharply reduced their purchases of semiconductors as fewer cars were sold. Meanwhile, demand for home computers and health care devices exploded. When semiconductor manufacturers restarted with reduced production, the limited available volumes had already been booked elsewhere. When automotive markets recovered in the third quarter of 2020, this naturally led to supply restrictions. This was compounded by other bad news for the automotive sector. Two of the five automotive semiconductor manufacturers were forced to suspend production at their plants in Texas due to winter storms in February.

The impact on the automotive supply chain - which operates on a just-in-time basis - is obvious. In a best-case scenario, the shortage could result in the unavailability of certain trim levels or optional equipment. In the worst case, it could lead to the interruption of production of an entire model line. More specifically, the semiconductor shortage is expected to reduce production by 202,000 units this year, according to Auto Forecast Solutions. A quarter of this lost volume is in Europe. European trade association ACEA expects supply restrictions through the third quarter of 2021, resulting in "significantly lower" production volumes and delivery delays for the rest of the year. The same is true among automakers. Ford expects a 10 to 20 percent drop in production. Volkswagen is citing an impact on its MQB platform vehicles, which make up a portion of its lineup. Nissan and Honda briefly halted production in the UK due to supply problems, and Daimler expects - cautiously - that they will be able to make up for the lost first quarter volume over the rest of the year[3].

According to the consulting firm Alix partners, the loss of revenue for automakers could be $210 billion for the year 2021. This is almost double the previous forecast in May 2021 where the revenue loss was estimated at $110 billion. It must be said that the situation is only getting worse, forcing a growing number of manufacturers to reduce production. In September 2021 the

[3] `www.fleet.be/comment-la-penurie-mondiale-de-semi-conducteurs-affecte-votre-travail-de-gestionnaire-de-flotte/?lang=fr`

Japanese giant Toyota announced the shutdown of 14 of its plants during the month of October 2021! That represents 3.9 million vehicles that might not be produced this year. According to Automotive News Europe, delivery times for micro drivers are now 21 weeks, and the crisis could last for several more years[4].

2.5 Crisis creates opportunities - Recovery outlook

Covid-19, as described above, unleashed a crisis of exceptional ferocity on countries around the world, with severe impacts on lives and livelihoods. The crisis is still unfolding today – and its consequences for the world's energy future remain highly uncertain. Despite these challenges, there is also space for building resilience. The massive sums of money the European Union countries are committing to spur economic recovery are a historic opportunity to significantly accelerate transitions towards a cleaner and more resilient energy future. This is the moment for ambitious actions over the next decade: over 125 countries (including the European Union) had set or were actively considering long-term net-zero emissions targets. The European Parliament and the European Council have endorsed a target to achieve net zero GHG emissions in the European Union (EU) by 2050. This target is a central component of the proposed "**European Green Deal",** and the €750 billion recovery package agreed by EU heads of state and governments in July 2020 to boost the recovery from the Covid-19 pandemic aims for spending to be in line with the net-zero GHG [IEA2021].

In 2020, the world's 50 largest economies announced **€12 trillion** in fiscal measures to address the crisis. Of the €12tn, €1,56tn (13%) was directed to long-term 'recovery-type' measures. €2,16tn (18%) of long-term spending was for green initiatives. In a quadrant of best and worst performing countries, several northern European economies are cited as doing well – Denmark, Finland, Germany, and Norway. Despite being a heavy coal-user, Germany is now pursuing plans to decommission coal-fired power plants, including offering financial compensation[5].

While the current crisis has led to an overall drop in vehicle sales worldwide, electric cars have fared relatively well, with sales expected to increase from 2 million cars in 2019 to almost 2.5 million in 2020, or 3% of global car sales. Uptake of electric vehicles (cars, buses, trucks, and two/three wheelers) continues to accelerate in the future with 150 million electric vehicles, including 35 million electric cars, added to the global fleet between 2020 and 2025, increasing electricity demand by around 150 TWh. By 2030, a fleet of 110 million electric cars together with other kinds of electric vehicles account for over 500 TWh

[4] Autotrends.be `https://magazine.autotrends.be/fr/actualit%C3%A9/nouvelles-voitures/La-crise-des-semi-conducteurs-pourrait-couter-210-milliards-de-dollars-aux-constructeurs-automobiles-cette-annee`

[5] `https://recovery.smithschool.ox.ac.uk/are-we-building-back-better-evidence-from-2020-and-pathways-for-inclusive-green-recovery-spending/` Are We Building Back Better?, Report from the Oxford University's Global Recovery Observatory

of demand, with total transport electricity demand surpassing 1 000 TWh or 3.5% of the global total. The global electric car fleet will triple between 2030 and 2040, adding another 450 TWh to electricity demand and bringing total electricity demand in transport to over 2 000 TWh, which will represent 6% of the global total in 2040 [EU2021c].

The most likely scenario of recovery for the automotive sector at time of writing this White Paper (2021) appears to be U-shaped [ACEA2021c]. [6]. Even though the second COVID wave brings less severe restrictions for the automotive industries and their production facilities, the EU passenger car market contracted by 23.7% year-on-year compared to 2019, corresponding to about 9.9 million units in 2020, due to the COVID-19 pandemic. A persistent drop in sales into 2021 is likely, due to smaller production capacity, as distance regulations remain in place in factories, and decreased consumer confidence. The European Automobile Manufacturers' Association (EAMA) forecasts that the fallout in sales will continue during the first quarter of 2021 before recovery will pick up in the second half of the year. Another issue emerging in the automotive industry relates to the changing circumstances of the industry, namely relative to the development and expected uptake of connected, autonomous and electric vehicles. COVID-19 is argued to accelerate and amplify these trends and contribute to affecting consumer behavior [McKinsey2020f].

There is an ambition to strengthen Europe's role in all parts of the battery value chain. In December 2020, a proposal for a new battery regulation was adopted by the European Commission with the goal to develop sustainable battery production. The establishment of the European Battery Alliance launched in 2017, and subsequent investments seem to have invigorated the value chain. There are more than ten battery factories under construction in Europe. Due to the push towards sustainability, continued demand for electro mobility and strong public support, we expect that the value chain will continue to grow in the EU. In fact, investments in the EU were outperforming the US and China in 2020 [SP2020].

Particular technological opportunities may arise especially for the utility vehicle segment in the area of digitalization (digital services, data management, smart farming services, data management, smart farming, IT services in logistics) and the automation of production processes. For the vehicle industry in Rhineland-Palatinate, there is also the potential to test and develop innovations in the commercial vehicle sector and, if development is successful, to transfer and scale up the products to the passenger car sector. In order to be able to exploit the emerging opportunities and, at the same time, to mitigate risks arising from the high pressure of transformation, it is of central importance to react at an early stage on the supply side. Through targeted transfer and networking offers in conjunction with research projects and innovation cooperations it will be important to support corporate innovation management [wemoveit].

[6] Passenger car registrations: -23.7% in 2020, -3.3% in December, `https://www.acea.be/pressreleases/article/passenger-car-registrations-23.7-in-2020-3.3-in-december`

2.6 Change in mobility behavior

Covid-19 swept across the whole globe and only in a matter of months it had already jeopardized human lives, threatened the continuation and in some cases, the existence of businesses and set off a worldwide economic decadence. The consumers' preferences have drastically changed. Emphasis is given on safety, health and reducing the risk of infection. Private cars are preferred, the use of public transport has plummeted, and shared mobility seems to be out. While consumers have traditionally focused on time to destination, cost, and convenience when selecting transport mode, they now cite the ability to reduce the risk of infection as their major consideration.

Based on a recent McKinsey survey of consumer-car-buying behavior during the pandemic [McKinsey2021b], nearly 70 percent of mobility users in the United States, United Kingdom, Germany, France, Italy, Japan, and China said they would choose to walk or bike at least weekly even after returning to normal life (up six percentage points from pre-crisis levels). Likewise, private cars gained one percentage point (from 78 percent pre crisis to 79 percent after returning to normal life). Moreover, after intense drops in ridership, public transportation users will likely return to at least weekly usage, at around 40 percent. Moreover, shared micro mobility, e-hailing and car sharing should all be slightly more popular, gaining 1 to 2 percent post crisis when normal life returns. Hence, the overall desire of customers to "move" remains intact.

Opinions of members of the High Patronage Committee regarding the change in mobility behavior

Michael Grandfils: *All of a sudden, you start to have people working from home like two days a week. I think that it is going to have a big impact because, potentially, you no longer need two cars, but one car actually because you are living in the periphery and working in the city center. I think this is going to be also a bit of a cultural shift, you know people like to do things differently... I think it's a good way to make them change their habits. You know, if you don't have that bit of striking elements to make them change, it's more complicated.*

Pierre Courbe: **J***ust have a look at the financial crisis in 2008-2009 and therefore make a graph of the evolution of the ratio between the power and the mass of the cars (what measures how powerful they are). This ratio regularly increased from 1980 until 2008 and then suddenly decreased because, due to the financial crisis, people tended to buy less powerful cars that are also cheaper. Directly after the crisis, the evolution of the ratio became positive again, but with a higher growth. So, the effect of the financial crisis was very restricted in time and we went back to the old ways after the crisis. If the impacts of the actual crisis are not too important, in my opinion, we will observe the same phenomena.*

Francesco Ferrero: *Of course, there is for the moment a massive impact on the mobility behavior of people, which reflects in the purchasing intentions for the near future. It is clear that we are using the car less than before and a lot less in many cases. This is up to the decision to buy new cars. There is probably fear for the people who can afford it because there is also this aspect to shift from* *public transport and shared transport to go back again to individual means of transport; then compensate only partially the trend that you mentioned before; I am not super convinced these trends that we are seeing, will remain when the problem is solved. So, I think that it is more likely that we will revert to the situation of before, with respect to teleworking or other phenomena. I think that it will be maybe a marginal increase, but I don't think that it will remain, as the new normal and so my expectation is that we will move back to where we were before.*

Damien Ernst: *People do not want to travel by bus and train.*

Jean Pierre Heijters*: Less people travel. Working from home the way we do now will be the new future, at least for 20-50%. Less mobility requests. Six months ago, people did not want to go on public transport. A lot of second hand, small cars were sold in NL. I think that will come back to normal.*

Frederic Christen: *There will be less miles traveled after the crisis because working from home will become a standard. That doesn't mean that all work will be done from home (for office jobs) but employees will work from home some days per week.*

2.7 The way forward - The "next normal"

In a time of global uncertainty, it is easy to lose sight of the big picture. The damage is likely to be more contained. Certainly, some industries, like travel and hospitality, are reeling from a precipitous drop in demand, and healthcare faces some unique pressures. But, at least in theory, the danger could start to recede in weeks or months rather than years.

It is likely that the COVID-19 pandemic may result in a long-term revamping of supply chains to better focus on resilience. With learnings from the outbreak, the competitive forefront of supply chain operations may likely move toward more comprehensive, proactive modeling. Companies should understand their supply chains more deeply and in more dimensions. This will help prepare the industry for the next disruption.

For some companies, the COVID-19 crisis may also highlight some issues that have needed attention and can no longer wait. When your team cannot get to the office, you may discover just how many manual workarounds your company has put in place for routine activities. Suddenly, finance and human resource transformation becomes more important. When your data centers are in affected areas, or scammers try to take advantage of market noise, cloud transformation and fraud/economic crime solutions become a higher priority.

The 'next normal' anxiety related to the virus combines with economic and financial factors to influence longer term demographic trends and consumer behavior. The shift towards urbanization in some developing economies slows, as employment opportunities become scarce, and some migrant workers return to their hometowns and villages in rural areas. Even more developed economies see a drift towards rural and suburban living, meaning larger average home sizes and more reliance on personal vehicles. Commuters in all parts of the world tend to shy away from transport in favor of home working – where this is possible – or travel by car or bike. International travel stays lower too.

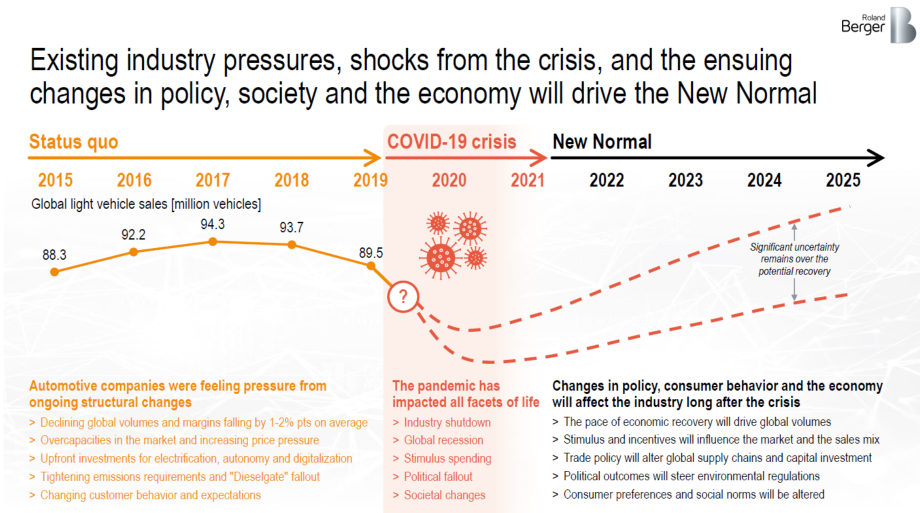


Figure 2.7: Source Ronald Berger

Opinions of members of the High Patronage Committee regarding Covid crisis and the next normal

Etienne Jacqué: *The short term impact is already there: uncertainty about the future leads people to postpone their car replacement. The car industry makes their money on the last 5 or 10 percent of cars sold, so a 5 to 10% market drop can lead to a crisis, causing an avalanche effect similar to the housing crisis 10 years ago. I think the politicians are doing the right thing, they use the crisis as an opportunity to drive change and innovation. This maintains jobs and keeps the economy going, even if it is somewhat artificial. They inject the money in new technologies, positioning for a new post-crisis economy with a technology shift, in this case to electric cars or new energy solutions like hydrogen. It remains to be seen of course how self-sustained the new technology once the crisis measures finish.*

Pierre Courbe: *I would say that there are two possible trends. Human beings are in need of contacts and e-commerce reduces the number of human contacts. So I think that we will probably see a diminution, or at least a smoothing of the growth of e-commerce after the crisis. That is the first possible trend. Human beings are also in need of, well, showing that they have money, that they are in good health and so on. Therefore, the risk of an ageing of the car fleet is limited because, just after the crisis, people will need to show to other people that they are able to buy new cars and so on. That's the second possible trend. So, this probability to have a continuity in the actual tendencies is relatively low. At least if things are not too bad concerning the financial situation of people. But it's very difficult to say.*

2.8 Brexit

Since 2016, Brexit has dominated the political agenda. Up until late December 2020, the chance of a deal between the UK and the EU to regulate seamless cross-border trade was considered highly unlikely. This fundamental uncertainty about future trading conditions presented major challenges for UK-based companies that rely on international supply chains. On 1 January 2021, the United Kingdom left the EU Single Market and Customs Union, and all EU policies. This brings far-reaching changes, affecting citizens, businesses, public administrations, stakeholders and of course the automotive sector in both the EU and the UK as their automotive industries were closely interwoven [ACEA2021c]:

- 51% of all exported UK-built cars were bought by customers in the European Union,
- more than 8 out of 10 passenger cars made in the United Kingdom are exported,
- less than 4 out of 10 cars made in the EU27 were exported (38.3%), with roughly one third of total exports heading to the UK (or 12.4% of total production),
- the EU represents 85% of the UK's passenger car imports by volume

The automotive industry is a vital part of the UK economy, generating 12% of total exports and a turnover of £82 billion. The industry indirectly employs over 800,000 people across the UK. However, the loss of the free, frictionless movement of goods between the EU and the UK, and wider consequences of Brexit could have significant impacts on the industry, including the likelihood of additional customs procedures and tariffs. The sector also depends upon existing EU third country FTAs benefitting from preferential access to markets outside of the EU and reduced tariffs, to which the UK may lose access post-Brexit [DELOITTE2019].

After having been agreed by EU and UK negotiators on 24 December 2020, the Trade and Cooperation Agreement is provisionally applicable from 1 January 2021.

When Covid is cyclical, Brexit is a structural problem [Hancke2021]: Brexit will seal the fate of both old and new investment in the automotive industry. Companies are often located in the UK because of the English language, the deregulated labor market, and the permissive business environment. When the UK is no longer an easy entry port into the EU's Single Market, the main competitive advantage in the race for Foreing Direct Investment disappears.

The Rules of Origin (RoO) requirements seem to throw up important new barriers to trade. Before January 1st, 2021, any product legally made in the UK could be sold anywhere in the UK and the EU. From January 1st, 2021, UK carmakers will have to prove that at least 40% of the value of parts in a finished car that is exported to the EU – be they internal combustion engine vehicles (ICEVs), battery-powered electric vehicles (EVs) or plug-in hybrid electric vehicles (PHEVs) – were produced in the UK or the EU. The threshold for so-called originating content will climb to 45% from 2023 until the end of 2026, and to 55% from 2027. This is particularly challenging for EV production because the batteries alone, which are currently mainly imported from Asia or the US, often make up 50% of the total value of a car. The costs of setting up EV assembly facilities in the UK are prohibitively high without a sufficiently developed battery supply chain. Or, as Ralf Speth, the CEO of Jaguar Land Rover is quoted in AM Online (an automotive industry magazine): "If batteries go out of the UK, then automotive production will go out of the UK." Honda has already announced capacity reductions, and BMW is likely to do the same for the Mini factory near Oxford. In addition, without a significant push towards a large-scale British battery supply chain, it is unlikely that newcomers would choose the UK, now outside the EU, as a production site.

Nissan announced[7] that it will increase production in their Sunderland plant, including EV assembly. While, over the last few years, they were planning to reduce their capacities in the UK, Nissan's exclusive deal with the battery producer Envision has shifted the company's cost-benefit analysis drastically. Envision's plant, which is conveniently located right next to Nissan in Sunderland, was previously owned by the Japanese manufacturer, and currently produces batteries with a capacity of 40kWh. Expanding Envision's portfolio, including the production of 62kWh batteries – which Nissan needs for the Leaf, one of its flagship EVs produced in the UK – enables the carmaker to avoid problems related to the new RoO requirements and invest in the future of its British operations.

Luxury car manufacturer Bentley, owned by Volkswagen, but with production facilities located in Crewe, Cheshire, implemented risk mitigation measures by chartering cargo planes to ship parts in case of delays at seaports in an attempt to avoid any potential supply disruptions in early 2021. In addition to this expensive and unusual form of shipping, Bentley has also been stockpiling parts for up to two weeks of production, up from their usual two days' worth of production. The concerns surrounding Brexit in business and the scientific community are not new. Even though Brexit, and possible future issues regarding the relationship with the EU, are certainly going to be a test for the UK economy, there is the possibility that the changed situation might lead to an increase in both domestic manufacturing and reshoring, with manufacturers seeking to eliminate the risk of future tariffs or possible supply chain disruptions (Bailey and Tomlinson, 2017; Vanchan, Mulhall and Bryson, 2018; Kinkel, Pegoraro and Coates, 2020).

M. Friedrich, CEO Fonderie Lorraine S.A. made an interesting point regarding Brexit; *The English state also subsidizes its industry or the players in or around the automotive industry. We have been confronted with a competitor who has emerged, who we never saw appearing, and who must have all his in-*

[7] https://www.theguardian.com/business/2021/jan/22/brexit-has-given-competitive-edge-on-car-battery-tariffs-says-nissan-chief

vestment paid for by the English state and who manages to position himself. In the past, it never managed to position itself. So there is also something that is happening.

Consequences of Brexit are still unclear as long as the relation between the EU and the UK is only regulated by the current trade agreement. For sure, the pre-Brexit situation can only be maintained if further trade agreements are signed between the EU and UK ensuring the development of an integrated production model. As for now, the supply chain is maintained as it is, yet new technologies like electric cars, autonomous cars require new investments. The actual trade agreement in place is not enough to ensure the development of these new technologies in an integrated scheme like the existing one when some spare parts are produced in the UK and assembled in the EU.

If the actual situation continues, European car manufacturers may hold off making decisions on assembly in the UK until they know whether they will face tariffs when exporting to the EU. On the other hand, the UK might react in developing a more integrated production model specific for the UK brands (e.g., Jaguar Land Rover as mentioned in [Bailey2017]. Consequently, it is likely that the two automotive industries will evolve in more separate ways with specific production lines in the UK and the EU.

Chapter 3

Electrification

3.1 Decline of Diesel and Internal Combustion Engine

The **diesel gate** crisis has clearly cast doubt on the ability of manufacturers to develop clean engine technologies. In addition, the growing pressure of increasingly stringent emission standards is pushing manufacturers towards electrification, which currently seems to be the only way to reduce fleet emissions significantly and sustainably, especially from premium vehicles. The concern of citizens for better air quality in large cities is a global concern, first originating in Asia and now spreading to large European cities: Paris, Stockholm, London, etc. An increasing number of jurisdictions limit the use of, if not outright ban, the most polluting ICE-powered vehicles in city centers using **Zero Emission Zones**. In the future, associations and politicians are even considering banning internal combustion engines in cities. Paris intends to ban gasoline and diesel vehicles in the city center by 2030. Rome has announced plans to ban diesel vehicles from the city center by 2024, and Milan by 2030. German cities have gained the legislative power to make these decisions independently of the federal government.

The crises have accelerated the trend away from internal combustion engines. For many car manufacturers, the financial crisis of 2008 and then, the sanitary crisis of 2020 have thrown companies in difficult financial situations. State aids have often been accompanied by conditions on the greening of fleets. Today, the recovery plans of several countries clearly emphasize electric and hydrogen powertrains. Research programs for internal combustion engines have been in sharp decline. Today, it is the development teams for new models that are massively shifting towards electric, hybrid or fuel cell technologies.

Recently, several manufacturers have announced that they are switching their fleets to electric vehicles: Volvo, Ford and Toyota are joining Tesla, Pole Star, etc. The change seems radical and irreversible. Most manufacturers are announcing more than two hundred new electric models by 2022-2023. The tipping point seems to be around 2024-2025, with electric powertrains costing less than equivalent internal combustion engines equipped with all the depollution and after treatment systems required to comply with coming standards.

After a century of domination without compromise, the combustion engine seems to be giving way to the electric motor, which it had supplanted since 1905-1915. A new era is beginning with this decade.

3.2 Market Overview

The global electric vehicle (EV) industry continues to expand rapidly, and regional performance varies considerably. The growth in the electric-vehicle market including battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) can be assessed using McKinsey's proprietary Electric Vehicle Index (EVI) [McKinsey2020c]. The EVI is a composite index accounting for different sub criteria. It explores two important dimensions of electric mobility: *Market demand & Industry supply.* The EVI assesses the key performance indicators in each country and rates them on a scale from 0 to 5 for every dimension. These scores serve as the basis for the final country ranking. According to McKinsey's Electric Vehicle Index* (EVI), growth in the electric-vehicle market globally has slowed. EVs sales rose 65% from 2017 to 2018. But in 2019, the number of units sold increased only to 2.3 million, from 2.1 million, for year-on-year growth of just 9%. Equally sobering, EV sales declined by 25% during the first quarter of 2020. The days of rapid expansion have ceased—or at least paused temporarily. Nonetheless, Europe has seen the strongest growth in EVs.

Key EV markets suggest shifting regional dynamics, with China and the United States losing ground to Europe. EV sales remained constant in China in 2019, at around 1.2 million units sold (a 3% increase from the previous year). In the United States, EV sales dropped by 12% in 2019, with only 320,000 units sold. Meanwhile, sales in Europe rose by 44%, to reach 590,000 units. These trends continued in first-quarter 2020 as EV sales decreased from the previous quarter by 57% in China and by 33% in the United States. In contrast, Europe's EV market kept on increasing by 25%. The EVI of 2020 shows that the Nordic countries lead for market demand, while China and Germany dominate industry supply.

Unlike other key EV markets, Europe has seen significant EV growth [McKinsey2020c]. In 2019, sales increased by 44%, the highest rate since 2016. The European Union's new emissions standard—95 grams of carbon dioxide per kilometre for passenger cars—could also boost EV sales because it stipulates that 95 percent of the fleet must meet this standard in 2020 and 100 percent in 2021. BEV sales picked up speed substantially, with a 70% growth rate propelled by three models: Tesla Model 3, Hyundai Kona, and Audi e-tron.

According to BCG's latest global automotive powertrain forecast [BCG2020], sales of electrified vehicles (xEVs) will grow even faster than expected. These cars will seize a third of the market by 2025 and 51% by 2030, surpassing sales of vehicles powered purely by internal combustion engines (ICEs). The

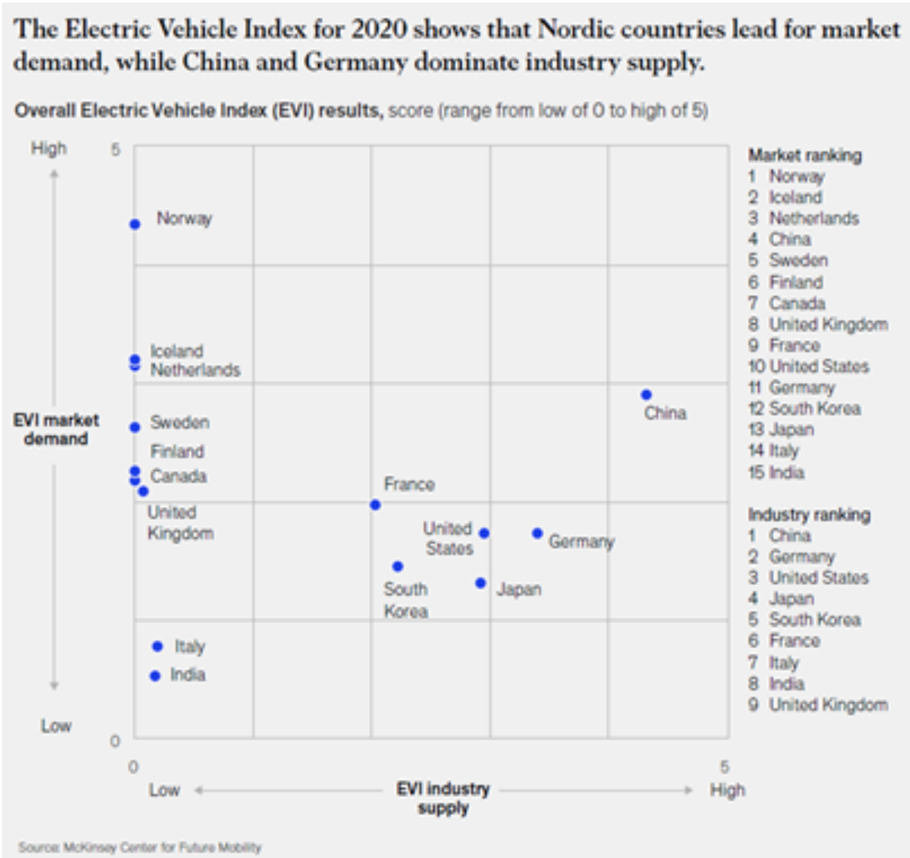


Figure 3.1: Electric Vehicle Index 2020

previous forecast showed xEV sales taking a quarter of the market by 2025 and approaching 50% by 2030.

Electric-vehicle makers are debuting new models and boosting sales of existing ones

Automakers launched 143 new electric vehicles—105 BEVs and 38 plug-in hybrid electric vehicles (PHEVs) in 2019 [BCG2020]. They plan to introduce around 450 additional models by 2022. Most are midsize or large vehicles. Given the estimated production levels, German manufacturers, with an expected volume of 856,000 EVs, could overtake Chinese players in 2020. That would boost Germany's global production share from 18 percent in 2019 to 27 percent in 2020. The top 29 OEMs already plan to invest more than $300 billion over the next 10 years to further xEV production, and many claim they can do so profitably [McKinsey2020c].

At the Munich Motor Show 2021, BMW reinforced its environmental ambitions, announcing its intention to become CO2-neutral and to promote the

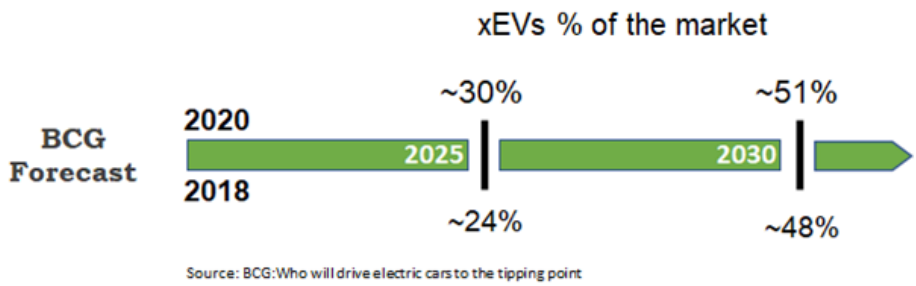


Figure 3.2: BCG forecast for xEVs

circular economy. The iVision Circular concept illustrates these ambitions[1]. Porsche showed up with a vision of a future electric race car.

Figure 3.3: Source Autotrends - Volkswagen ID.Life

With a starting price of €20,000, the ID.2 foreshadowed by this concept car may well democratize zero-emission propulsion. Based on the MEB electric platform already used by the ID.3 and ID.4, but in a shortened and simplified version called "Entry", the Volkswagen ID.Life is a small crossover equipped with a single 231 hp engine. In the spirit of economy, the car uses its user's smartphone as the multimedia system and the majority of the controls are on the steering wheel. Using many recycled materials, it foreshadows the ID.2 that

[1] https://magazine.autotrends.be/fr/actualit%C3%A9/nouvelles-voitures/BMW-au-Salon-de-Munich---electrique-et-circulaire

will be on the market by 2025. The manufacturer has announced a base price of around €20,000[2].

Francesco Ferrero (LIST) thinks that *we are approaching the* ***tipping point*** *where electric vehicles will move on from being futuristic technology for early adopters. We are in this process already and it will take a few more years for it to become irreversible.*

In the same spirit German Castignani (MOTION S) thinks that *in Europe it was the first-time in October 2020 that we sold more EVs and hybrids than diesel vehicles, so that shows that we are crossing the* ***equilibrium point****. This will grow and grow; people are getting convinced about electrification. Maybe first it will be hybrids, maybe people will first take a hybrid and not take the risk to directly buy an electric vehicle, because they know which are the inconveniences, but we should have a substantial amount of hybrid vehicles within the next 2-3 years.*

3.3 What are the drivers for accelerated EV acceptance?

Multiple factors are driving rising EV sales, especially in the near term, but at a macro level the two most important ones are on the one hand the fact that EVs offer appealing Total Cost of Ownership (TCO) for consumers, and on the other hand, that they represent the lowest-cost solution to meet regulatory standards for the industry.

3.3.1 Falling Total Cost of Ownership (TCO)

By far, the biggest cause of falling TCO for BEVs is battery prices, which are decreasing more steeply and more quickly than expected. It is expected that battery pack costs will fall below $100 per kilowatt hour (kWh) by 2030 [BCG2020]. In the 2018 forecast the battery pack cost by 2020 was estimated at 176$/kWh and in the 2030 forecast the estimated cost has dropped even further. As estimated by several car manufacturers the pitch point between EV and ICE should occur around 2024.

3.3.2 Regulatory Considerations

Several types of regulations will accelerate electrification in the years before EVs reach a favorable TCO relative to ICEs. The most important, of course, is emission standards. In Europe, OEMs need to decrease CO_2 emissions by about 20% to meet 2021 targets. Recent increases in fleet wide emissions underscore the challenge. For example, Europe's fleet wide emissions have risen, rather than fallen from 118 g/km of CO_2 in 2016 to 120 g/km in 2019—as the share

[2] https://magazine.autotrends.be/fr/actualit%C3%A9/nouvelles-voitures/Volkswagen-IDLife--la-future-citadine-electrique-abordable

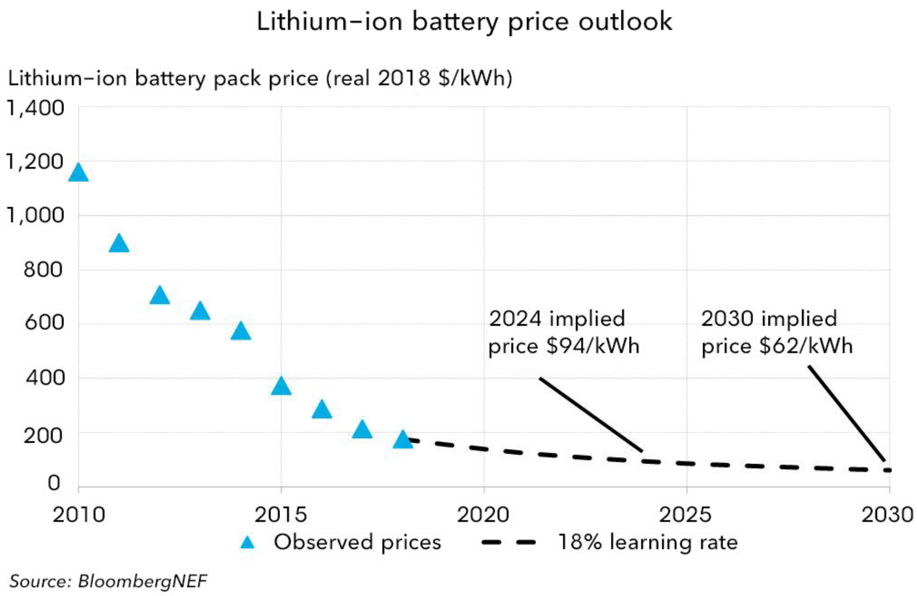


Figure 3.4: Lithium-ion battery pack drop as estimated by Bloomberg `https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/`.

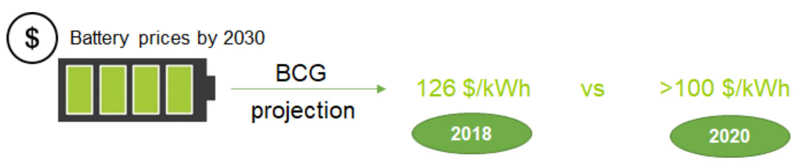


Figure 3.5: BCG forecast for battery pack prices

of gasoline engines, replacing diesel, and of SUVs has increased. TCO-driven forecasts suggest that without government incentives the EU fleet mix will not be able to reach current CO_2 targets, which could result in heavy penalties for the industry [BCG2020]. Finally in 2021, most car makers could avoid penalties entering pooling arrangements with BEV manufacturers: FCA with Tesla and Honda, Ford with Volvo, and Polestar, while VW integrated EV manufacturers as MR, Airways, LEVC and e.Go. Ultimately, they also made use of the super credits rule that BEVs and PHEVs can be counted twice. The success of Audi's e-tron model contributed to the group's overall reduction of 20% with demand for the electric SUV growing by almost 80% last year and achieving more than 47,000 sales across Europe. Only the VW group had to pay a fine of 100 Million euros.

Pierre Courbe (IEW) described the regulation that boosts the EV mar-

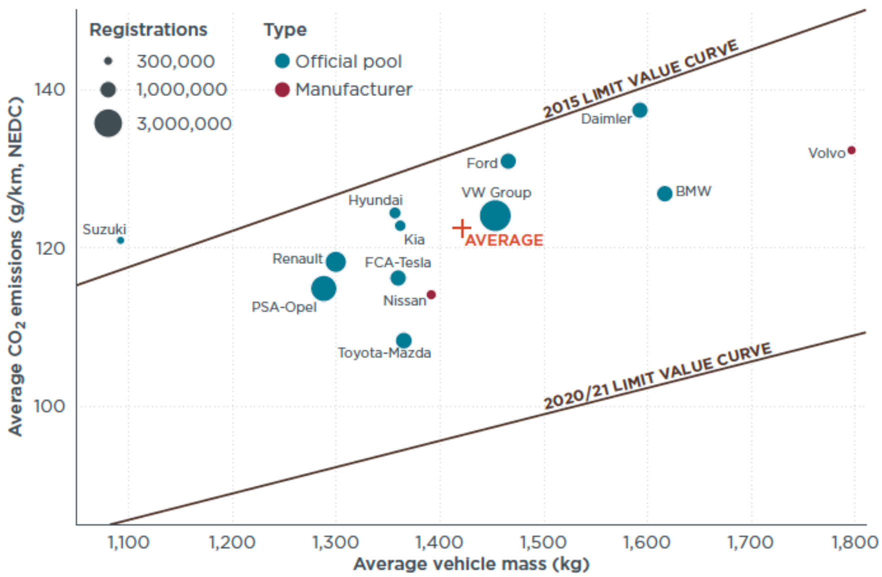


Figure 2. Performance of top-selling EU passenger car manufacturers in 2019 compared to 2015 and 2020/2021 emissions target compliance curves.

Figure 3.6: CO2 fleet emissions of EU passenger car manufacturers in 2015 and 2019. Source: ICCT The international council on clean transportation `https://theicct.org/publications/co2-new-passenger-cars-europe-aug2020`.

ket *regulation (EU) 2019/631 contains three elements that clearly boost the EV market. The first one is the fact that the regulation considers that BEVs are zero emission, without considering the LCA of the electricity. The second element is the super credits in which BEVs and PHEVs can be counted twice in the calculation of the emissions of the car manufacturers. And the third is the objective of the car percentage. The percentage of EVs should be 15% in 2025 and 35% in 2035. These elements are sufficiently powerful to shift the market to electric cars.*

German Castignani (MOTION S) brought another important matter into attention, regarding regulations in the charging network: *The regulations in some countries like in France and Belgium prevent the charging network from selling the energy per kWh, which is a means of pressure. One can only buy charging time, there is a lack of transparency there, the regulations should be clearer. For example, when one buys gasoline, it is in liters, when one buys electrons, it should be in kWhs and not in time. This is something that should be a clear change in the regulations, a unit is fixed and there is clarity for everybody.*

3.3.3 Offered Incentives

Government subsidies remain a major driver of electric-vehicle (EV) sales. Fiscal measures to stimulate EV sales are available in nearly all EU member states now, but still the monetary value of these benefits and incentives varies widely across Europe. Today, stimuli for electrically chargeable cars are available in 26 out of the 27 EU countries [ACEA2020b]. Twenty EU member states offer incentives (such as bonus payments or premiums) to buyers of electric vehicles. Six countries do not provide purchase incentives, they merely grant tax deductions or exemptions for electric cars (Belgium is amongst those countries). One country does not provide any tax benefits or incentives at all (Lithuania).

German Castignani (MOTION S) shares an interesting point of view regarding the price of kWh: *Something that might boost a little bit more for full electric would be the price of electricity for this type of mobility. What there is right now is a big difference between the kWh one pays at home and the kWh that is paid at the charger.*

Etienne Jacqué (Cebi group) perceives fiscal incentives as means to get through a 'learning curve': *We must go through a painful learning curve, to get a good technology in 10 or 20 years and to make this learning curve less painful we need incentives. So, the fact of giving money to the people that are ready to buy electric cars makes it a little less painful to go through this learning curve to help the development.*

Pierre Courbe (IEW) believes that consumers preference for EVs is strictly dependent on fiscal incentives: *If we have a look at fiscal incentives at the level of the member states, in my opinion, the main effect is bargain-basement effect / windfall (in French we say* ***"effet d'aubaine"****) the fact that consumers tend to electric cars only to get the incentive. But when the incentive disappears people will get back to their old habits. It is an opportunity effect. If I have a look at the state of the market in the Netherlands and Norway, of course, but also in other countries, in my opinion it is just an opportunity effect, but not able to influence the car market in the long term.*

Jean Pierre Heijsters (ANL) shares the same opinion: *In NL there is a particularly good way of taxing EV driving and that is why it is interesting to drive such a car, due to the tax regulations. Now these regulations are brought on the same level as for normal cars because the government needs an amount of taxes and the number of EVs is growing then tax income is lost. Now, that does not really push EV sales. For normal people, an EV is still more expensive.*

Mr Marc FRIEDRICH CEO, Fonderie Lorraine S.A. shares a different opinion: *So personally, I would say that the subsidies we give for electrification are not adapted. So, if we want to promote electrification, we'd better change several things. Today, for example, you live in an apartment, you have no chance to change your battery? To have the chance to charge your battery, you have to live in an individual house. That's the first thing for everyone who lives in an apartment, it doesn't work. That's the first one. So, we should already change the law and impose that in any new construction, there should be charging stations in parking spaces, underground garages and things like that.*

Catching up with all the buildings that are built today would not work either. Today in France, on a winter evening at 7 p.m., if there were 10% of the park that was electric, everyone would plug in their electric plug in winter, while heating is already often electric. With all this, the electrical system would collapse. Here again, we would have to invent a system that would say: I plug in my car, I press a button and EDF tells me when there is energy available and when it can be charged. There should be an intelligence somewhere behind it, especially in France, in connection with the atomic energy somewhere. Afterwards, in Germany and in other countries where there is no such atomic energy, it is a bullshit to electrify somewhere because finally, you are going to burn coal or gas to make electricity that you are going to transport and that you are going to inject... It's better to have a good gasoline engine that doesn't consume much.

3.4 Consumer preference and EV buyer profile

The fourth key dimension, after regulation & incentives, battery technology and charging infrastructure, is consumer demand. The opinions of the members of the High Patronage Committee are various and rather complementary to each other. According to Mr Francesco Ferrero (LIST) *the consumer preference is always crucial. The difficult question is to also understand whether the consumer will get, when they buy an electric car, what they expect, the user experience. That is difficult to predict. Only the people who have an electric vehicle, in the end, know how it is, what it requires to maintain it, to recharge, to drive it. So, the shift is difficult, let's say, turning.*

The latest Deloitte study on the car purchase intentions of Belgians highlights a growing interest in electrified vehicles. Almost half of the respondents say they are ready to take the plunge, but mainly in favor of hybrid engines[3].

In the same spirit, Mr German Castignani (MOTION S) thinks that *even though right now sales are driven by fiscal incentives, tax credits, subsidies, etc., in the end the ones that do not know a lot about the technology, the question they ask is, 'is this fitting my mobility? Is this fitting the trip that I have to do and the distance I'd like to do?'. People are mainly still driven by fiscal incentives, but people are also concerned by topics like the environment and climate change.*

From a slightly different perspective Mr Etienne Jacqué (Cebi group) and Mr Pierre Courbe (IEW) think that consumer demand *is driven by good marketing and by availability* and that *it is driven by the manufacturers policies,* respectively.

As far as the EV buyer profile is concerned, Mr Pierre Courbe (IEW) identifies *four different profiles. The first one is early adopters that are motivated by new products, the desire to be looked at as interesting people. The second type is ecologists. They are convinced that technology can save us and so they want to save the planet. And they want a new product to save the planet. The*

[3] `https://magazine.autotrends.be/fr/actualit%c3%a9/mobilite/Etude-Deloitte--les-Belges-sont-ils-prets-pour-lelectrique` Etude Deloitte: les Belges sont-ils prêts pour l'électrique ? (autotrends.be)

third type is the opportunists that are interested in subsidies to buy electric cars and so on. They try to capture the subsidies. And the fourth type is the ones who can make a good calculation on the life cycle of the car and on the total cost of ownership and they realize it is interesting financially for them to buy an electric car. And, in my opinion, they are quite different from the typical car buyer.

Mr Marc FRIEDRICH identifies one target. The *target is the second car, a woman who has means, who has a store in town and who, every day, has to drive from her single-family home, into Frankfurt, into Stuttgart 15-25 km and out again. For this purpose, the electric car today is very suitable. And I think it is very suitable for certain professional vehicles. A postal worker, for example, who only does stop-and-go, whether it's a small electric bike or a small electric moped or an electric scooter for certain deliveries in the city where we stop a lot. For example, I think that UPS, this kind of thing, electric vehicles, it's quite adapted. They have stopover periods where they can recharge for very short, intense periods of deliveries, with a lot of stops.*

3.5 CO_2 footprint of EVs

The real CO2 footprint accounting for direct and indirect emissions is for sure a raging question which is often put at the front stage by electric skeptic people. Many fake information is moving around on the net. The debate is also strongly discussed in the cozy circles of scientific meetings. However, scientifically validated investigations converge to a new well-established conclusion: BEVs are less polluting than ICE fueled with petrol even if as much as possible indirect emissions are integrated in the life cycle assessment. We report here the published work by The Transport and Environment organization[4] that sounds to be quite convincing for public dissemination.

Three types of mid-size cars (Gasoline, Diesel and EV) sold in 2020 are compared. Two extreme scenarios are considered to produce electricity. In the **best-case scenario**, if the electric car is run on clean renewable electricity (e.g., Sweden hydro power). In the **worst-case scenario**, the battery would be produced in China and the EV would run on one of the EU's most carbon intensive grids (e.g., Poland) [TE2020a]. The medium-sized EU-average electric car emits about 90 gCO_2e/km over its lifetime, while a diesel counterpart emits 234 gCO_2e/km and a gasoline car 253 g/km [TE2020a]. In other words, on average in the EU, the EV emits about 2.7 times less CO_2 than the conventional car in 2020 (2.6 times less than diesel and 2.8 times less than gasoline). When the battery is produced with clean electricity (e.g., in Sweden), the impact of electric cars decreases to 86 g/km or 2.7-3.0 times less than ICE. In this **best case scenario**, running the electric car on clean renewable electricity (e.g. Sweden hydro power) cuts the GHG impact down to 47 g/km which is 5.0 and 5.4 times less than diesel and gasoline equivalents (Fig. 3.7).

[4] `https://www.transportenvironment.org/what-we-do/electric-cars/how-clean-are-electric-cars`

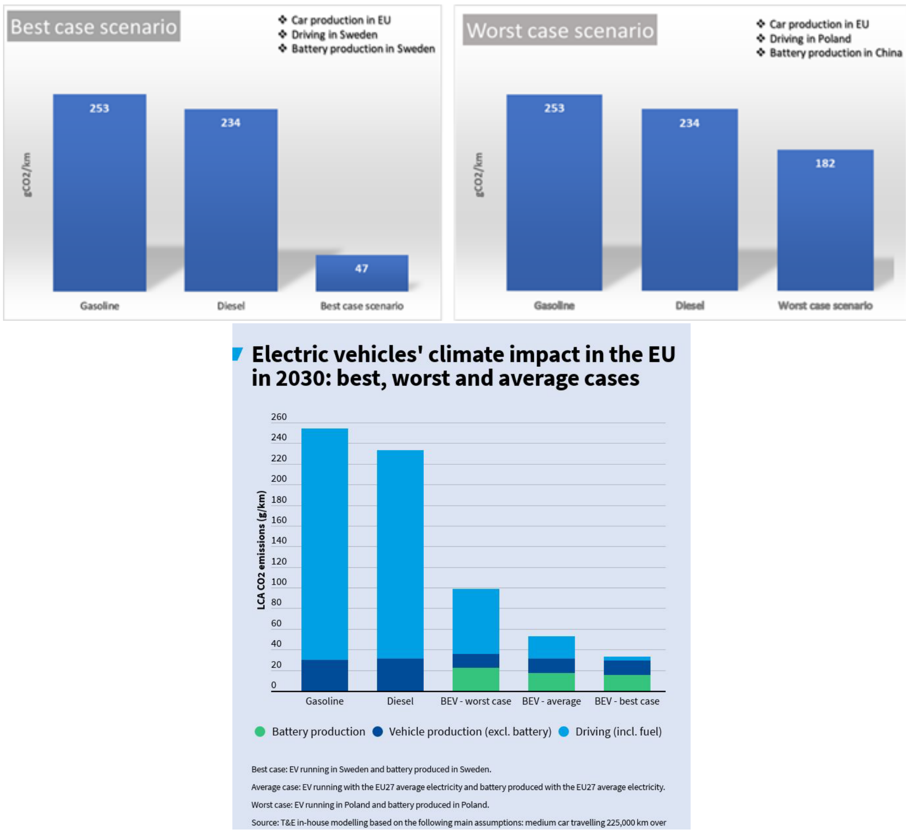


Figure 3.7: EVs in EU are cleaner

In the **worst-case scenario**, the battery is produced in China and the EV would run on one of the EU's most carbon intensive grids (e.g., Poland) . In this situation, the lifetime impact increases to 182 g/km, but EV is still 22% cleaner than its diesel counterpart and 28% cleaner than its gasoline counterpart.

A major difficulty in conducting LCA for batteries is firstly, the large uncertainties related to material extraction and the battery production. Secondly, LCAs are inherently uncertain. Each value calculated by the tool should be considered as a range given the uncertainties and variabilities underlying the assessment. Therefore, Inter Environment Wallonia prefers *to have rough figures, today, on an LCA basis. BEVs are 50% less polluting, less emitting CO2, than an ICE, but it is a rough figure. We do not have to consider that more precise figures are reliable.*

As pointed out in this study, resorting to green electrical energy production will be a key factor for making cleaner road transport based on BEVs and PHEVs. As mentioned by Francesco Ferrero, *the renewable energy generation is less than 10% in Europe and it is projected to go up to 30% in the next 20* *years which will be a better leverage for EVs.*

A second heavy issue emphasized by Etienne Jacqué is "*The next thing is the battery production and recyclability*". As stressed by an auto maker developing engineer during the Automotive congress held in September 2019 in Liege, *the connection with the recycling processes and the teaming up with good industrial partners is a crucial issue to master the overall CO2 and environmental impact.* Huge efforts are currently deployed in research and in industrial developments, which are now paving the way to a massive recycling of BEVS and PHEVs. In addition, ensuring a minimum lifetime and usage of batteries is necessary to move over the breakeven point over which the BEVs and PHEVs are taking advantage of the CO2 investments put in the battery's fabrications. As mentioned by Etienne Jacqué: The CO2 equivalent emissions for producing an electric car are higher than a combustion vehicle. A Diesel car may drive approx. 50,000km (according to some studies) for the equivalent emissions of a newly produced electric car. Lifecycle considerations are critical to compare technologies, but they also require care and transparency in the assumptions used for calculation.

3.6 Charging infrastructure

As EVs become mainstream, the related EV ecosystem must grow. Access to efficient charging infrastructure could become a roadblock to EV uptake. Total charging energy demand for the EV vehicle population across China, Europe, and the United States could grow dramatically from 2020 to 2030, increasing from roughly 20 billion kWh to about 280 billion kWh (Figure 3.8).

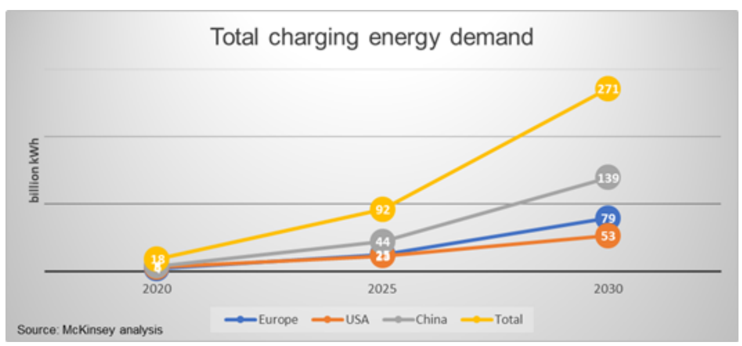


Figure 3.8: Total charging energy demand forecast

Unlike ICE vehicles which typically refuel solely at gas stations, EVs can recharge at multiple locations and in multiple ways, e.g., at home, at work, in public, and on highways for long-distance trips. In the European Union, as EVs go mainstream, most sources guess that charging will likely shift toward public options and away from the home over time, with the share of home charging declining from approximately 75 percent in 2020 to about 40 percent by 2030. This lags from the forecast that in the decade, more middle and lower-income households without home-charging options are expected to buy EVs from 2020 onward.

This charging infrastructure issue was widely discussed in the High-Level Committee with sometimes quite different and opposing opinions.

Damien Ernst, as a specialist of the electrical grid and energy market, thinks that *charging infrastructure will be different for autonomous. Second, the government should put in place the infrastructure to regulate the market, while the private sector should invest in the charging infrastructure. In addition, smart metering, and computer layers to control the grid should be installed to make sure that the consumption of the EVs is compatible with the electricity grid and production. This is under the responsibility of the distribution network operator with the supervision of the government.* **German Castigan**i raises the question of the role of OEMs that *might try to sell electrical cars as well as charging boxes for the house and may be a kind of subscription for charging!* It will be interesting to see the positioning of car vendors and to see if they take the lead on this market, trying to sell coupled offers. In this case would it be reasonable to ask them to take part in the dead costs of the kWh!

Franscesco Ferrero was questioning the sustainability of cable charging because of difficulty to define standards that are commonly admitted by all parties. He is *guessing more on wireless charging (induction charging) because it is easier to come to a harmonized standard. However, this technology is often blamed for its lower efficiency.*

Environmental organizations see in the definition of charging infrastructure *a political tool to refocus the need for personal mobility and to introduce a bit of rationality in the way we look at cars. While fast-charging and DC infrastructure would be interesting for public transport, taxis, etc. slow charging will regulate car usage for personal mobility.*

Damien Ernst envisions the question of charging infrastructure should be also considered considering the coupled evolution in the market towards electrical and autonomous vehicles. He thinks that *charging infrastructure will be different for autonomous vehicles.*

Jacques Haenn, Head of the Hydrogen sector of the Grand Est Pôle Véhicule du Futur, puts forward an interesting opinion: *In France, the French strategy is to create ecosystems around a hydrogen production and a station. Germany had adopted a slightly different solution. Germany had pushed for the deployment of stations along the highways. Today, in Germany, we have more than 100 stations, whereas in France, we have only 40. Why is that? On the other hand, if we look at the numbers of vehicles, France has the same number of vehicles that run on hydrogen as Germany. Can you imagine that number? I think there are 400 or 400 light vehicles. You imagine that in all Germany, there are 400 mg for 100 stations built or that the person he thinks is hydrogen at the station must be on fire? It must wait for a law. He must be able to embrace the person who arrives. Finally someone with someone who has a good roadmap. So he must then, of course, that these stations were subsidized, but still. The amortization of the station that France has decided to work in a different way, is to say I want to promote. So that's why there are calls for projects from the City. That makes* *echo, this system and where we make it, we try to find industrialists, fleets of heavy vehicles. We see well the main systems around this station and those of its production.*

3.7 New opportunities (recycling, reuse, stationary storage)

As electric vehicles become mainstream the related EV ecosystem grows accordingly and that creates needs, for example the need for charging infrastructure as it was described before, but also opportunities. One of the opportunities that was identified by all the interviewees, members of the High Patronage Committee lie in battery reuse and/or recycling. *Recycling will become an extremely important topic and indeed Europe can have a role in this key domain, because it is an economy that is mature, in terms of the risk management of the recycling of material*s, as was cited by Mr Francesco Ferrero.

In the Grand Duché of Luxembourg, there is an open discussion now on the topic of circular economy and what should happen after 4-5 years of use of an EV, when the battery will need to be replaced**.** Mr German Castignani opinion is that *it should normally be the duty of OEM, but the infrastructure is not there. The dealers do not have the infrastructure either, since it needs a lot of space. Something should be done there, to aggregate brands and dealers in richest territories so that there is a recycling center for EVs for an entire area, offered by the government. OEMs should of course contribute because they are obliged to recycle. However, it is hard to see every OEM to have its own recycling units.*

Mr Etienne Jacqué gives a specific example for an OEM entering the recycling business. They make cars, but they also control the entire material value chain including the recycling chain. That way, critical materials always remain in their hands, they understand that it is good business because you make money when they sell the material and they make money when they recover the material. Business and sustainability play together here, the more you recover, the more profitable it becomes. A good concept

Mr Pierre Courbe puts forward an interesting opinion, regarding the fact that battery recycling is necessary, it is an opportunity, but it is not the silver bullet: *Recycling is not only an opportunity but also a necessity for environmental reasons, but it is not the silver bullet. If you consider that you recycle 50% of the quantity, you have an X quantity. Now you recycle it with 50%. If you do it 5 times, 5 Cycles, at the end of these five cycles, you will only get three percent because of 50% of 50%... so it is not the silver bullet. It is necessary. But it is also necessary to get policies to attempt to limit the size of the batteries, the size of the cars and so on, to reduce the need of raw materials or of recycled materials. It is very complimentary from our point of view to recycle.*

In the Netherlands the situation is a bit different, and they propose another business model. According to Jean Pierre Heijsters *in France and Germany the* *car manufacturers are responsible for the end-of-life. In NL the government is responsible for the end-of-life, we are very busy with the EVs that are coming to an end-of-life to develop a system to deal with the batteries. There are also DAF trucks and VDL, they also produce trucks with batteries, and we look at what we are going to do with these.*

Another identified opportunity regards the reuse of EV batteries for stationary storage purposes. EV batteries are typically replaced after they lose around 20% of their capacity, which means that there is still up to 80% capacity remaining that can be used for stationary storage applications. New research, growing automotive industry interest and an expanding start-up ecosystem suggest that an opportunity emerges.

Nissan was one of the first major automakers to pilot second-life EV batteries in a grid-scale storage installation in 2015. That same year, BMW tested used batteries in demand response events during an 18-month pilot project in partnership with Pacific Gas & Electric. Also in 2015, Daimler AG announced plans to build a 13-megawatt-hour second-life battery storage unit at a recycling plant in Lünen, Germany. Daimler subsidiary Mercedes-Benz Energy teamed up in 2019 with Beijing Electric Vehicle, one of China's largest EV makers, to build an energy storage system that uses retired EV batteries.

Another battery storage project using second-life EV batteries is set to be built in Germany, with an aim of developing an installed capacity of 20MW. A new joint project company has been set up to run the project between the Group Renault, The Mobility House, Mitsui and Demeter. The project is being billed as the largest stationary electricity storage system using EV batteries in Germany, following on from an initial 45MW project in France.

3.8 The effect of the pandemic on the electrification

COVID-19 crisis has significantly influenced major demand drivers

The COVID-19 crisis presents the greatest challenge to the global economy since World War II and has already exacted a heavy toll on the auto sector. Within the LV market, global sales for 2020 are currently expected to decline 20 to 25 percent from pre-pandemic forecasts in a virus-contained scenario. In the hardest-hit countries, the crisis could force staggering drops of up to 45 percent in LV sales for the year.

Europe: Positive momentum, with emission regulations potentially pushing market share higher by 2022

Despite the COVID-19 pandemic, European leaders have maintained a strict fleetwide CO_2 emission target of 95 grams of CO_2 per kilometer by 2021. Many major European-based OEMs have publicly committed to reaching that target and have rolled out an unprecedented number of battery-powered- EV and plug-in hybrid-EV models. They introduced 42 models in the first quarter of 2020 alone. European governments have introduced new purchase subsidies, tax breaks, or a combination of incentives to encourage EV adoption and promote green mobility. While they implemented those policies to improve emissions, they are also responding to increased consumer concerns about sustainability and environmental issues. The incentives (such as Germany's subsidies toward the purchase of an EV), combined with the increase in EV models, has led to soaring consumer demand— despite the continued COVID-19 pandemic. For example, vehicle registrations for plug-in hybrid EVs and battery powered EVs in Germany in the first half of 2020 increased by 200% and 43%, respectively, over the first half of 2019. Overall, the sales of electric vehicles in Europe will increase until 2022. Before the Covid-19 crisis there was a forecast for an increase from 600.000 units in 2019 to 2.000.000 units in 2022. The current forecast as it is established with the pandemic can be seen in Figure 3.9.

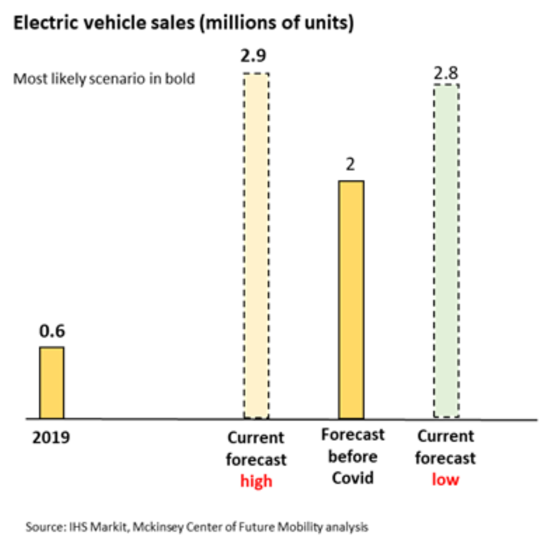


Figure 3.9: Electric vehicle sales forecast in Europe

The market share of EVs in Europe in 2019 was at 3% and the forecast before the pandemic rose to 14% for 2022. In the new forecast, post-pandemic, it may vary between 12-15%, even slightly higher from the initial forecast (Figure 3.10).

The above are in accordance with what Jean Pierre Heijsters (ANL) cites: *NL is a supplying country, 8% of what is produced is supplied to other countries. What we see now is that the transition to EV is going fast. Even Covid has sped up the transition.*

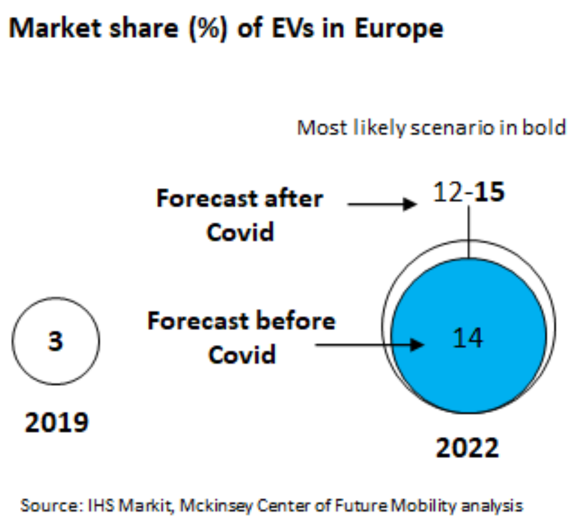


Figure 3.10: Market share of EVs forecast in Europe

3.9 The Impact of Electromobility on Powertrain Machinery

Undoubtedly, electrification has a positive impact on climate change and is going to play a major role in the years to come. But it comes with implications for the types of engines and demand for fuel moving forward. It also has implications for the underlying automotive production technologies as well as the required components, and, thus, on the machine tool industry.

There are key questions that are top-of-mind for industry players nowadays, such as '*How can players along the value chain in general, and machine tool manufacturers, successfully respond to and prepare for the challenges they face?*' or '*Why, to what extent, where, and by when are significant changes in the powertrain machine tool market to be expected?*'.

In the most recent McKinsey report [McKinsey2021] four important key messages are distinguished:

- The electrification of powertrains leads to shifting demand for components and, consequently, a change in the machine tools required to manufacture these components. The transmission is the most impacted part of the powertrain.
- The number of key components will decrease from around 30 in an ICE powertrain to around 9 in a BEV powertrain.
- A significant decrease in machinery capex per vehicle is expected over the next 10 years, as the decrease in demand for ICE powertrain manufactur-

ing technologies such as drilling, milling, or punching will not be offset by the growth of e technologies such as stacking or winding.

- Players along the value chain, predominantly machine tool manufacturers, need to rethink how they will cope with the changing market environment due to the shift towards e-mobility.

The shift towards electrification will lead to a shift in component demand. Components that are largely present in ICE powertrains today but are also needed in EV powertrains will have an increased demand between 2020 and 2030. For example, blade carriers, gear wheels, planet carriers, shafts, transmission pumps, battery cells and modules, compressors, etc. On the other hand, components which are specific to ICEs will likely decrease in demand, for example, high-pressure fuel pumps, gasoline particulate filters, pistons, etc.

3.10 China and Europe are leading global electric car sales

Government policies remain the key driving force for global electric car markets, but their dynamism in 2021 also reflects a very active year on the part of the automotive industry. Announcements, targets and new model launches have helped strengthen the view that the future of cars is electric. At the same time, the huge success of electric vehicles was challenged by tight supplies for components and increases in the prices of bulk materials, bringing supply side concerns to the top of the agenda for government and industry alike.

Over the course of 2020 and 2021, many governments set targets to phase out sales of internal combustion engine cars within the next two decades, as did several car manufacturers. Electric vehicles have become the road transport technology of choice for many governments and the automotive industry. The US government announced in November 2021 an ambitious 50% electrification target for new cars by 2030, supported by the announcement of the installation of 500 000 charging points to help increase consumer confidence. In Europe, the EU Commission proposed to bring the CO2 emission standard for new cars to zero by 2035. At the same time, several automakers announced electrification targets. For example, Volkswagen said that half of its sales would be electric by 2030. Ford said it expects 40%-50% of its sales to be electric by the end of the decade. Another significant milestone in 2021 was the statement by Toyota, the largest car manufacturer in the world, announcing new investments aimed at achieving electric car sales of 3.5 million a year by 2030[5].

The People's Republic of China (hereafter 'China') led global growth in electric car markets in 2021 as sales nearly tripled to **3.4 million**. The Chinese government's official target is for electric cars to reach a market share of 20%

[5] `https://www.iea.org/commentaries/electric-cars-fend-off-supply-challenges-to-more-than-double-global-sales?utm_source=SendGrid&utm_medium=Email&utm_campaign=IEA+newsletters`

for the full year in 2025, and their performance in 2021 suggests they are well on track to do so.

In Europe, electric car sales increased by nearly 70% in 2021 to 2.3 million, about half of which were plug-in hybrids. While annual growth was slower than in 2020, when sales more than doubled, this took place against the backdrop of an overall European automotive market that had not recovered from the pandemic. Total car sales in 2021 were 25% lower than in 2019. The surge in EV sales in Europe last year was partially driven by new CO2 emissions standards. Purchase subsidies for EVs were also increased and expanded in most major European markets. (https://www.iea.org)

In absolute terms, the largest electric car market in Europe in 2021 was **Germany**, where more than one in three new cars sold in November and December was electric. Overall, electric cars accounted for 17% of total European sales in 2021, but there were significant differences across markets. **Norway** at 72%, and **Sweden** and the **Netherlands** at 45% and 30% respectively, sat atop global rankings. At 25%, Germany had by far the highest market share among large European markets, followed by the **United Kingdom** and **France** (both around 15%), **Italy** (8.8%) and **Spain** (6.5%)[6].

3.11 Conclusions

The decline of diesel and ICE during the last few years is undoubtable and the diesel gate crisis has accelerated things. In addition, the growing pressure of increasingly stringent emission standards is pushing manufacturers towards electrification, which currently seems to be the only way to reduce fleet emissions sustainably, especially from premium vehicles.

Europe has seen significantly and significant EV growth. In 2019, sales increased by 44%, the highest rate since 2016. The European Union's new emissions standard—95 grams of carbon dioxide per kilometer for passenger cars—could also boost EV sales because it stipulates that 95 percent of the fleet must meet this standard in 2020 and 100 percent in 2021. Automakers launched 143 new electric vehicles—105 BEVs and 38 plug-in hybrid electric vehicles (PHEVs)—in 2019 [McKinsey2020c]. They plan to introduce around 450 additional models by 2022.

Falling total cost of ownership (TCO), regulatory considerations, and offered incentives are amongst the drivers for accelerated EV acceptance. The members of the High Patronage Committee shared their opinion on all the above and identified consumer preference as another key dimension.

Nowadays there is a strong debate around the CO2 footprint of EVs and despite the skepticism scientifically validated investigations converge to a new well-established conclusion: BEVs are less polluting than ICE fueled with petrol

[6] https://www.iea.org/commentaries/electric-cars-fend-off-supply-challenges-to-more-than-double-global-sales?utm_source=SendGrid&utm_medium=Email&utm_campaign=IEA+newsletters

even if as much as possible indirect emissions are integrated in the life cycle assessment.

As EVs become mainstream, the related EV ecosystem must grow. Access to efficient charging infrastructure must not become a roadblock to EV uptake and that is pointed out by the members of the high patronage committee. At the same time, new opportunities emerge, concerning re-use, recycling, stationary storage, and that is discussed in detail.

In addition, governments have a crucial role to play in the transition to zero-emission mobility. The security of affordable electricity supply and recharging of electric vehicles are priorities.

The COVID-19 crisis has significantly influenced major demand drivers, but for Europe, overall, the momentum is positive, with emission regulations potentially pushing market share higher by 2022. The market share of EVs in Europe in 2019 was at 3% and the forecast before the pandemic rose to 14% for 2022. In the new forecast, post-pandemic, it may vary between 12-15%, even slightly higher from the initial forecast.

Chapter 4

Trucks

4.1 Introduction

Today almost 98% of the 6.2 million trucks currently operating on European roads run on diesel. Zero-emission vehicles, on the other hand, only account for 0.04% of the total truck fleet right now, or a mere 2,300 vehicles. On top of that, the latest figures show that the age of the EU truck fleet keeps increasing year after year. Trucks are now 13 years old in the European Union on average. Aged more than 21 years, Greece has the oldest truck fleet of the whole EU.

European truck makers estimate that around 200,000 zero-emission trucks will have to be in operation by 2030 to meet the CO_2 targets for heavy-duty trucks. But to make zero-emission trucks the preferred choice of transport operators, urgent action is needed on European and member state levels.

The European truck manufacturers together with the Potsdam Institute for Climate Impact Research (PIK), one of the world's leading institutions for integrated research on global sustainability, have embarked on a science-business dialogue on possible pathways and policy framework conditions for a sustainable, carbon-neutral road freight transport system [ACEA2020a].

The following three key building blocks were agreed by the CEOs of European truck manufacturers in October 2020 as the starting point for shaping a 'transformation roadmap' for the heavy-duty transport system. These interdependent factors are all crucial, and must be put into place simultaneously:

- **Functional, reliable and efficient vehicles:** European truck manufacturers are fully committed to carbon neutrality by 2050 at the latest. This implies that by 2040 all new commercial vehicles sold will have to be fossil-free.

- **A dense network of charging and refueling infrastructure suitable for trucks:** The availability of clean electricity, clean hydrogen and low- or zero-carbon fuels, such as advanced, renewable biofuels will be crucial for the transition towards a carbon-neutral transport sector.

- **A coherent policy framework which enables and drives the transition to carbon neutrality:** For a successful decarbonization of the road freight sector, zero-emission vehicles will have to become the best option and preferred choice for transport operators as soon as possible. Although efficiency gains and cost reductions can be expected over the coming years, a coherent, enabling policy framework is indispensable to shift key cost factors towards zero emission technologies.

4.2 CO_2 emission standards for heavy-duty vehicles and incentives

In May 2018, the Commission proposed a regulation setting the first-ever CO_2 emission performance standards for new heavy-duty vehicles in the EU, as part of the third mobility package. It would require the average CO_2 emissions from new trucks in 2025 to be 15 % lower than in 2019. The overall proposed target is translated into binding CO_2 emission targets in grams of CO_2/km for each manufacturer, considering the composition of its fleet, including technical and business characteristics. Manufacturers would have full flexibility to balance emissions between the different groups of vehicles within their portfolio. For 2030, the proposal sets an indicative reduction target of at least 30 % compared to 2019. While the 2025 target could be met by deploying readily available cost-effective technologies, achieving a more ambitious 2030 target would require the implementation of new technologies that are not yet on the market.

Special incentives are provided for zero- and low-emission vehicles in the form of 'super-credits'. Each zero-emission vehicle is counted as two vehicles. Each low-emission vehicle is counted as less than two vehicles, in relation to its CO_2 emissions. To limit the risk of weakening the CO_2 targets, the average emissions of a manufacturer can be lowered, based on the super-credits earned, by no more than 3%. Zero-emission buses, coaches and small trucks can also benefit from super-credits, but in this case the average emissions of a manufacturer cannot be lowered by more than 1.5 %, to avoid distortions in the market.

The proposed regulation applies to four categories of large trucks which, together, account for 65 % - 70% of CO_2 emissions from heavy-duty vehicles. It will be reviewed in 2022, to set the binding target for 2030 and to extend its scope to smaller trucks, buses, coaches, and trailers. The review should also assess the effectiveness of the modalities for implementation, for instance, the incentive system for zero and low-emission vehicles.

4.3 The New-Energy Powertrains

The new-energy technologies show especially strong commercial promise [BCG2019]:

- **Liquefied natural gas (LNG).** LNG is natural gas or biogas that has been liquefied by bringing it down to low temperature. When the gas liquefies, it reduces in volume that makes it possible to have enough fuel on board to drive long haul transports. Its fast-refueling ability and its support for long-range transport are among LNG's most appealing qualities. Yet its commercial viability depends on the presence of an ample natural supply or on public policy support, as well as on adequate infrastructure (fueling stations and a distribution network). These conditions favor adoption in countries such as the US and China.

- **Compressed natural gas (CNG)**. CNG is natural gas or biogas compressed to a high pressure and stored in tanks in the truck. The CNG-powered trucks offer enough power, torque, and range to handle demanding delivery transport and waste collection. When using compressed biogas, the CO_2 emissions are reduced by up to 70% (This covers the emissions from production and usage of the fuel so called "well to wheel".)

- **Battery-powered electric.** Fully battery-powered electric vehicles tapping a zero-emissions power source are ideal for LCVs used for in-town, short-distance driving. A major drawback of batteries is their output relative to weight, which restricts payload

- **Hydrogen fuel cell.** Its advantages, which are zero emissions, quick refueling, and long-range capabilities, make this expensive technology attractive. But the viability of hydrogen fuel cell powertrains depends on the availability of cheap electric power, which makes countries such as China and France the most likely candidates for adopting it. Fuel cell technology will be most favorable for long-distance uses because of its quick refueling abilities.

Although diesel will remain the "volume and profit engine" for the foreseeable future, diesel efficiency optimization is going to become increasingly challenging. According to McKinsey, alternative powertrains (battery electric, hydrogen/fuel cell, CNG/LNG, synthetic fuels, biofuels) are likely to gain importance in achieving emission goals and reducing the logistics sector's CO_2 footprint [McKinsey2018a].

Diesel is not foreseen to be replaced by a single technology soon, as all alternatives have disadvantages when it comes to selected criteria.

Instead, it is expected that different alternative powertrains will penetrate certain market segments. Battery electric powertrains should be predominant (among alternatives) for last mile, distribution & long haul, whilst hydrogen / fuel cells could be envisioned mainly for distribution & long haul.

ACEA states that a quarter of all new cars in the EU are alternatively-powered. 96.5% of new trucks in the EU are fuelled by diesel (ACEA, The Automobile Industry Pocket Guide 2021-2022).

Jean Pierre Heijsters (ANL) shares the same opinion for the Netherlands: *on the light and medium size I think we will get rid of the diesel engine in 5-10 years. If we look at the last mile solutions inside cities, I think it will be mainly electric in 5 years, for mid-size we go to hybrid powertrain development.*

If we look at heavy duty, long haul, I think for the moment the only possibility we have is diesel. But in 10 years we will have the opportunity to use alternative fuels like synthetic and I especially think there are a lot of opportunities with hydrogen as a fuel. I know many truck manufacturers are working on a lot of developments now.

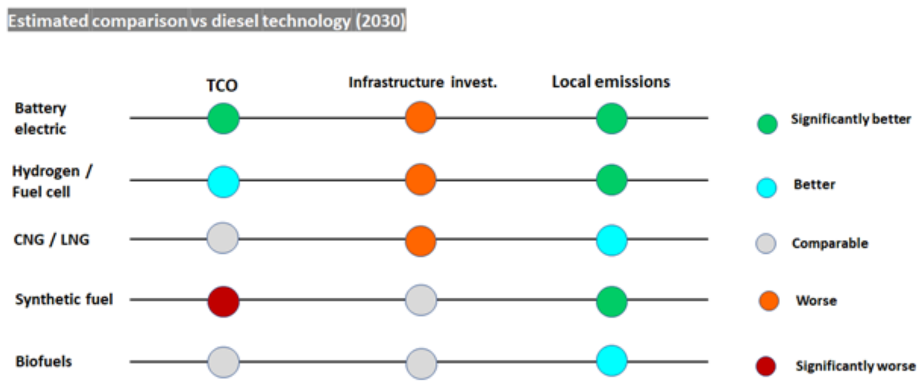


Figure 4.1: Alternative powertrains which will complement diesel McKinsey, Source : 'Route 2030-The fast track to the future of the commercial vehicle industry', September 2018

4.3.1 What do the big players plan?

In October 2019 Daimler Trucks & Buses [DAIMLER2019] announced that it targets a completely CO_2-neutral (tank-to-wheel) fleet of new vehicles by 2039 in the triad markets of Europe, Japan, and NAFTA by 2039. Already by 2022, Daimler Trucks & Buses' plans to include series-produced vehicles with battery-electric drive in its vehicle portfolio in its main sales regions Europe, USA, and Japan [DAIMLER2019]. By the end of the next decade, Daimler Trucks & Buses will extend its range of vehicles with hydrogen-powered series production vehicles. However, Martin Daum, Member of the Board of Management of Daimler AG, responsible for Trucks & Buses, points out a major issue: *'Locally CO_2-neutral trucks and buses will not sell themselves, because even in 2040 -- despite all efforts by manufacturers -- the acquisition and total cost of ownership of trucks and buses with electric drives will be still higher than for diesel vehicles. We therefore need government incentives to make locally CO_2-neutral trucks and buses competitive.'*

Trucks must transition to meet the climate challenge quickly. To immediately operate more on biodiesel, ethanol and biogas is a beneficial and important first step and the domestic production of biofuels must therefore increase. But that is not sufficient.

The Swedish Climate Policy Council has shown in its report that the electrification of heavy transport on roads is crucial to reach the climate target for domestic transport by 2030. It is therefore gratifying that this technology is already sufficiently mature to be implemented as soon as there is an established charging infrastructure, both stationary charging points and electric roads for trucks.

To make zero-emission trucks the preferred choice of transport operators, urgent action is needed on European and member state levels. This includes establishing CO_2-based road charges, energy taxation based on the carbon and energy content of fuels, a sound CO_2 emissions pricing system and, most importantly, a **dense network of charging and refueling infrastructure suitable for trucks** [ACEA2021f].

According to the study conducted by BCG [BCG2019] (Figure 4.2), new-energy powertrain trucks could take 31% of the total sales in Europe by 2030 . Most new-energy vehicle sales in Europe will be for in-town LCVs (46% of total sales). Among these battery-powered electric vehicles are expected to take the biggest part with 40% of sales of new energy powered vehicles, because, in in-town use, distances are relatively short, and the necessary infrastructure is easy to build. For inter-city MDT use and long-haul HDTs, LNG is likely to prevail (at least in regions with sufficient supply, such as Italy), even in the midterm, hydrogen fuel cells can be a serious contender.

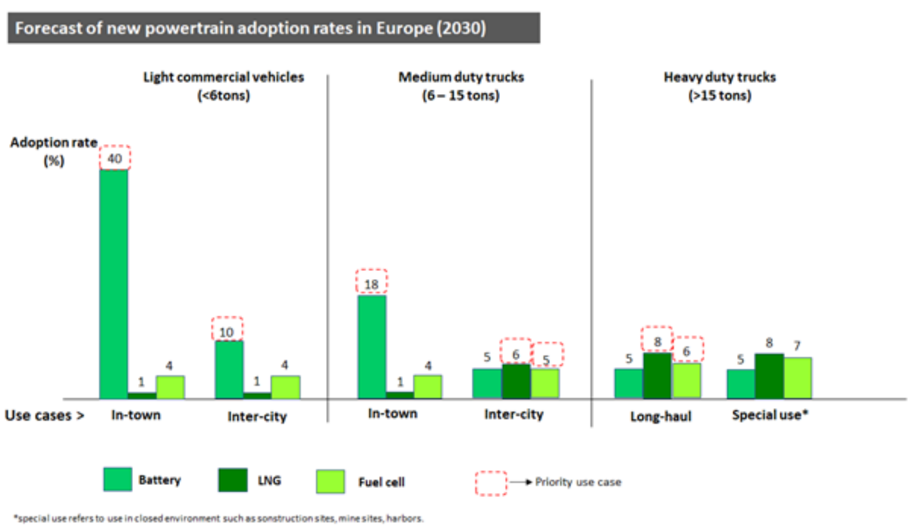


Figure 4.2: Forecast of new powertrain adoption rates in Europe; Source BCG, 2019 'The future of commercial vehicles'.

4.4 The electric trucks

Heavy e-trucks can presently operate efficiently up to approximately 300km on batteries if there are public charging facilities adapted for trucks. For medium and long-distance transport, the e-road technology (see section out Siemens e-Highway) is also already well-proven. With this technology, batteries are charged during a stretch of the journey, for example through catenary lines, which reduce battery size requirements. Furthermore, Scania estimates that battery electric trucks would hit price parity with diesel trucks for long haul in 2027, while fuel cell vehicles could reach parity in 2047 [SCANIA2018].

	Model	Stage	Production	GVW	Battery	Range	Source
Daimler trucks	eCanter	In production		7.5 tonne	83 kWh	120 km	(Mitsubishi Fuso, 2017)
	eActros	Customer tests	2021	26 tonne	240 kWh	200 km	(Daimler AG, 2018)
MAN	eTGM, 6x2	Customer tests	2021	27 tonne	225 kWh	200 km	(electrive.net, 2018)
	eTGM, 4x2	Customer tests	2021	32 tonne	149 kWh	130 km	(eurotransport.de, 2018)
	CitE	Customer tests	2021	15 tonne	110 kWh	100 km	(MAN AG, 2019)
Volvo Trucks	FL Electric	Customer tests	2019	16 tonne	300 kWh	300 km	(AB Volvo, 2018a)
	FE Electric	Customer tests	2019	27 tonne	300 kWh	200 km	(AB Volvo, 2018b)
Reanault Trucks	D Z.E.	Customer tests	2019	16 tonne	300 kWh	300 km	(Renault Trucks, 2018)
	D Wide Z.E.	Customer tests	2019	26 tonne	200 kWh	200 km	(Renault Trucks, 2018)
DAF	LF Electric	Customer tests	Not anounced	19 tonne	222 kWh	220 km	(DAF, 2018a)
	CF Electric	Customer tests	Not anounced	37 tonne	170 kWh	100 km	(DAF, 2018b)

Table 4.1: Electric trucks from main truck makers in the EU[1].

4.4.1 The charging issues and e-highway initiative

As with cars, the availability of sufficient charging infrastructure is a bottleneck for the deployment of electrified propulsion systems in heavy vehicles. For urban use, the problem is partly related to the creation of a charging station network. In this respect, the use of electric commercial vehicles is favored: the distances covered are moderate, the vehicles are often used in captive fleets that can be recharged at night or in off-peak periods.

For medium and heavy commercial vehicles and those used for long-distance journeys, the problem becomes more acute. To increase autonomy, the size of the battery becomes much larger, downtime is rarer. In addition to these technical problems, there are new difficulties linked to the current lack of uniformity in recharging systems, payment systems, etc. It is therefore not easy for a transport operator to travel from the Netherlands to Spain and to find compatible recharging systems along the way.

To partially answer the difficult question of electric trucks, several initiatives should be mentioned. Among these, the e-Highway system developed by Siemens Mobility deserves to be mentioned as it seems to offer an efficient, safe, sustainable, and innovative, solution for trucking freight on heavily used routes. It has already reached a high degree of product maturity and it has been validated in Germany and Scandinavia. The e-Highway supplies hybrid trucks with electricity from an overhead line via a pantograph. The system not only slashes energy consumption by half, but also substantially reduces local air pollution.

The core element of the system is an intelligent pantograph combined with a hybrid drive (see Figure 4.3). Semi-trailer or other types of trucks equipped with the system draw electricity to run their traction motors and charge their batteries from overhead lines along the e-Highway and operate without local emissions. Passing other vehicles on the highway or taking evasive manoeuvres is possible using the truck's battery. The battery pack can be adapted in capacity to meet operational requirements. When running on non-electrified highways, the truck uses a hybrid engine. The system can be configured in a wide variety of ways: Serial or parallel hybrid systems with various internal combustion engines or fuel cells can be used, as well as purely electric drives. A sensor system enables the pantograph to extend and contact the overhead line or retract at speeds up to 90 kmh. This is a technical innovation compared to electric trolley buses and hybrid trucks such as those used in open-pit mines: the traditional system limits operation to directly beneath the overhead line.

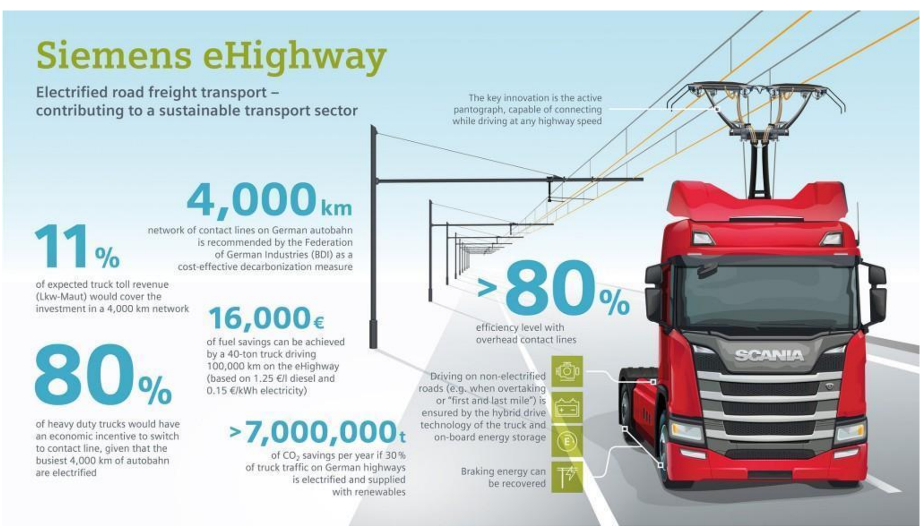


Figure 4.3: E-Highway system by Siemens allows to connect to the grid and so to reduce battery size in long-haul electrified trucks (`http://www.siemens.com/press/ehighway`).

4.4.2 Fuel cell hydrogen trucks

Fuel cell hydrogen heavy-duty trucks could offer a zero-emission alternative with high operational flexibility. Fuel cell hydrogen (FCH) heavy-duty trucks use an electric motor powered by a fuel cell, combined with a battery (hybrid powertrain). They are potentially applicable to long-haul rides, depending on the storage system. With compressed hydrogen gas (CGH_2) 350bar the autonomy is at 500km, whilst at 700bar the autonomy rises to 1000km. When using liquid hydrogen (LH_2) the autonomy rises to 1.250k. The cost of such a vehicle today is relatively high as is the production cost of H_2 compared to conventional diesel. It has about 16% higher powertrain efficiency than diesel, it is possible to be applied for long daily driving ranges, and the refueling time is shorter compared to a Battery Electric Truck (BEVT).

The availability of refueling infrastructure is currently limited. Today there are mainly Hydrogen Refueling Stations (HRS) for passenger cars in Europe, whilst the dedicated infrastructure for trucks is limited. About 1.000 hydrogen refueling stations are planned for 2030 and the overall development shows ambition for the uptake refueling infrastructure for trucks.

Europe shows an increasing focus on FCH heavy-duty trucks trial and demonstration projects, levelling up with US efforts (Table). European projects often include multi-national stakeholders with a strong participation of wholesale and retail companies. There are also several ongoing demonstration projects in FCH waste collection and garbage trucks. FCH technology is particularly suited for such an application as FCH technology can also well cater for the additional power needs of garbage trucks (e.g., hydraulics for lifting and compressing garbage). Due to a back-to-base schedule, operation of a fleet of vehicles is possible as trucks can be fueled by one HRS. Year-round (daily) operations result in high utilization of both trucks and infrastructure and there is potential noise reduction during start-stop operations and idling.

The Technology Readiness Level (TRL) for FCH HD trucks is presently around level 7, still at prototype-stage. Different demonstrator projects in Europe deploy examples of prototypes such as the H2Haul (Belgium, France, Germany, and Switzerland) where 16 heavy-duty hydrogen fuel cell trucks are tested in commercial operations in Europe and Hydrogen region 2.0 (Flanders and the Netherlands) where the first large (40 ton) hydrogen truck is developed and demonstrated by VDL.

4.5 Autonomous trucks

The trajectory toward full autonomy is long – more than ten years before trucks are expected to drive on the road fully autonomously – but first use cases are expected to hit the market within the next few years. The autonomous trucks will likely roll out in waves as is presented in Table 4.3.

The pace of adoption of fully autonomous vehicle technology will be less directly tied to new-energy vehicle development in the commercial vehicle sector

Number of FCH heavy-duty trucks trial & demonstration projects	
Europe	12
Belgium	5 (5)
France	5 (3)
Germany	5 (3)
Netherlands	6 (5)
Norway	1
Sweden	1
Switzerland	4 (1)
UK	1 (1)
North America	9
Asia	2
*Number in () signals the number of cross-national projects	

Table 4.2: FCH heavy duty trucks trial & demonstration projects around the globe

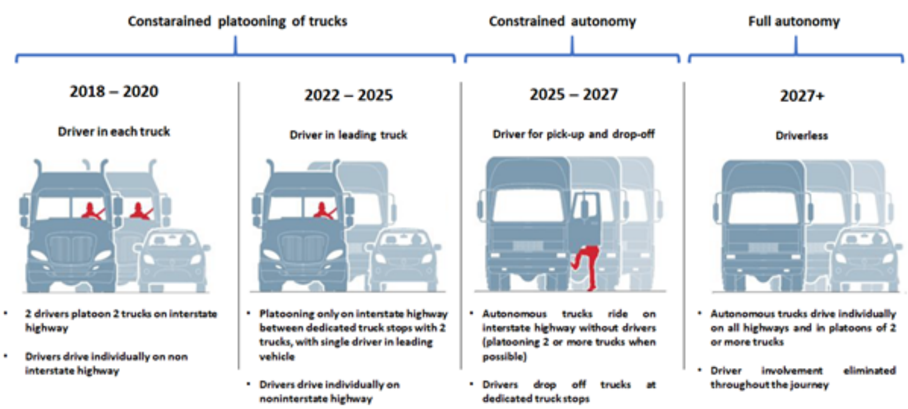


Table 4.3: Forecast of the waves of autonomous trucks roll-out [McKinsey2018a].

than in the passenger vehicle market. Because commercial customers tend to be more sensitive to the total cost of ownership, the internal combustion engine will likely continue to dominate in the initial stages of AV adoption in the commercial sector.

It is expected only about 10% of new Light Commercial Vehicles (LCVs) will be autonomous by 2030. (Fig. 22). The technology is not yet ready for the rigors of typical light-vehicle applications, and regulatory frameworks have yet to be worked out.

As stressed by Dr Christen (FORD), first industrial projects on public roads could target platooning, in which several trucks will follow each other, the first driver overseeing leading the platoon, which automatic control systems will take care of the driving for the other ones.

Completely automatic driving systems which are expected to be able to take care of the driving on highways should not come to the commercial stage before

2027. They should be penalized compared to passenger cars by their high cost and would not give a sufficient pay-back in a short term. However, some tier one suppliers like VALEO are pushing forward that introducing autonomous driving in trucks during highway driving would have for sure a great benefit in safety, trucks being often related to severe accidents on highways.

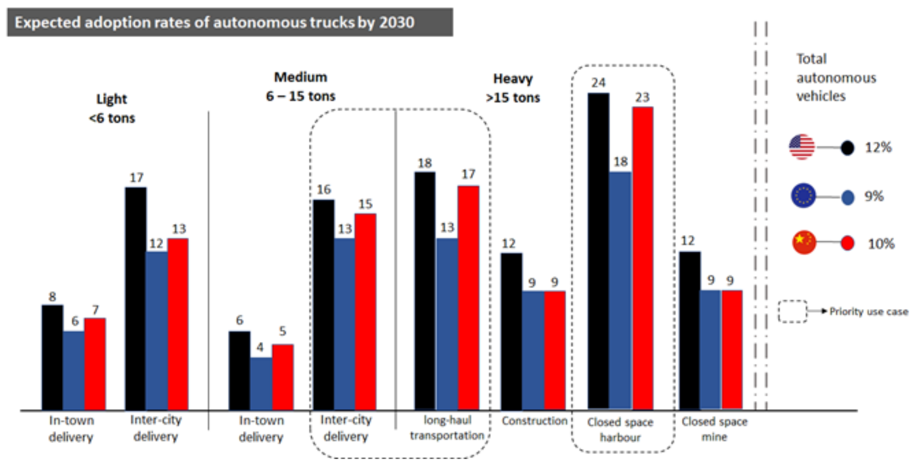


Figure 4.4: Expected adoption rate of autonomous trucks in different markets by 2030 [BCG2019].

4.5.1 Significant efforts around autonomous trucks

A lot of movement is observed as traditional OEMs and startups have announced significant efforts around autonomous trucks. For example, Daimler AG joined forces with the German state of Baden-Württemberg to present a world premiere the 'Future Truck 2025 which will be able to drive autonomously on highways in Europe.

Volvo Trucks has signed a landmark agreement with Brønnøy Kalk AS in Norway to provide its first commercial autonomous solution transporting limestone from an open pit mine to a nearby port. The solution consists of limestone being transported by six autonomous Volvo FH trucks on a five km stretch through tunnels between the mine itself and the crusher and has become fully operational by the end of 2019.

Navistar International announced in July 2020 a strategic partnership with TuSimple, a global self-driving technology company. The aim is to co-develop SAE Level 4 self-driving trucks targeted for production by 2024.

Volkswagen Truck & Bus leads two innovative pilot projects in truck platooning. Scania will be developing and testing a comprehensive platooning solution in Singapore. In what is the world's largest pilot project of this kind, truck platoons each composed of four trucks are to cover ten kilometers on public roads to transport containers between various port terminals. The driver of the first truck will set the speed and direction, with the following three vehicles driving autonomously.

Many new mobility players are also moving to autonomous trucks through technological stacks. For example, the company Embark is building self-driving truck technology to make roads safer and transportation more efficient. Starsky robotics is working to make trucks autonomous on the highway and remote controlled by drivers for the first and last mile. Peloton technology is developing a vehicle "platooning" system to enable pairs of trucks to operate at close following distances with a stated goal of improving safety and fuel efficiency.

4.6 Other Sustainable Propulsion

4.6.1 EU's Strategy

EU Green Deal - a roadmap to sustainable economies

The European Green Deal[2] presents a roadmap for making the EU's economy sustainable by turning climate and environmental challenges into opportunities across all policy areas and making the transition just and inclusive for all. The European Green Deal aims to boost the efficient use of resources by moving to a clean, circular economy and stop climate change, revert biodiversity loss and cut pollution. It outlines investments needed and financing tools available, and explains how to ensure a fair and inclusive transition. The European Green Deal covers all sectors of the economy, notably transport, energy, agriculture, buildings, and industries such as steel, cement, ICT, textiles and chemicals.

The European Green Deal provides an action plan[3] to boost the efficient use of resources by moving to a clean, circular economy and to restore biodiversity and cut pollution. It embraces various policy areas (compare timeline to the right). Policy areas of the EU Green Deal[4].

One area embraces the EU action plan[5] for the Circular Economy (CEAP) II: The Circular Economy Package has been adopted with a view to boosting global competitiveness, fostering sustainable economic growth and generating new jobs. It consists of two EU Action Plans for the Circular Economy (2015 and 2020), with measures covering the full life cycle of products: from production and consumption to waste management and the market for secondary raw materials. Building on the work done on the circular economy since 2015, the CEAP II focuses on resource intensive sectors where the potential for circularity is high. Aiming to keep resources in economic cycles as long as possible, the plan addresses key product value chains: electronics and ICT, batteries and vehicles, packaging, plastics, textiles and food.

[2] https://ec.europa.eu/info/files/communication-european-green-deal_en

[3] https://ec.europa.eu/info/files/annex-roadmap-and-key-actions_en

[4] https://www.switchtogreen.eu/the-eu-green-deal-promoting-a-green-notable-circular-economy/

[5] https://ec.europa.eu/environment/circular-economy/

The Farm to Fork Strategy[6] lays down a new approach to ensure that agriculture, fisheries and aquaculture, and the food value chain contribute appropriately to the objective for a climate neutral Union in 2050. Food systems remain one of the key drivers of climate change and environmental degradation. The manufacturing, processing, retailing, packaging and transportation of food make a major contribution to GHG emissions, air, soil and water pollution, and have a profound impact on biodiversity. On the other side, consumers also need to be empowered to choose sustainable food. The creation of a favorable environment that makes it easier to choose healthy and sustainable diets will benefit consumers' health and quality of life, and reduce health-related costs for society.

The new 2030 Biodiversity Strategy[7] is a comprehensive, systemic and ambitious long-term plan for protecting nature and reversing the degradation of ecosystems. It is a key pillar of the European Green Deal and of EU leadership on international action for global public goods and sustainable development goals. With an objective to put Europe's biodiversity to recovery by 2030, the Strategy sets out new ways to implement existing legislation more effectively, new commitments, measures, targets and governance mechanisms[8].

4.6.2 The EU's Smart and Sustainable Mobility Strategy

The EU has released its 'Smart and Sustainable Mobility Strategy' which sets out a number of goals for how people and goods will move around and between our cities in the coming decades. To achieve the goals the European Commission has identified 82 different initiatives which it has conveniently organized into 10 'flagships[9]. The European Commission wants to change travel within and between cities:

Sustainable For transport to become sustainable, in practice this means: Boosting the uptake of zero-emission vehicles, vessels and airplanes, renewable & low-carbon fuels and related infrastructure – for instance by installing 3 million public charging points by 2030. Creating zero-emission airports and ports – for instance through new initiatives to promote sustainable aviation and maritime fuels. Making interurban and urban mobility healthy and sustainable - for instance by doubling high-speed rail traffic and developing extra cycling infrastructure over the next 10 years. Greening freight transport – for instance by doubling rail freight traffic by 2050. Pricing carbon and providing better incentives for users – for instance by pursuing a comprehensive set of measures to deliver fair and efficient pricing across all transport.

[6] `https://ec.europa.eu/food/farm2fork_en`

[7] `https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu/eu-biodiversity-strategy-2030_en`

[8] `https://www.switchtogreen.eu/the-eu-green-deal-promoting-a-green-notable-circular-economy`

[9] (energy-cities.eu)

Smart Innovation and digitalization will shape how passengers and freight move around in the future if the right conditions are put in place. The strategy foresees:

- Making connected and automated multimodal mobility a reality – for instance by making it possible for passengers to buy tickets for multimodal journeys and freight to seamlessly switch between transport modes.
- Boosting innovation and the use of data and artificial intelligence (AI) for smarter mobility – for instance by fully supporting the deployment of drones and unmanned aircraft and further actions to build a European Common Mobility Data Space.
- Resilient; Transport has been one of the sectors hit hardest by the COVID-19 pandemic, and many businesses in the sector are seeing immense operational and financial difficulties.

The Commission therefore has committed to reinforce the Single Market[10], for instance through reinforcing efforts and investments to complete the Trans-European Transport Network (TEN-T) by 2030 and support the sector to build back better through increased investments, both public and private, in the modernization of fleets in all modes.

In 2020 the European Parliament ”Draws attention to the high added value provided by autonomous vehicles for persons with reduced mobility, as such vehicles allow such persons to participate more effectively in individual road transport and thereby facilitate their daily lives; stresses the importance of accessibility, especially when designing MaaS-systems (Mobility as a Service)” (European Parliament resolution of 20 October 2020 with recommendations to the Commission on a framework of ethical aspects of artificial intelligence, robotics and related technologies (2020/2012(INL)), Jerome De Cooman, Uliege, PhD Student - Research and Teaching Assistant, ”From the Regulation of Artificial Intelligence by Society to the Regulation of Society by Artificial Intelligence: All Along the Watchtower”, in Time to reshape the Digital Society: 40th anniversary of the CRIDS, 2021.)

With transport contributing around 5% to EU GDP and employing more than 10 million people in Europe, the transport system is critical to European businesses and global supply chains. At the same time, transport is not without costs to our society: greenhouse gas and pollutant emissions, noise, road crashes and congestion. Today, transport emissions represent around one quarter of the EU's total GHG emissions. This push to transform transport comes at a time when the entire sector is still reeling from the impacts of the coronavirus. With increased public and private investment in the modernization and greening of our fleets and infrastructure, and by reinforcing the single market, we now have a historic opportunity to make European transport not only more sustainable but more competitive globally and more resistant to any future shocks.

[10] A fundamental transport transformation (europa.eu), `https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2329`

However, this evolution should leave nobody behind: it is crucial that mobility is available and affordable for all, that rural and remote regions remain connected, and that the sector offers good social conditions and provides attractive jobs.

Along with the 10 flagship priorities the European Commission released a set of milestones attached to some ambitious dates:

By 2030: at least 30 million zero-emission cars will be in operation on European roads; 100 European cities will be climate neutral; high-speed rail traffic will double across Europe; scheduled collective travel for journeys under 500 km should be carbon neutral; automated mobility will be deployed at large scale; zero-emission marine vessels will be market-ready.

By 2035: zero-emission large aircraft will be market-ready

By 2050: nearly all cars, vans, buses as well as new heavy-duty vehicles will be zero-emission. Rail freight traffic will double.

According to the strategy, all large and medium-sized cities should have a sustainable urban mobility plan by 2030. This should include integrated electronic ticketing facilities for multimodal transportation and automated mobility should be deployed on a large scale.

4.6.3 Energy Efficiency Directive: Fit for 55 package

On 14 July 2021 the European Commission adopted the 'fit for 55' package with a view to adapting existing EU climate and energy legislation to the new EU objective of a minimum 55% reduction in greenhouse gas (GHG) emissions by 2030, in accordance with the new European Climate Law.

This package consists of 13 legislative proposals that aim at aligning EU climate and energy policies with the new climate targets set by the recently adopted Climate Law – a GHG emission reduction of at least 55% by 2030 compared to the 1990 levels, and climate neutrality by 2050.

The following are the legislative instruments that are subject to revision: the Emission Trading System (ETS) Directive; the Effort Sharing Regulation; the Renewable Energy Directive; the Energy Efficiency Directive; the Energy Tax Directive; the Regulation setting CO2 Emissions Performance Standards for Cars and Vans; the Directive on deployment of the alternative fuels infrastructure; and the LULUCF Regulation. These revisions are complemented by new legislative proposals for a Carbon Border Adjustment Mechanism, a Social Climate Fund, as well as two initiatives called ReFuelEU Aviation and FuelEU Maritime. On the same day the Commission also released its new EU forest strategy for 2030[11].

The fit for 55 package is part of the European Green Deal, that will involve further climate-related legislation and other new initiatives to set the EU firmly

[11] https://www.etuc.org/en/document/etuc-position-just-transition-legal-framework-complement-fit-55-package

on the path towards net zero GHG emissions (climate neutrality) by 2050. The fit for 55 package includes a recast of the energy efficiency directive (EED), aligning its provisions to the new -55 % GHG target. The Energy Efficiency Directive (EED) currently sets out the level of energy savings that the EU needs to make to meet the agreed goal of 32.5 % energy efficiency improvements by 2030. The recast EED would require Member States to almost double their annual energy savings obligations, leading the way by means of action throughout the public sector, action to address energy poverty, and other measures to help to deliver 9% more energy savings than envisaged by the existing EED and in the 2021-2030 national energy and climate plans[12].

4.6.4 Hydrogen Vehicle

Besides battery-electric drives, hydrogen-based electric drives have also to be considered. The so-called e-fuels (generation of liquid or gaseous fuels from green electricity) in combination with more efficient combustion engines are also considered in a further section. The prevalence of alternative drives will mainly depend on the environment in which they are used and the necessary technical equipment and infrastructure they require.

Hydrogen has been presented for several months as a promising strategy. In particular, the use of green hydrogen in industry, energy and mobility sectors is considered to be one of the most important decarburization vectors of our economies. By green hydrogen, it means di-hydrogen (H2) molecules produced by renewable resources (e.g., photovoltaic panels, wind turbines, hydro power plants) rather than producing it from natural gas.

Europe, in particular, is investing massively in this sector and hydrogen, which currently represents less than 2% of the energy mix, should represent around 14% by 2050. Significant efforts are being put in place, to this end, to produce green hydrogen at competitive prices compared to hydrogen produced from fossil resources [Richel2021].

The hydrogen molecule is a gas widespread in the universe which does not exist abundantly in its natural state. Hydrogen is not an energy resource in itself but an energy carrier, just like electricity or heat. To be able to use it, it is necessary to synthesize it artificially, starting from a raw material such as water or biomass. The problem lies in the fact that the current production routes of hydrogen (transformation stage to make it liquid and make it possible to store it) are highly energy-intensive and impactful, as they emit greenhouse gases. Indeed, of the 115 million tons of H2 produced in 2018 (mainly intended for the industrial sector - refining, transport, agro-food), 98% comes from fossil resources, including overwhelmingly natural gas and coal. Production from natural resources only represents around 2%.

Hydrogen fuel cell cars are powered by an electric motor and are therefore classified as e-cars. The common abbreviation is FCEV, short for “Fuel

[12] `https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/698045/EPRS_BRI(2021)698045_EN.pdf)`

Cell Electric Vehicle," in contrast to a BEV or "Battery Electric Vehicle." Along with battery electric vehicles (BEV), hydrogen-powered fuel cell passenger cars are the only zero-emission alternative drive option for motorized private transport. Several major car manufacturers are starting to offer early series-production vehicles which are now just as good as conventional internal combustion engine cars in terms of functionality. Hydrogen cars effectively have their own efficient power plant on board: the fuel cell. In the fuel cell of an FCEV, hydrogen and oxygen generate electrical energy without the transition through the thermal phase. This energy is directed into the electric motor and/or the battery, as needed.

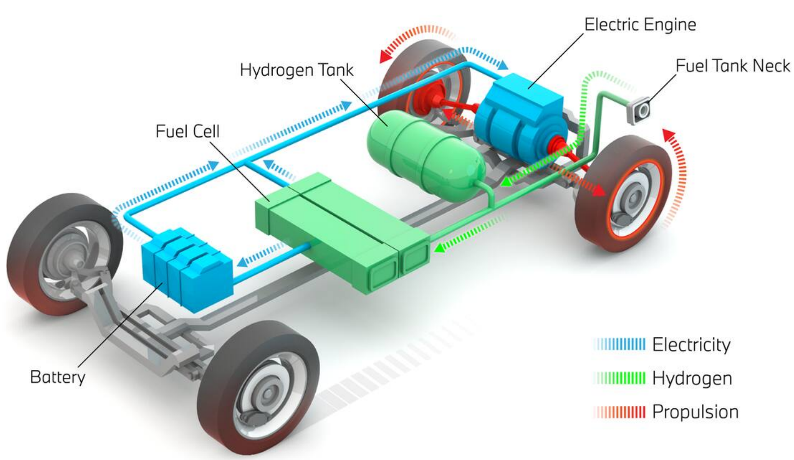


Figure 4.5: Source BMW (`https://www.bmw.com/en/innovation`)

In the fuel cell technology, a process known as reverse electrolysis takes place, in which hydrogen reacts with oxygen in the fuel cell. The hydrogen comes from one or more tanks built into the FCEV, while the oxygen comes from the ambient air. The only results of this reaction are electrical energy, heat, and water, which is emitted through the exhaust as water vapor. This is why hydrogen-powered cars are considered locally emission-free.

The electricity generated in the fuel cell of a hydrogen engine can take two routes, depending on the demands of the specific driving situation. It either flows to the electric motor and powers the FCEV directly or it charges a battery, which stores the energy until it is needed for the engine. This battery, known as a Peak Power Battery, is significantly smaller and therefore lighter than the battery of a fully electric car, as it is being constantly recharged by the fuel cell. Like other e-cars, hydrogen vehicles can also recover or "recover" braking energy. The electric motor converts the car's kinetic energy back into electrical energy and feeds it into the peak power battery. Already in use in trains and trucks, it is estimated that by 2030 hydrogen will be used in all modes of transport except cargo ships and aircraft. Unlike battery electric cars, hydrogen vehicles have a greater range – of around 400 to 500 kilometers today – with a lower vehicle weight and much shorter refueling times of three to five minutes. They usually carry 4 to 7 kg of hydrogen on board, stored in pressure tanks at 700 bar.

Since the late 1990s, there has been huge investments in this technology by car makers. Large-scale introduction has been hampered not so much by the tech but by the difficulty and cost of establishing a filling station network. That is about to change, though, thanks to international plans for hydrogen to become a major component of energy systems across the board. Not just for cars but also for domestic and industrial heating and power, for fueling trucks, trains, and ships and, perhaps most importantly, for storing and stockpiling surplus electrical energy when the share of renewable sources in energy systems will be close to 100%.

The pros and cons of a particular propulsion technology can be seen from two main perspectives: that of the user, and that of the environment. If any technology is to succeed as an alternative to the combustion engine, it must be user-friendly and significantly reduce the emission of pollutants[13].

One advantage of these vehicles is that the propulsion in hydrogen fuel cell cars is purely electrical. When you drive one, it feels like driving a regular electric car. What does that mean? Virtually no **engine noise** and a lively **start** because electric motors provide full torque even at low speeds.

Another advantage is the quick **charging time**. Depending on the charging station and battery capacity, fully electric vehicles currently require between 30 minutes and several hours for a full charge. The hydrogen tanks of fuel cell cars, on the other hand, are full and ready to go again in less than five minutes. For users, this brings vehicle availability and flexibility into line with those of a conventional car.

For the time being, hydrogen cars still have a longer **range** than purely electric cars. A full hydrogen tank will last around 300 miles (approx. 480 kilometers). Battery-powered cars can match this with large batteries – which in turn will lead to an increase in both vehicle weight and charging times.

The range of fuel cell vehicles is not dependent on the **outside temperature**. In other words, it does not deteriorate in cold weather (like it does with battery electric cars).

Actually, the biggest shortcoming of hydrogen fuel cell cars is the sparsity of options for refueling. A hydrogen engine is refueled at special fuel pumps, which in the future will probably find their way into ordinary service stations. As things stand, however, there are still very few refueling stations for hydrogen-powered cars. At the end of 2019 there are only around 40 in the U.S., as compared to approx. 80 in Germany.

In 2019, the British company **Ineos**, active in the chemical sector, embarked on a new adventure with the production of a 4X4 vehicle inspired by the Land Rover Defender, called Grenadier. It will be marketed in summer 2022 and will be available with internal combustion engines from BMW. However, Ineos is a

[13] Axel Rücker, Program Manager Hydrogen Fuel Cell at the BMW Group

fervent supporter of hydrogen and it is therefore no surprise that this young manufacturer has announced the development of a fuel cell version. After announcing a partnership with the **Hyundai** group, which is a pioneer in this field, Ineos plans to invest 2 billion euros in the production of hydrogen without CO2 emissions in Europe[14].

BMW's homeland of Germany leads the way in terms of infrastructure for hydrogen fuel cell cars. In order to promote the expansion of refueling infrastructure there, vehicle manufacturers like BMW have joined forces with hydrogen producers and filling station operators in the Clean Energy Partnership initiative, which plans to expand the hydrogen fueling station network to 130 stations by 2022. That would allow the operation of about 60,000 hydrogen cars on Germany's roads. The next target, with a corresponding increase in fuel cell vehicles, will be 400 stations by 2025. More fueling stations are also needed in neighboring countries to make it possible to travel outside Germany via FCEV (Source BMW).

The development and expansion of the hydrogen infrastructure is of great importance for the further development of the commercial vehicle sector and future value creation for the Great Region. The efficient and competitive use and application of hydrogen in the relevant areas of commercial vehicle construction, the provision of infrastructure should be accompanied by the creation of test areas (e.g. demonstration projects, test tracks) along the value chain of sustainable generation, storage/fueling, transport and open-technology use of hydrogen (fuel cells, gas engines/ direct combustion of hydrogen). In addition, the development of the hydrogen sector, for example by networking relevant stakeholders, strategic topic development as well as concrete development initiatives and networks (in particular for small and medium-sized enterprises) for new system innovations is a key prerequisite for further value creation and innovations in this field [wemoveit].

Mr Jacques HAENN, Pôle Véhicule du Futur, gives the example of *French strategy. It is already decarbonizing its hydrogen. By producing large quantities of decarbonized renewable hydrogen. So we're talking about green or blue carbonated or decarbonized. And so, in fact, what is also very interesting is that if we take advantage of this production, what can also be very interesting is to use this hydrogen for heavy mobility. These are also vehicles that consume a lot. And so, in the end, you amortize your investments in production and stations more quickly. In France, the French strategy is to create ecosystems around a hydrogen production and a station. Germany had adopted a slightly different solution. Germany had pushed for the deployment of stations along the highways. So yes. Today, in Germany, we have more than 100 stations, whereas in France, we are only at 40. On the other hand, if we look at the numbers of vehicles, France has the same number of vehicles running on hydrogen as Germany. I think there are 400 light vehicles. You can imagine that in the whole of Germany, there are 400 vehicles for 100 stations built. So, of course,*

[14] Autotrends.be, https://magazine.autotrends.be/fr/actualit%C3%A9/nouvelles-voitures/LIneos-Grenadier-a-lhydrogene-aussi

these stations were subsidized, but still. France decided to work in a different way. So that's why there are calls for projects from the City. This creates an ecosystem where we try to find industrialists, heavy vehicle fleets and create an ecosystem around these stations and the production. The advantage is that if you put buses, it is a captive fleet that always comes back to the same place. You have dumpsters, it's the same. They always come back to the same place. You put a station that must be judiciously placed where the vehicles can come and fill up. And finally, you are going to mesh the big cities like that. So, today, there is Metz which is working on a bus system. There is Mulhouse with garbage trucks. Strasbourg is in the process of creating something. We are going to progressively network France around the major cities, and little by little, all we will have to do is build the intermediate bridges. So today, it's true that we're thinking more about large productions. One of the most important projects in Europe is Dijon, which is planning a project involving almost 200 buses. Not immediately, but in five or six years. But the whole bus fleet will be replaced and switched to hydrogen. They're going to replace the whole fleet of garbage trucks. I think there's about 30 dumpsters, so it's going to be a huge ecosystem. It's one of the biggest projects in Europe today.

In addition to the thin fueling station network, there is another reason for the yet low demand for hydrogen fuel cell cars: they are relatively expensive to buy. The few models of fuel cell vehicles already available on the market cost around EUR 65.000 for a mid- or upper-mid-range vehicle. That is almost twice as much as comparable fully electric or hybrid vehicles.

There are a range of reasons why hydrogen fuel cell cars are still expensive. In addition to small volumes, there is also the question of the need for the precious metal, platinum, acting as a catalyst during power generation. The amount of platinum needed for vehicle fuel cells has already been greatly reduced but still.

BMW is convinced that hydrogen can make an important contribution to sustainable mobility alongside BEVs in the future – provided the necessary hydrogen infrastructure is in place and offers a good price for hydrogen, and the price of the vehicles decreases. In those circumstances, hydrogen fuel cell cars can be the zero-emissions technology that allows users to maintain the flexible driving habits they are accustomed to.

Following the example of PSA, now Stellantis, Renault is continuing to advance in hydrogen. Initially associated with Symbio to develop a first range of fuel cell vans, the group changed its mind at the beginning of the year by announcing a partnership with PlugPower, an American company specialized in the development of hydrogen fuel cells. T he two structures are now taking this partnership a step further by announcing the creation of Hyvia. Hyvia, a combination of "HY" for hydrogen and the Latin word "VIA" for road, is a 50/50 joint venture between the two partners[15].

Toyota Motor Europe held a forum in Brussels in December 2021 during which the manufacturer presented the Lexus ROV (for Recreational Off-Highway Vehicle). This small buggy with a very nice look and a particularly

[15] https://www.h2-mobile.fr/actus/hyvia-renault-lance-offensive-hydrogene

well cared interior is designed to evolve on rough terrains. It has a 1.0 liter engine that is powered by hydrogen. The Japanese brand justifies the development of this concept by the fact that it represents the preservation of off-road driving pleasure, while being environmentally friendly. Almost carbon neutral, this vehicle will unfortunately not be produced in series.

Figure 4.6: Source: `https://magazine.autotrends.be`

The Hydrogen Council[16], a global initiative of leading energy, transport, and industry companies, is also convinced of this. The council sees hydrogen not only as a sustainable future means of propulsion for fuel cell vehicles, but also as a clean energy source for heating, electricity, and industry.

Jacques HAENN explains the **electrolysis**:*Electrolysis is something that is mature. The only drawback is that it is not highly industrialized. So it's not automated at all. Today, we will have to industrialize and automate this kind of thing. So we have Jon Cockerill, a Belgian company, which is going to install a site to assemble the electrolyser stocks. These stocks will be sent to Belgium and assembled on a more industrial scale. The competitor called ??? has announced a similar electrolysis assembly site near Belfort. We have two competitors near us to produce large-scale electrolyzers. So on the battery, that's the hydrogen production part. On a vehicle, we are talking about a fuel cell. On fuel cells, we have. Today we have Plastic Omnium and Faurecia, which produce hydrogen tanks. So yes, that can supply the market. Even Hyundaï in trucks. Manufacturers are starting to mass produce fuel cells. So we have a lot. We have French players who are on the scene. It is a French company, Savio. It's a company that came out of Michelin and Faurecia. At first it was on its own and in fact, they were taken over by a consortium and are in the process of setting up a site near Lyon. The first stone was laid not long ago. The good thing is that we have a European player in place. But we are not behind.*

He also *puts forward an interesting opinion for t**he role that the PME can play : They can have a role to play in bringing new ideas for new solutions**. Because we don't talk about it much, we talk about extension, industrialization. So, there may be a PME that can play this role. So no. In the Club Hydrogène, we see for example companies that are boilermakers, locksmiths have joined the Club Hydrogène. They think that when John Cockerill needs parts and mechanics, and if they want to work locally, they will be able to buy*

[16]`https://hydrogencouncil.com/en/`

from us. So, in the end, they could very well produce tanks for this sector. But these small companies can become suppliers to these large industrial companies that are going to develop. There are two sides to developing in the supplier and getting into this value chain. We have start-ups that become PME. For example, on a Burgundy Franche-Comté, we have myTech which manufactures tanks. And today, it is a startup that has become a PME. We have H26 like a company that now provides hydrogen generatorsWe also have a start-up in Strasbourg which develops a new method of non-mechanical compression thanks to heat and the person has associated with the AirInOK project in Strasbourg, to experiment its solution on this project. And so, if the solution works, it is something where we eliminate the mechanical. It can be very interesting. And this start-up may become a PME one day.

M. Friedrich puts forward an interesting opinion "With hydrogen, one big issue is that there is *no production capacity that is installed. Even more important, di-hydrogen (H2) molecule is also the smallest molecule that exists, meaning it crosses everything. Under pressure, it will bind with carbon chains and embrittles steel somewhere. This means that if you put a hundred such hydrogen cars in an underground parking lot and if they lose 1% of their tank, you make them rolling bombs. So, hydrogen seems to me very good too, but maybe not for all vehicles. I would say for big trucks for which we know that they charge to go 500-600 km and then they charge again at the same place, it's fine. Why not for individual cars? You don't know how they are used and how they are parked, how they are surrounded. On the contrary, for example for Alstom and regional trains, I think hydrogen is a real solution rather than diesel. For the individual vehicle, electricity might be a better solution. The main issues are: how do we produce hydrogen? How do we store it? How do we avoid leaks?"*

4.6.5 E-Fuels

E-fuels are synthetic hydrocarbon fuels similar in composition to other fossil fuels except that they are synthesized from hydrogen from water electrolysis and carbon from carbon dioxide capture or biomass gasification process. The production process involves several stages to combine these feeds such as first producing methane, then methanol, and finally diesel or gasoline. These processes are not new as they have already been used in situations where access to petroleum was expensive or impossible (like the Fischer-Tropsch process used by Germany during the second world war to produce liquid fuels from coal).

E-fuels synthesis has again received great attention in the context of renewable resource use to produce liquid fuels. Compared to hydrogen and electricity, e-fuels have the advantage of being easy to store and transport due their high energy density. However, the production of these e-fuels is not energy efficient. Their production cost becomes competitive only when they are generated from power in excess that is cheaply available. For example, from renewable intermittent production that would be lost otherwise. Even though e-fuels are often considered to be cleaner than fossil fuels, only hydrogen and battery electric vehicles are locally 100 percent clean (https://www.adlittle.com).

ExxonMobil and Porsche are testing advanced biofuels and renewable, lower-carbon e-fuels as part of a new agreement to find pathways toward potential future consumer adoption (https://newsroom.porsche.com). As early as 2022, the companies plan to test the second iteration of Esso Renewable Racing Fuel, which will contain e-fuel components. The e-fuel is anticipated to achieve a reduction in greenhouse gas emissions of up to 85%, when blended to current market fuel standards for today's passenger vehicles. In the pilot phase, around 130,000 liters of e-fuels will be produced as early as 2022. In two further phases, capacity will then be increased to about 55 million liters of e-fuels a year by 2024, and around 550 million liters of e-fuels by 2026. Porsche will be the primary customer for the green fuel. The e-fuel will be sourced from the Haru Oni pilot plant[17] based in Chile that generates hydrogen, which is then combined with captured carbon dioxide drawn from the atmosphere to produce methanol. ExxonMobil is providing a license and support for the proprietary technology to convert the methanol to gasoline, which will result in a lower-carbon fuel.

Volkswagen announced that its 4-cylinder diesel engines marketed since last June 2021 are compatible with the new paraffinic diesel, of which there is a wide range: some are produced from biological residues and wastes such as HVO for example, hydrotreated vegetable oil. This waste is converted to hydrocarbons by reaction with hydrogen and can be added to diesel. However, they can also be used alone as fuel. Vegetable oils such as rapeseed oil can also be used for the production of HVO, but the environmental benefit is only optimal by using biological residues and wastes such as used cooking oil, sawdust. wood, etc. The HVO is already available on the market, in a few rare stations. Volkswagen announces CO2 emissions reductions of around 70 to 95% compared to conventional diesel[18]

The opinion of the high Patronage Committee experts regarding e-fuels, hydrogen and the way to decarbonize

Damien Ernst: *While you may have hydrogen, perhaps still hydrogen for cars for big trucks, I do not exclude this, but I think that we will see bigger EVs for, even for trucks. They will have batteries of around 100 kWh, 1000kWh, 1500kWh on which they will be able to drive certainly for 1000km or even more and then charge rapidly. Yes, even EVs for trucks. My main advice for the truck companies: do not focus on gas, CNG engines, not even hydrogen. Perhaps a little bit on hydrogen, there is this "Nikolas truck" I saw in the US. Well, the company's value is already 50 billion of dollars, you know, and they plan to build trucks powered by hydrogen, but then you start reading more and more articles describing the devaluation of this company. So, I do not believe that they will be powered by hydrogen and everything will be electric for all transportation.*

Etienne Jaqué: *The problem of batteries is their low energy density. When weight or size are a factor, for example on airplanes, hydrogen or e-fuels are*

[17] https://newsroom.porsche.com/en/2020/company/porsche-siemens-energy-pilot-project-chile-research-development-synthetic-fuels-efuels-23021.html

[18] Selon VW, le diesel n'est pas mort, autotrends.be), https://magazine.autotrends.be/fr/actualit%C3%A9/opinions/Selon-VW--le-diesel-nest-pas-mort--21

the energy carriers to consider. E-fuels are already being tested successfully on commercial flights. The production of these carriers from electricity is less efficient than using the electricity directly, but producing and carrying batteries also impacts efficiency or may be a no-go anyway. Energy efficiency is actually not taken into account in the car industry. A small light battery electric car is certified 0 gCO2, but a large heavy battery electric SUV is also certified 0 gCO2, while it may be energetically wiser to run that one on hydrogen or e-fuels. When assuming that all electricity is zero carbon in the future, the choice of energy carrier (battery, hydrogen or e-fuel) shall depend on the application. Hydrogen has the particular benefit in that it can either be converted into electricity in a fuel cell or burned in a classic combustion engine.

German Castignani: *The topic of hybridization is important. Depending on how you drive you might end up with a hybrid vehicle that is more used as an ICE vehicle. The hybrid vehicle is quite simple, there is a small battery, if you demand a lot then it will switch to ICE. There is the need for driving education on how to drive a hybrid. There is a component that decides when to keep the electric mode and when to switch to gasoline and there is a lot to do there. Right now, it is based on parameters like the pressure you put on the pedal. It would be a good topic to try to understand which kind of trips are being done, using the navigation data. When the person needs to arrive at the destination, which roads he can use instead of the high wear with a speed of 130km/h the vehicle will switch to gasoline. The battery will be charged at the end of the trip, but the car will be contaminated. Hybrid powertrain could be optimized by using algorithms for switching.*

4.6.6 Bio-fuels

Contrary to fossil fuels that are sourced from plants and animal remains that transformed into hydrocarbons over millions of years, bio-fuels are sourced from plant material or animal waste from easily replenishable sources. Bio-fuels are thus often referred to as a renewable energy source that could drastically reduce global emissions and help to combat climate change. However, bio-fuels are renewable and carbon free if and only if the exploitation of the resource does not affect the available stock.

The term "biofuel" was first coined in 1984 when an Austrian agricultural college successfully manufactured diesel using sustainable feedstock material. While it wasn't until the 1980s that biofuel started garnering attention, some historians credit German mechanical engineer Rudolf Diesel with the concept. Not only did he invent the first diesel engine in the late 1800s, but he also experimented with the use of peanut oil as a fuel. For this reason, some people refer to Diesel as the grandfather of biofuel. Similarly, in the beginning of the automotive era, Henri Ford equipped all of his cars with a fuel switching system enabling the burning of petroleum based gasoline or ethanol generated from corn (or all other sugar-rich biomass).

Europe has been commercially manufacturing biodiesel since 1992, with Germany the largest producer. The United States is also a biodiesel champion, with

Yellowstone National Park sourcing fuel from the University of Idaho to power its trucks. Other national parks soon followed suit, embracing biodiesel for its low emissions and eco-friendly credentials. From beer by-products to marine algae, the scope for biofuel feedstocks is enormous. Stinkweed[19], a flowering plant considered a weed by most dairy farmers, is the latest feedstock to win headlines. While the plant harbors a bad reputation for adding a sour taste to the milk of dairy cows, a new genetically modified version suppresses the "stink" compound and produces a useful oilseed crop that can be used not as livestock feed but also to produce lower-carbon biofuels.

While few airlines have transitioned to sustainable aviation fuels[20] (SAFs) there is huge potential for biofuels for aviation.

Scientists have been trying to discover a biofuel extraction process that is inexpensive, not time consuming, and sustainable for almost four decades. It has been a long journey thus far and the road ahead may contain many obstacles, but each step on this journey is a step towards a stable, secure, and renewable world. With increasing energy demands, the demand for biofuels is growing every year, while the availability of fossil fuels is projected to decline steadily. Slow, steady progress towards a renewable world is noticeable. Scientists are constantly coming up with new and ingenious ways to solve the world's energy problems. While time is of the essence, these breakthroughs and innovations may lead to a world powered by clean and sustainable energy[21].

Mr Jacques HAENN remarqued that *at the level of the Grand Est, there is a contract for the biofuel sector which is being set up at the regional level. So there is a lot of work around that. They have put all the fuels in it, whether liquid or gaseous, including hydrogen, and they have worked hard to try to clarify this.;;There is bio, there is bio-GNV. There are biofuels, there is mechanization. and synthetic fuels; They are subjects that remain on the table. And the Grand Est is putting the energy mix forward. The idea is to think intelligently, that is to say a place where you will have a lot of resources for methanation. You have to use it and evaluate the bio-GNV. When you have a lot of photovoltaic or wind power, it may be wise to put in electrolyzers and to develop the electrolyzers. The idea is* ***energy transition****. There will not be a single solution.* ***It's a mix of all the solutions and thinking about the right energy, in the right place.***

Mr Jacques HAENN also explained to us the ***natural hydrogen.*** *So we realize today that in 2010, there were geologists who said that there is natural hydrogen on the planet and that there is a significant quantity. They were taken for fools. Today, we realize that they were not necessarily totally wrong. We discover, we will say almost daily, new places, hydrogen emanations. And so, there was. At the beginning of June, there was the HNAT summit, the first world congress on natural hydrogen, and we have a start-up in the subject which is very, very advanced and which will obviously be the most advanced company.*

[19] https://ilmt.co/PL/P9R0
[20] https://ilmt.co/PL/XG00
[21] https://www.petro-online.com/news/biofuel-industry-news/22/breaking-news/what-is-green-fuel-and-will-it-replace-petrol/55123

It is called 458 Energy. This could be a great future in this field. It is a subject that France is a priori leader.

Chapter 5

Autonomous Driving

5.1 Context

Today's automotive industry is increasingly interested in advanced technology with the goal of making driving fully autonomous. The development of autonomous vehicles and their introduction on our roads is at the forefront of media, politics, philosophical debates and the research industry. Although their introduction represents a huge step forward on many levels, autonomous vehicles remain an innovative technology with new complexities. (What ethical rules for autonomous vehicles in the event of an accident, Israel Collier, Sacha 2020). The actors of the automotive world are reorienting their efforts and developments on an intermediate stage, more plausible in the near future: that of a vehicle with increasing levels of autonomy, initiated since the arrival on the market of the first driving assistances - cruise control, adaptive distance control, then more recently parking assistance, lane keeping assistance,... [HAUER2018].

In the literature, several definitions have been attributed to the autonomous vehicle. According to the automotive vocabulary, **autonomous vehicles** (AV) or fully driverless cars (DC) or self-driving cars are vehicles that, once programmed, move automatically without the intervention of their users. (JORF, June 11, 2016, text n°111) The automotive industry is shifting towards the future, where the role of the driver is becoming smaller and smaller, until a moment where the car will be totally driver-less. Designing an AV is the most challenging automation project at present, since complex processing and decision making of driving a heavy and fast-moving vehicle in public, must be automated.

Autonomous driving can be divided into three stages: perception of the environment, trajectory planning and vehicle control [Moussa2020]. Vehicle control consists of maneuvering the vehicle using actuators such as the steering wheel, brake, and gas pedal to pursue the reference trajectory[1].

[1] Control and planning of trajectories for the navigation of autonomous vehicles, Gilles TagneFokam

The architecture of the automated vehicle integrates two types of components: sensors allowing it to perceive its environment: radars, lidars, cameras, ultrasonic sensors; a set of on-board computers allowing the vehicle to understand its environment and to make driving decisions [DAGNOLLES2018]. Driving assistance systems are on-board assistance and information systems designed to make driving the vehicle easier and safer. **Delegated Driving Vehicle** usually refers to advanced vehicle automation technologies and highlights the fundamental change in the nature of the driving act. **Autonomous vehicles** (AVs) will represent the ultimate manifestation of Advanced driver-assistance systems **(ADAS)**, marking the shift from driver-assisted functionality to fully autonomous vehicle operation. Autonomy will progressively transform the car into a platform from which drivers and passengers can use their transit time for personal activities, which could include the use of novel forms of media and services.

Connected and autonomous vehicles (CAVs) are identified as strategic for the EU because the transition to autonomous driving offers a significant potential to expand Europe's economic and innovative power. CAV technology is seen as a crucial innovation for the EU, not only for sustaining market leadership and employment but also for improving motorway safety and the efficiency and resilience of supply chains. Apart from the traditional automotive value chain subsectors, the CAV value chain is characterized by key technologies. These technologies include light detection and ranging (LIDAR), radar and camera sensors, mapping hardware and software, control systems and computing hardware and software, among others. It is estimated that about 68 to 70% of CAV innovations come from European suppliers, and the export share of European suppliers is estimated to be at around 15% [2].

5.2 Key Components in Driverless cars - AVs

Experimental work has been going on in the field of driverless cars since 1920. In 1977, the first truly automated car was invented by Tsukuba Labs in Japan. This car traveled at the speed of 30 km per hour with the help of two cameras. In 2015, the US government gave clearance to test the AVs on public roads. In 2017, an Audi A8 was proved to be the first Level 3 automated car that traveled at the speed of 60 km per hour using Audi artificial intelligence (AI). In 2018, Google Waymo started to test its autonomous car and completed around 16,000,000 kilometers of Road Test by October 2018[3].

Nowadays, an AV has the capability to sense its environment and move ahead on its own. AVs contain various sensors and cameras such as Radars (Radio Detection and Ranging), LIDAR (Light Detection and Ranging) and SONAR

[2]Ecorys, TRT Srl., and M-Five GmbH, 2020, Study on exploring the possible employment implications of connected and automated driving: `https://www.ecorys.com/cad`

[3]Autonomous Cars: Technical Challenges and Solution to Blind Spots Issue, Hrishikesh M. Thakurdesai1 and Dr. Jagannath Aghav, College of Engineering, Wellesley Rd, Shivajinagar, Pune, Maharashtra 411005)

(Sound Navigation and Ranging) to understand the surrounding environment.

Radar is a detection system which makes use of radio waves to determine various parameters like distance, speed, or angle of the object.

SONAR, ultrasonic sensors, make use of Sound waves to determine the presence of Objects.

LIDAR is considered as an eye of CAV. It uses pulsed laser light for detection. These sensors and other actuators generate huge amounts of data in real time. This data is processed by a central computer for driving decisions.

GPS (Global Positioning System) antennae are on the top of AV which gives the car position on the road.

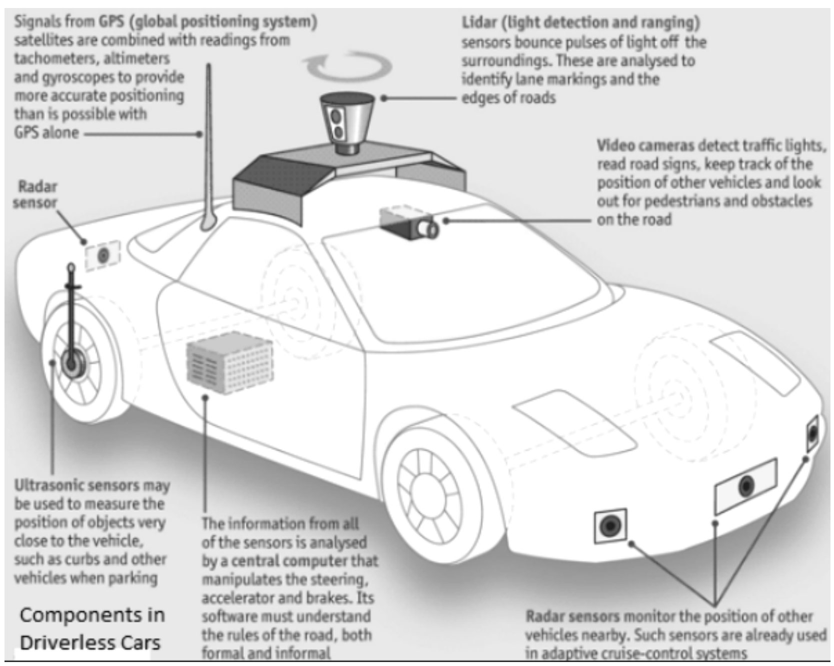


Figure 5.1: Components in Driverless Car (Source: The Economist, How does a self-driving car work, `https://www.economist.com/the-economist-explains/2015/05/12/how-does-a-self-driving-car-work`)

5.3 The five levels in the driving system

According to the SAE (Society of Automotive Engineers), there exist five levels of driving systems. As they are often referred to in the following, they are recalled hereafter:

Level 1: This level involves some functions for driver assistance. For example, brakes will be applied more powerfully if some vehicle comes suddenly in front of the road. Still, most of the main tasks like steering, braking, and monitoring are handled by the driver only.

Level 2: This is Partial Automation level. Most of the companies are working currently on this level where drivers get assistance for steering and acceleration. Here, the driver must always be attentive and monitoring to take control in case of safety-critical issues.

Level 3: This level also includes monitoring assistance along with steering and braking. The vehicles in this level use LIDAR (Light Detection and Ranging) Sensors as an eye of the car. This level does not require human attention when the speed is moderate (around 50 km per hour) and conditions are safe. But in case of higher speed and unusual scenarios, drivers' control plays a critical role.

Level 4: It is known as High Automation. Here, the vehicle can take steering control, braking, acceleration, and monitoring. Human attention is required only for certain critical scenarios like complex traffic jams or merges into highways.

Level 5: This level involves Complete automation. Here, absolutely no human attention is required for driving. All Complex situations like traffic jams are also handled by vehicle, allowing the driver to sit back without paying attention. Still the research is going on at this level and there are many technical and moral challenges which are to be addressed before these cars are made available to the public.

The vehicle will only be truly autonomous when an on-board artificial intelligence will allow it to have a capacity of self-learning and decision making according to the acquired knowledge and the driving environment, i.e. without responding automatically to a pre-programmed situation [HAUTIERE2017].

According to the Alix Partners [AlixPartners2021], the field of autonomous vehicles is expected to have the highest growth rate (11.2%/year) and represent **41% of the market in 2030.**

5.4 The attractiveness of autonomous vehicles

AV has huge benefits in various domains, mainly in military and surveillance. For civil applications, these vehicles will be extremely useful for elderly, disabled people, and children as they will be safer and secure without human interventions. Today, close to 1.25 million people are killed annually in traffic accidents (twice the number killed by war, crime and terrorism combined. AV will reduce the number of accidents that are caused by human errors in driving. 94% of total accidents are because of human errors: somebody drinking alcohol and driving, somebody texting a message while driving; somebody falling asleep at the wheel; somebody daydreaming instead of paying attention to the road. 2,800 people lost their lives on the roads of the European Union in 2019[4]. Replacing all human drivers by computers is expected to reduce deaths and injuries on the road by about 90 per cent. In other words, switching to autonomous vehicles is likely to save the lives of millions of people every year [Harari2018].

5.4.1 Social Benefits

Because Connected Autonomous Vehicles (CAV) interact with many systems, they can improve traffic flow both for the individual vehicle and for traffic throughout the city. Not only can connected vehicles limit congestion on the roads, but the new services also created by connectivity can make commuters' lives easier in a variety of ways. For instance, a connected vehicle can use the cloud to find open parking spaces, recommend the best routes, and allow riders to surf the web or take conference calls while commuting. A connected infrastructure also supports ridesharing and robo-taxis, which provide economic and environmental benefits as well as promoting social interaction[5].

5.4.2 Economic and Environmental Benefits

CAVs use AI and real-time cloud-based data to choose the fastest and most fuel-efficient routes. CAVs can also be programmed to follow rules for maximum efficiency all the time - in contrast with human drivers, who tend to overuse the accelerator or brakes, which burns excessive fuel. In fact, self-driving cars have the potential to cut energy consumption in transportation by up to 90 percent. This is both an economic and an environmental benefit, with reduced fuel consumption resulting in reduced carbon emissions.

Many CAVs are also electric vehicles (EVs) or hybrids, which can further reduce or eliminate reliance on fossil fuels altogether. And CAV technology makes the most of the EV advantage by using sensors and connectivity to optimize the vehicle's power usage. Electronic CAVs can even return excess power generated by the car's motor to the city's smart grid.

5.4.3 Safety Benefits

The main argument concerning the usefulness of the autonomous vehicle in terms of road safety is to decrease the number of accidents on the road by removing the human from the loop and, thus, by removing the risks related to the human factor. This argument must be taken with caution, as many problems have not yet been assessed. It is therefore necessary to provide for transition phases between manual (driver-driven) and autonomous (automatic control systems) driving modes. For example, when the driver delegates the driving task to the autonomous system (manual/autonomous transition), the system must be in a configuration where it can take control [HAUTIERE2017].

[4] `https://www.iew.be/route-dou-vient-le-danger`
[5] `https://social-innovation.hitachi`

The recovery procedures must be considered as particularly critical periods where the level of safety depends on the combined performance of the human and the automation system. It is therefore essential to take a closer look at this transition and the risks linked to human factors so as not to lose the benefit of all the gains made by automation [Moussa2020]. Indeed, a journey will be made in alternating sequences between automations and humans, with human/machine transitions to be optimized, especially in emergency situations, keeping in mind that even during level 3 autonomous phases, the driver will have to be able to supervise the automation, to remain aware of his driving environment, and be able to regain control at any moment. The project, supported by the MAIF Foundation and the PSA Group, pays particular attention to the question of the time required to regain control of the vehicle after a phase of driving delegation. Does this time of recovery depend on the duration of the autonomous phase? This question is crucial for manufacturers, because it determines the anticipation with which the autonomous system must inform the driver of the need to resume driving in manual mode. The consensus is currently around ten seconds. (https://www.fondation-maif.fr)

Figure 5.2: Example of a sequence of jerks and fixations at the time of the request to resume driving. Before the occurrence of the request; fixations 1, 2 and 3. After the occurrence of the request; fixations 4 and 5 `https://www.fondation-maif.fr/`.

Attention, engagement, and vigilance play a determining role in the quality of the recovery and their level directly impacts the driver's performance. The paradigm often used to test this point is that of the dual task which reveals, in this context, a notable increase in reaction time during the request for recovery. In addition, the study of eye movements shows that the driver, having to perform another task during the delegation phase (e.g. answering a phone call, sending an email, etc.), is less attentive to the road and that his reaction time increases in the presence of incidents to be managed. (https://www.fondation-maif.fr); The experimental procedure involves 4 independent groups, each group being associated with an autonomous period of time (5, 15, 45, and 60 minutes). Participants are equipped with physiological and oculometric measurement tools in order to assess sleepiness and visual strategy at the time of the recovery task.

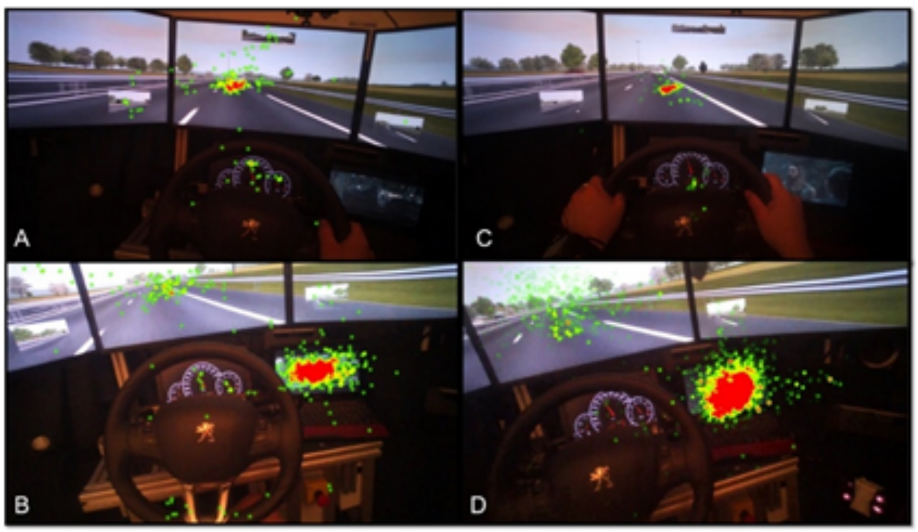


Figure 5.3: Illustrating the oculomotor behaviors of two participants, during initial manual driving (Panel A and C) and during autonomous driving (Panel B and D) `https://www.fondation-maif.fr`.

A session runs as follows: the participant drives manually for 2 minutes after which the system sends a signal to activate the autonomous function. After a variable autonomous period, a request to resume driving is presented. The participants must immediately regain control of the vehicle and perform an avoidance maneuver related to the occurrence of a dangerous event in the driving environment. During the autonomous period, participants engage in a secondary task, which consists of watching a movie on a screen positioned on the right side of the dashboard.

It is therefore necessary to work in particular on the problems of man-machine cooperation for the sharing of commands, on the implementation of indicators of the driver's activity to ensure his ability to take over the controls and ensure the supervision of the system to maintain the driver's ability to drive despite reduced driving activity [HAUTIERE2017].

Research shows that CAVs are safer than human-driven vehicles. They cause far fewer accidents than driver-operated cars. One reason for this is the technology - sensors on the car connect with their surroundings and can adapt to the changing environment to avoid collisions with other cars, pedestrians, and other objects. Another reason is that, unlike humans, CAVs do not get tired or distracted, and do not freeze in the middle of a judgment call. The vehicle's decisions are based on the analysis of data from the vehicle sensors and connected data from the cloud - data the human driver might not be able to access. For example, the vehicle's infrared sensors can "see" a hazard in the dark well before a human can.

At present, the industry is forming unexpected alliances: car manufacturers and suppliers (to date VW, BMW, Daimler, Bosch and Continental) are collaborating to develop a joint system for autonomous vehicles and are currently discussing how they can effectively pool their resources. In Japan, where the population is aging, autonomous cars are considered important. 80% of manufacturers plan to manufacture autonomous vehicles.

The demand for autonomous vehicles will be different in the large markets of Europe, the US and China. The development is currently limited – apart from technical issues – by a lack of legal principles where the legal framework is still unclear. Autonomous vehicles will have a strong positive impact on sharing concepts that will increase greatly in significance by 2030. Between 2022 and 2030, the market share of autonomous shared concepts could increase on average by over 70% per year – and thus make up more than 25% of mobility forms by 2030.

5.5 Technological Challenges

Extensive research is taking place in the field of autonomous vehicles and all big companies in the world are constantly working to make these cars available to the common public. The day is not far when the entire world will travel driverless. Still, there are a lot of technical, legal and moral challenges which need to be addressed before AV can be made available all over the world. In the current document, some of these challenges are explained.

Concerning autonomous driving, most of the research works are done on the environmental perception, the decision-making process and the motion control as well as its integration to higher level systems to provide multi-mode transport systems (link with public transport systems). However, some other research topics are also important even if they are not strongly related to autonomous driving, namely sensor systems, information processing systems and actuating systems.

The dominant hardware used today are LIDAR, stereo camera, millimeter-wave radar and V2X (vehicle to a parked fire truck that could suddenly appear ahead as other traffic changes lanes).

Lidar can send 150000 pulses of laser light per second at 186000mph; a sensor measures the time taken for each pulse to bounce back. As light travels at a constant and known speed it can accurately calculate the distance to everything). The main challenge being the accuracy of perception and recognition, especially on objects like pedestrians and bicycles [**?**].

A car's radar system will usually be programmed to detect moving objects and ignore stationary ones – such as objects. Elon Musk (Tesla) said that we will have fully autonomous cars ready by the end of 2020. "There are no fundamental challenges remaining," he said recently[6]. "There are many small problems. And then there is the challenge of solving all those small problems and putting the whole system together[7].

German startup Apostera[8] offers an advanced driver-assistance system (ADAS). The startup's platform combines augmented reality (AR), smart camera, and surround-view monitoring to illuminate the route on turns, curves, slopes as well as complex junctions. This assists the drivers in keeping lanes, prevents collisions, and enables autonomous driving options. Moreover, the solution is customizable to any car model or specific OEM requirements.

The technology company EasyMile has become the first driverless solutions provider in Europe authorized to operate at Level 4 (without any human attendant onboard) in mixed traffic, on a public road. The authorization was handed down from France's Ministry of Transport and Ministry of Ecological Transition, on advice of the Minister of the Interior and local authorities, for its experimentation in Toulouse, a public service at the Oncopole medical campus in the southern city, in partnership with Alstom.

Figure 5.4: `https://easymile.com/news/easymile-first-authorized-level-4-autonomous-driving-public-roads`

[6]`https://www.bbc.co.uk/news/technology-53349313`
[7]`https://theconversation.com`
[8]`https://apostera.com/#technology`

The US-based startup Udelv provides autonomous vehicles for last-mile deliveries. It combines advanced AI algorithms and hyper-speed teleoperations for human-assisted guidance in unique situations. The startup's vans have a payload capacity of approx. 360 kg and reach speeds up to approx 100 km/h. The vans deliver groceries from nearby stores and send out a push notification when the order arrives.

The US-based startup Awayr develops human-machine interfaces for vehicles, unmanned aerial vehicles (UAVs), and robots. The startup works with automotive original equipment manufacturers (OEMs) to decrease HMI development cycle time and enhance the safety of interfaces. Awayr also builds solutions to manage driver attention in unconventional situations, such as autonomous vehicles that may occasionally need human intervention.

Frédéric CHRISTEN, Ford-Werke GMBH, *underlines that the only one who is not going for LIDAR now is Tesla. Elon Musk said that we do not need lidar; The rest of the industry is thinking that LIDAR is a must-have but very cost intensive. There are also a lot of startups working in that area to reduce the cost and to go for solid state LIDAR instead of rotating LIDAR.*

In practice, there are still fundamental challenges to the safe introduction of fully autonomous cars. However, Brm Hendrix Automotive NL cites an interesting opinion: *The major challenges are not technological. It is more about collaboration between partners because autonomous driving is not something that only the government or only industry can do. Of course, there are still challenges on a technological level, but they are not bigger than the collaboration between all stakeholders.*

Listed below are some of the biggest remaining technological obstacles[9].

5.5.1 Unpredictable road and weather conditions

As described above, autonomous cars use a broad set of sensors[10] to "see" the environment around them, helping to detect objects such as pedestrians, other vehicles and road signs. Cameras help the car to view objects. Lidar uses lasers to measure the distance between objects and the vehicle. Radar detects objects and tracks their speed and direction.

These sensors all feed data back to the car's control system or computer to help it make decisions about where to steer or when to brake. A fully autonomous car needs a set of sensors that accurately detect objects, distance, speed and so on under all conditions and environments, without a human needing to intervene.

Autonomous vehicles and robots must overcome obstacles and limitations that are very varied in nature, such as uneven sidewalks, traffic lights, bridges, tramline crossings, and steps. Road conditions vary from place to place. Some roads are exceptionally smooth and contain proper lane markings whereas some

[9] Autonomous Cars: Technical Challenges and Solution to Blind Spots Issue Hrishikesh M. Thakurdesai1 and Dr. Jagannath Aghav2 College of Engineering, Wellesley Rd, Shivajinagar, Pune, Maharashtra

[10] `https://www.itransition.com/blog/autonomous-vehicle-sensors`

roads are very deteriorated which can contain potholes and are mountainous. It becomes challenging for an AV to drive itself on such a road where there are no signs and lane markings. Lane markings can also disappear because of quick snowfall. Humans can still identify lanes by natural road curves, but AVs may not.

Lousy weather, heavy traffic, roads signs with graffiti on them can all negatively impact the accuracy of sensing capability. To enable truly autonomous cars, these sensors must work in all weather conditions anywhere on the planet, from Alaska to Zanzibar and in congested cities such as Cairo and Hanoi. Accidents with Tesla's current (only level 2) "autopilot"[11], including one in July 2020 hitting parked vehicles[12], show the company has a big gap to overcome to produce such a global, all-weather capability. Advanced information about wet roads or snow will help the AV to decide exactly where it can drive autonomously. This system aims to increase driving safety and availability of autonomous driving functions.

5.5.2 Traffic conditions

There are many different participants in urban traffic, such as human-driven vehicles, cyclists, pedestrians, electric scooters, and more. Participants do not necessarily always follow traffic rules, which makes them unpredictable, and traffic conditions are dynamically changing. In addition to that, areas that are more densely populated present bigger challenges, and require a higher level of autonomy and technological sophistication.

Also, this may lead to a lot of problems as drivers from different countries will have different behaviors; For example, Indian drivers show their hand to turn on the road which may not be identified by the AV. It is essential to develop some sort of universal signaling language which can be followed by all to avoid failures.

5.5.3 Machine learning - Radar Interference

Most autonomous vehicles will use artificial intelligence and machine learning[13] to process the data that comes from its sensors and to help make the decisions about its next actions. These algorithms will help identify the objects detected by the sensors and classify them, according to the system's training, as a pedestrian, a streetlight, and so on. The car will then use this information to help decide whether the car needs to act, such as braking or swerving, to avoid a detected object.

In the future, machines will be able to do this detection and classification more efficiently than a human driver can. But now there is not a widely accepted

[11] `https://www.bbc.co.uk/news/technology-51645566`

[12] `https://www.torquenews.com/1083/police-tesla-autopilot-hits-not-one-two-parked-first-responder-vehicles`

[13] `https://iiot-world.com/artificial-intelligence-ml/machine-learning/machine-learning-algorithms-in-autonomous-driving`

and agreed basis for ensuring that the machine learning algorithms used in the cars are safe. There is no agreement across the industry, or across standardization bodies, on how machine learning should be trained, tested, or validated. Fully autonomous capabilities are yet to be proven.

As AV uses Machine Learning algorithms, we cannot be 100% confident about any result when human safety comes in, as it learns from experience. Even a small error in the code can cause huge consequences. The example of Elaine Herzberg Death can be given to prove the point. This was the first death case of a pedestrian killed by an autonomous car on 18th March 2018[14]. This lady in Tempe, Arizona was struck by an Uber car that was operating in self driving mode. As a result, Uber suspended testing of AVs in Arizona. This death was caused by bugs in the system of AV. These bugs can be missing lines of codes or external attacks in the system which ignored the sensor data.

Machine learning systems learn from datasets and experience which results in detection of various objects like cyclists, pedestrians, road markings, signs etc. Hence, if something is missing in the Data set used to train the car's AI, there is a risk of misinterpretation resulting in malfunctioning, for example, the STOP sign dropped on the side of the road which is not supposed to be followed, may confuse AV.

The US-basedartup **Intvo**[15] develops a pedestrian behavior prediction technology. Unlike two-dimensional (2D) and three-dimensional (3D) object detection technologies that consider limited parameters, their solution checks for head position, eye contact, and leg movements of the pedestrians, weather conditions, and assigns a risk level. This reduces false positives in pedestrian detection and enhances the safety of autonomous vehicles.

5.5.4 The open road

Once an autonomous car is on the road it will continue to learn. It will drive on new roads, detect objects it hasn't come across in its training, and be subject to software updates. How can we ensure that the system continues to be just as safe as its previous version? We need to be able to show that any new learning is safe, and that the system doesn't forget previously safe behaviors, something the industry has yet to reach agreement on.

First works of the project Benefits and limits of autonomous cars, 4 vehicles among the most performing of the market (Tesla, BMW, Mercedes and Volvo) have been tested on open road over several hundreds of km in most traffic conditions. The main benefits, common to the 4 tested vehicles, are the following:

- cruise control and speed limiter,
- recognition and tracking of road markings,
- blind spot management of the rearview mirror,

[14] Elaine Herzberg Death: Self-Driving Uber Ignored Jaywalking Pedestrian, `CarComplaints.com`

[15] `intvo.com`

- emergency braking.
- Radars and Lidars are not disturbed by fog, rain or night;
- the cameras can compensate for the lack of vigilance of the driver [Moussa2020].

Main limitations common to the 4 vehicles teste:

- They do not see the tolls;
- they do not see (all) work zones;
- they do not recognize road signs well;
- they allow overtaking on the right (except Tesla);
- the "autopilot" modes do not work on roads without line markings;
- they don't master all the situations of insertion more or less fast;
- they do not stop at stops, yield signs, traffic lights, do not respect the right of way; do not see traffic circles, medians and other delimitation equipment[16].

5.5.5 Digital maps

Today, everything is connected to the internet, and vehicles by themselves transport passengers to their destination. Doing so, they need to locate every object in the way, know every lamppost, every turn, and tunnel, which means autonomous vehicles demand a huge amount of data to transport passengers from point A to point B without causing any harm to them. In short, we need a 3D map more than ever and more accurate than ever[17].

The maps that we use daily are not good enough for this task as they are created with GPS and aerial photography. Although they are sufficient for people to drive around the unknown neighborhood, it is not suitable for autonomous vehicles as GPS is accurate to about five meters and that will not keep the autonomous car out of trouble. According to Allied Market Research, the global digital map market[18] is projected to reach $3.67 billion by 2023. The ruthless competition between market players to accurately map the world and increasing demand from autonomous vehicle companies have boosted the market growth. Today, Google Maps is dominated by its billion users. However, even Google aims to improve digital mapping and make it ideal for driverless cars. Recently, Google added a satellite layer to Google Photos that enables a user to see your path through the world using the location history-powered timeline feature[19]. Not only can you see where your pictures were taken, but the map view could

[16] https://www.fondation-maif.fr/
[17] https://www.geospatialworld.net
[18] https://www.alliedmarketresearch.com/digital-map-market
[19] https://9to5google.com/2020/12/18/google-photos-map-timeline/

also show your exact traveled route. However, Google ensured that this information is completely private and visible to the only user. With the help of AI, digital mapping can be done in a short period while improving accuracy and detail. With the help of computer vision, roads and buildings could be generated straight from satellite imagery and then converted into usable data. Apart from this, digital mapping has several challenges to tackle. The biggest challenge is importing readily available authoritative data sets. Several government agencies already have map data available for free. In the future, autonomous vehicles are the most important end-user of digital maps. Thus, the current digital maps must be updated and improved. In the future, digital maps must dynamically reflect and understand the environment. Moreover, with help of AI and Machine Learning algorithms, it would become easier to find patterns in generated data. For autonomous vehicles to run smoother on the road, we need powerful computing to create maps that offer more accurate data and detailed information regarding every corner, street, road, and lamppost, than we currently possess. The future of digital mapping lies with AI and IoT devices. What is more, developers are improving 3D mapping for autonomous vehicles and moving toward "living maps". The aim of living maps is to constantly update the map in real-time and build maps on data collected by radar, video, and LiDAR, rather than satellite imagery. Apart from this, the developments in sensor technology have opened new doors of opportunities for improving digital maps. Companies and even startups have been working to integrate smart sensors into cars and planes to create accurate maps. Digital mapping ultimately holds the progress of the future. Every novel technology that we develop and aim to launch in the future completely depends on accurate mapping of the world. Satellite images and GPS are not enough, and the developers and researchers across the globe are working continuously to improve current digital mapping technology to make it smarter, better, and more accurate.

5.6 Making the AV cost effective

As stated above, AV uses LIDAR, various cameras and sensors which are very costly. In particular, the cost of LIDAR is huge which increases the overall cost of AV. At present, a DC setup can cost up to $80,000 in which LIDAR cost itself can range from $30,000 to $70,000. One strategy to reduce cost is to use LIDAR with fewer lasers. Audi has claimed that LIDAR with only four lasers will be sufficient for safe driving on highways. Further, research is going on in companies like Valeo and Ibeo to make LIDARs in less than $1000. (Autonomous Cars: Technical Challenges and Solution to Blind Spots Issue Hrishikesh M. Thakurdesai1 and Dr. Jagannath Aghav2 College of Engineering, Wellesley Rd, Shivajinagar, Pune, Maharashtra).

Among our panel of experts, some expressed their concerns in the progress that are still to be made on the reliability of the environmental perception in bad weather conditions, with poor road infrastructure and more aggressive driving attitude of the other users of the road. These aspects might have been overlooked when testing an autonomous car in California with large roads, slow traffic and good weather conditions but will it be the same in the *center* of European capitals ?

Mr Etienne Jaqué: *I participated in an autonomous vehicle demo drive in California back in 2015. All the driver did was to give a voice command asking the car to go to a place. The ride was smooth and except for a small intervention to confirm a detected bicycle, all went well. Now this was on large roads, good weather, and known tracks. I imagined Paris or Rome downtown traffic, with many unwritten rules and habits, and concluded that the co-existence of autonomous and non-autonomous systems (including humans) will be the main transition challenge. Even though sensors and software's progress tremendously, there will always be situations that are not handled by the system. Automated systems will save lives for sure, but not all of them. And for those that fail, assignment of responsibility will be the problem. Society will have to adapt slowly and progressively to these systems, starting with low-risk applications like last mile mobility, people movers or special use vehicles under certain conditions. The change of individual mobility to automated systems is a human challenge more than a technical one, and human change takes time.*

Mr Bram Hendrix: The *major challenges of autonomous vehicles are not technological. It is more about collaboration between partners because autonomous driving is not something that only the governments or industries can do. You need the collaboration between the industry and the road owners, the infrastructure. Technologies are available for car-to-car and/or car-to-infrastructure communication but their large scale deployment is still lacking. We saw in the past years a lot of projects and pilots, but the next step is deployment. Of course, there are still challenges on a technological level, but they are not bigger than the collaboration between all stakeholders.*

Mr Frédéric CHRISTEN: *Perception is really a key thing. So, we could imagine a lot of algorithms, a lot of systems, but we need to* ***understand our environment****. We need to see other cars, to see the roads, objects to predict how the other traffic participants move. The sensing side is really the bottleneck. I would see for all those systems, would it be ADAS or automatic driving,* ***the sensing*** *and perception is really the most important thing together with, of course, the* ***data processing*** *and* ***the related computational power required.*** *The more sensors we put in the car, the more data we get and the more we need to process them at the cost of a huge computational power into the car, which is on the one hand also cost sensitive. I think there's also a very big challenge on how to treat these data in an efficient manner. Especially if we move to electric vehicles, the power consumption is even of higher importance. So, the sensing together with this data processing are, for me, the most important challenges on the technical side. Then we have infrastructure, legislation, and user acceptance as challenges on the other side that do not have to be overlooked.*

Mr. Marc Friedrich: *If tomorrow, someone is telling me that there exists some car where you press the button and it brings you home by itself. Yes, I am signing !! What a comfort! How safe! I experienced that once and I enjoyed it! I mean, once you get used to it, I don't think anyone will ever look back.*

5.7 Autonomous vehicle infrastructure

EU roads are by far the safest in the world. As the world moves forward into a future where autonomous driving will gain more and more ground, it is important to keep in mind that the AV infrastructure will play a crucial role in it. Franceso Ferrero highlights that there is a need for *specialized infrastructure, e.g., lanes with special markings, road signs units that can support the driving functionalities of the vehicles,... Hopefully, there are cities in the world that are going in this direction and it's interesting.*

Different scenarios can be laid out, where, for example, fleets of autonomous buses and shuttles effortlessly navigate through city streets, robo-taxis drop off passengers at subway stops for the next legs of their trips, traditional car owners decide that they no longer need personal vehicles because shared-mobility AVs fulfill their needs, road congestion drops because there are fewer vehicles.

Or, on the other hand, everyone who once owned a traditional car changes for an AV. Many people without licenses also purchase AVs for their personal use, even though they have not had a car for years or never owned one. Passenger-miles travels increase, AVs circle while waiting for their owners to finish shopping or running errands if no parking spaces are available, or else they run a variety of errands, ranging from delivering groceries to picking up dry cleaning, themselves. City streets become even more gridlocked.

The scenario that will emerge in every part of the world will depend highly on the investment in the infrastructure required to enhance Shared Autonomous Mobility (SAM). To get the enabling infrastructure ready for this future state, public officials could determine whether potential transportation improvements promote SAM—both for current AVs and later models that will be fully autonomous. When potential infrastructure upgrades are considered, it will be important to monitor changes in AV technology. Furthermore, investment in vehicle-to-infrastructure (V2I) systems, such as sensors in roads or street signs that send signals to AVs, helping them navigate city streets, is a currently increasing debate.

In the field of infrastructure, there are several concrete needs for action for the future-oriented and opportunity-oriented development of the vehicle industry in the Great Region. This includes digital infrastructure (mobile communications, 4-G and 5-G networks, broadband Internet) as well as the transport infrastructure and strategic development of commercial areas at central locations of the automotive industry (linking with location development/ location marketing). To ensure that the automotive industry in the Great Region with its specific opportunities and potential for new value creation (especially in the commercial vehicle sector, mobile machines, digital services and autonomous driving) in the long term, it is essential to expand and develop the digital and transport infrastructure. It serves to retain skilled workers in the Great Region and to attract them from outside, to position itself attractively in the international competition between locations, and to open up prospects for digital innovation projects.

Francesco Ferrero. *The question is whether you need to re-engineer the*

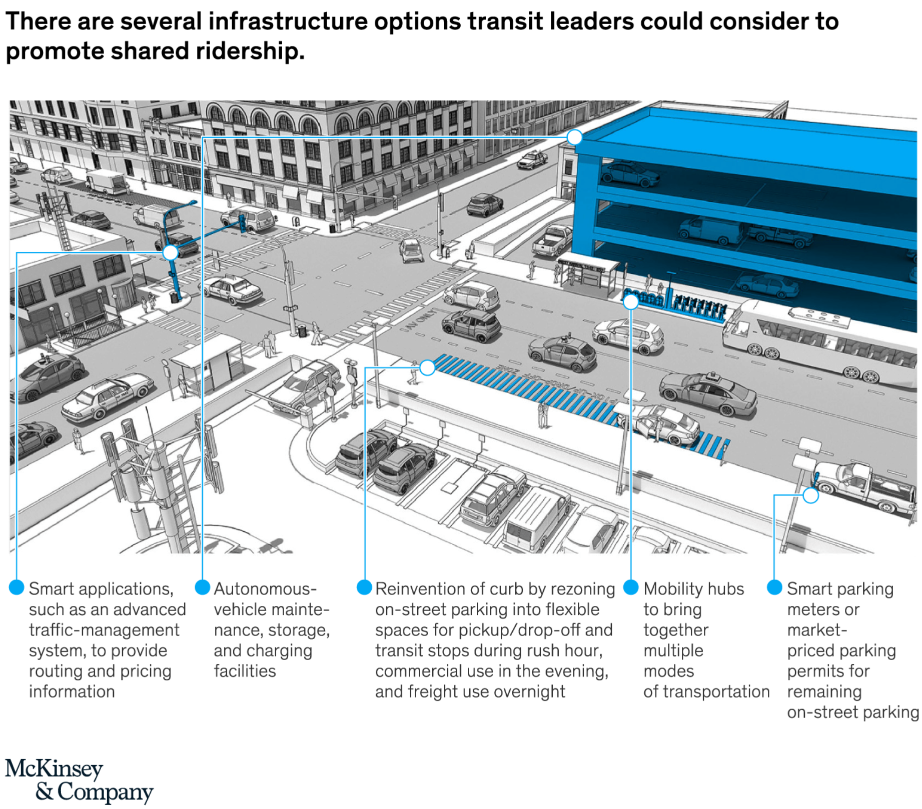


Figure 5.5: A new look at autonomous-vehicle infrastructure (Mc Kinsey)

cities and redesign the city infrastructure to support autonomous mobility. That is a key question. The technology is not mature enough for the vehicle to sense drive in whatever urban infrastructure. So, if you want autonomous vehicles to be driven in urban environments, you probably need to create specialized infrastructure, so lanes with special markings, road signs units that can support the driving functionalities of the vehicles.

Etienne Jaqué: *You have to work also on the infrastructure. In large cities or in highly-centralized and/or confined economies, for example in China, you can put intelligence in the infrastructure and make it complement the vehicle intelligence. In more diversified economies, like in Europe, it is much more difficult to agree on standards because each country may have different conditions or preferences to upgrade their infrastructure. Here, the car must be able to cope with its environment without necessarily relying on a given set of roadside devices or information.*

German Castignani: *Most of the advance has been done on the artificial intelligence embedded in the hardware and software, adapting to the environment, going from level 0 to level 5, enabling the user to disengage from the* *vehicle. Now in terms of major technological challenges, of course road marking is one of those. We have a very European or North American way of road marking and we can control the road network here. In North America it may be even better because the road network is only 200 years old. In Europe it is a little more complicated but still with particularly good signaling it is still possible. But what about the rest of the world? I come from Latin America and I do not see any autonomous cars safely driving there in the next decade because infrastructure is the problem.*

Frédéric Christen *I am not quite sure that the US has better urban infrastructure than EU. What will make the difference are these HD maps and that is what the companies are creating themselves by driving around. So, the infrastructure I guess would be good enough in Europe, of course infrastructure when we talk about intelligent traffic lights for example will need to improve in Europe.... Maybe in the beginning, autonomous driving will be possible only during daytime, not during the night, or only when it is sunny and not when it is snowy. I think there will be extremely limited service at first and then we will see an extension under every weather condition. It will be a step-by-step increase in functioning. And that is why I do not think we will start with level 5 because level 5 would mean you are able to deal with everything. And I do not think that this will be the case in the next coming years.*

5.8 User Acceptance - Social acceptability

At a global ministerial conference on road safety held in Stockholm in February 2020, participants recognized that "advanced vehicle safety technologies are among the most effective of all automotive safety devices" and called for countries to ensure that all vehicles sold by 2030 include safety performance technology. Although AVs are much safer than human drivers, governments are understandably concerned to ensure that AV technology is as safe as possible.

In the race for autonomous cars, consumer confidence is just as important as technology. If the public is to adopt autonomous vehicles on a massive scale, they must be able to trust the different technologies and their advantages and believe in the responsible attitude of the companies that will build them and benefit from them.

There have been numerous high-profile accidents involving Tesla's current automated cars[20], as well as with other automated and autonomous vehicles[21]. Social acceptability[22] is not just an issue for those wishing to buy a self-driving car, but also for others sharing the road with them. As Bram Hendrix underlines "*The best way to make it happen is in small steps. You cannot go from 0 to 100 km per hour in one second. When you look back for user acceptance*

[20] `https://www.bbc.co.uk/news/technology-51645566`

[21] `https://www.theverge.com/2019/11/6/20951385/uber-self-driving-crash-death-reason-ntsb-dcouments`

[22] `https://theconversation.com/finding-trust-and-understanding-in-autonomous-technologies-70245`

for automated driving, there is research every year and you can see that acceptance is growing. Although it is not still there and although we have seen some accidents over the years, Tesla is the nicest example, it is a new brand with great technology, everybody likes it, then it does not matter when they make accidents. If you google Tesla and accidents, then you see the most awful issues. If Mercedes Benz has an awful accident, they will have a big issue with their customers and on every levels. So, the acceptance has to happen in small steps and incrementally".

The public needs to be involved in decisions about the introduction and adoption of self-driving vehicles. Without this, we risk the rejection of this technology.

The first three of the challenges discussed above must be solved to help us overcome the latter two. There is, of course, a race to be the first company to introduce a fully self-driving car. But without collaboration on how we make the car safe, provide evidence of that safety, and work with regulators and the public to get a "stamp of approval" these cars will remain on the test track for years to come.

The opinion of the high Patronage Committee experts regarding user acceptance

Mr.Etienne Jaqué You may ask: What was the demand for smartphones before they existed? None! There was no demand. Then once they came out, suddenly everybody wanted one. It is similar to other technologies, like electric vehicles. Even though they existed before, there was no real pull or acceptance until they were pushed to the market with an image of innovation, technology, sustainability and, more recently, regulation and incentives. The consumer demand and acceptance follows availability. Availability follows demand.

Mr. Damien Ernst: *I think that after one single trip in such a car, user acceptance will be there. To me, it is more than user acceptance because you do not accept this. You will be willing to travel in an autonomous car like you have never accepted a smartphone. you are willing to have a smartphone. They will offer another service. There is a willingness to have autonomous cars. Personally, I would love to have an autonomous car.*

Mr. Michael Grandfils: *I think it is going to be fine if, you know, it's always that you can have some people that don't like it and some. But the convenience is so high, if you propose the final goal to a robot-taxi, that I think you are going to be able to convince people to do that transition. Today it is not the reality and of course you are going to keep a percentage of the population, 20% of the population so that just, you know, did not want to do. It is not good even if it sounds like a lot of reasons why they do not want that to happen. If I would ask my parents, who are sixty years old, if they would give control to a machine, you know probably they would say no. But again, you know I think I would be convinced, it is safe enough, I would be convinced to, you know like give control to the machines, I will show it to my parents, it would probably change their mind at some points and then some people would never change of course. It is going to be a bit like the vaccine, you will get what some people have said over my dead body. So, there is going to be that, but I think overall it should be* *fine.*

Mr. German Castignani: T*here are a lot of schools there, it depends on who you ask. A) Some might say that the car as an object succeeded in the past because there is a relation between the car and the driver. You buy a car not only because of your mobility needs but also because you like the driving experience. Those are the evangelists of 'ADAS is ok but level 4 or 5, forget it'. B) Then there are the computer scientists, like me, who say 'hey automated is great' but then honestly, I do not see completely automated, everyone being at level 5.*

Mr. Frédéric Christen*: My opinion, why this level 4 in level 5 will be a purely commercial application in the beginning. So, I do not think that you can buy a car as a private owner in the near term or maybe even not in midterm because it is too expensive so we will probably see cars with LIDAR's but then it will be shared Mobility Concepts or delivery services. Maybe you get your pizza from an L4 vehicle. In the mid or long term when the costs are so reduced that everyone can afford it, then maybe, the private ownership of those cars would be possible, until then a lot of time will pass and maybe the mindset of the people will change and the people which will then be drivers, they are nowadays, they are still kids and maybe they don't want to own and don't they don't want to drive in the future. They would like to be driven and maybe they do not buy any more cars. Because younger people just want to use a car to go from A to B and they do not want to own it. it is not that I do not want to own a car that I do not need one. But I just rent it for the time that I really need it.*

5.9 Legislation - Legal challenges

The performance of the AV functions requires the collection of a lot of data as well as possible exchanges with third parties to achieve the different objectives (delivery of information for cooperative systems, remote repair or maintenance operations, possibly in real time, emergency calls, traffic management, etc.). But the collection and processing of this data raises a problem, as it most often identifies the drivers, directly or indirectly [Moussa2020].

It is then possible to trace their roots, to know their travel habits, their driving style, and sometimes to characterize violations of road traffic rules. This data, legally qualified as "personal data", is protected by national and European law, even though drivers may be traveling as part of their professional activity.

The European regulation for the protection of personal data requires that this protection be taken into account at the design stage of systems ("Data protection by design").

The **General Data Protection Regulation (GDPR),** that became applicable on 25 May 2018, is aimed at protecting individuals with regard to the processing of their personal data, as well as, war ranting the free movement of such data within the EU.

"Recital 78 GDPR states that "in order to be able to demonstrate compliance with this Regulation, the controller should adopt internal policies and implement measures which meet in particular the principles of data protection by design and data protection by default. [...] When developing, designing, selecting and using applications, services and products that are based on the processing of personal data or process personal data to fulfil their task, producers of the products, services and applications should be encouraged to take into account the right to data protection.

Article 25(2) states that "the controller shall implement appropriate technical and organizational measures for ensuring that, by default, only personal data which are necessary for each specific purpose of the processing are processed" (GDPR). Some argued that there is a "terminological inconsistency with the GDPR 'privacy by design and by default' instead of 'data protection by design and by default'[23].

5.9.1 The Vienna Convention on Road Traffic

Sufficient standards and regulations for a whole autonomous system do not exist. Current standards[24] for the safety[25] of existing vehicles assume the presence of a human driver to take over in an emergency.

For self-driving cars, there are emerging regulations for functions, such as for automated lane keeping systems[26]. There is also an international standard[27] for autonomous systems that include autonomous vehicles, which sets relevant requirements but does not solve the problems of sensors, machine learning and operational learning introduced above - although it may in time. **Without recognized regulations and standards, no self-driving car, whether considered to be safe or not, will make it on to the open road.** German Castignani highlights *that there is enough regulation and legislation, liability mostly, not only legislation because the legislation gives the framework to drive but then who is liable in case of an accident? Up to level 2 it is clear who is liable. After level 3 it is more complicated. If you disengage completely then how can you share the liability between the OEM and yourself?* The Vienna Convention of 1968 is an international treaty designed to facilitate international road traffic and to increase road safety by establishing standard traffic rules among the contracting parties. All EU member states are signatories of the Vienna Convention – only Spain has not ratified it (Turkey ratified in 2013).

One of the fundamental principles of the Vienna Convention of 1968 is the concept, as laid down in Article 8, that a driver is always fully in control and responsible for the behavior of a vehicle in traffic: Article 8 (1): "Every moving vehicle or combination of vehicles shall have a driver...", **Article 8 (5): "Every driver shall at all times be able to control his vehicle ".**

In March 2014, an amendment to the Vienna Convention of 1968 was made stating that "systems which influence the way vehicles are driven ", as well

[23] Irene Kamara, "Co-regulation in EU personal data protection: the case of technical standards and the privacy by design standardization 'mandate'" (2017) 8(1) European Journal of Law and Technology, p. 14)

[24] `https://www.iso.org/standard/70939.html`

[25] `https://www.iso.org/standard/43464.html`

[26] `http://www.unece.org/fileadmin/DAM/trans/doc/2020/wp29grva/GRVA-06-02r1e.pdf`

[27] `https://ul.org/UL4600`

as other systems, which can be overridden or switched off by the driver, are deemed to be in accordance with Article 8. However, the amended convention still demands that every vehicle must have a driver. A further amendment process is therefore necessary to permit driverless vehicles.

Some countries that have ratified the Vienna Convention of 1968 believe that it does not prohibit the testing or use of automated vehicles. They state that the convention requires a driver to be able to control their vehicle, and it does not determine that a driver must be in their vehicle, nor defines the word "control ". Therefore, a driver, even if not in the vehicle, could control it by choosing a destination and route, and letting the automated vehicle steer, accelerate, and brake.

Technical requirements for vehicles are internationally harmonized in the framework of the two United Nations Economic Commission for Europe (UN-ECE) agreements: The 1958 agreement provides the framework for establishing international UN Regulations with uniform performance-oriented test provisions and administrative procedures for granting type approvals, for the conformity of production and for the mutual recognition of the type of approvals granted; while the 1998 agreement concerns the establishing of global technical regulations for the construction of new vehicles, including performance requirements. Its purpose is to further enhance the process of international harmonization through the development of global technical regulations. The 1998 agreement applies in parallel to the 1958 agreement. The EU is a contracting party to both agreements.

5.9.2 EU legislation

A legislative framework dedicated to the approval of automated vehicles in the EU does not yet exist, however, existing EU legislation is to a large extent already suitable for the placing on the market of automated and connected vehicles. At the EU level, Directive 2007/46/EC, modernized in 2018 and which becomes applicable from September 1, 2020, regulates how new vehicles should operate and be designed. Within the EU, mass-produced cars may only be used on public roads if they are type-approved in compliance with the administrative procedures and technical requirements established by the Directive ("Business Going Digital 2021" 2021).

In March 2019 the Commission published a delegated regulation which aims at stepping up the deployment of Cooperative Intelligent Transport Systems (C-ITS) on roads across the EU. C-ITS connects all road users and traffic managers so that they may share and use information in real time. This delegated act requires vehicles, traffic signs and motorways to be equipped with technology to send standardized messages to all traffic participants around them. This cooperative element is expected to significantly improve road safety, traffic efficiency and comfort while driving, by helping the driver to make the right decisions and adapt to the traffic situation.

In the EU it is already possible to validate new and ground-breaking vehicle automation technologies under the EU vehicle approval framework mentioned above. Nevertheless, technologies not foreseen by current EU rules can be approved through the so-called EU exemption – granted based on a national ad-hoc safety assessment. On April 9, 2019, the Technical Committee – Motor vehicles (TCMV) of the Commission published guidelines on the exemption procedure for EU approval of automated vehicles (Guidelines). The goal of these Guidelines is to harmonize the practice of member states for the national ad-hoc assessment of automated vehicles and to streamline the mutual recognition of such assessment, as well as to ensure fair competition and transparency. The guidelines focus on automated vehicles that can drive themselves in a limited number of driving situations (**Levels 3 and 4 of SAE**).

The Guidelines establish that the member state may grant a provisional approval to the vehicle type, valid only in its territory, provided that it informs the Commission and the other member states thereof without delay by means of a file containing the following elements: (a) the reasons why the technologies or concepts in question make the whole vehicle type incompatible with the current requirements; (b) a description of the safety and environmental considerations concerned and the measures taken; (c) a description of the tests, including their results, demonstrating that, by comparison with the requirements from which exemption is sought, at least an equivalent level of safety and environmental protection is ensured. The Commission shall decide whether to allow the member state to grant an EC type-approval in respect of that type of vehicle. The Commission decision shall be based on the Guidelines and shall clearly identify the functionality concerned and the basis under which the approval was granted.

Under the Guidelines, the manufacturer shall declare to the type-approval authority the scope of the automated driving mode where and when the automated driving system is designed to operate. This shall include at a minimum: road conditions (motorways/expressways, general roads, number of lanes, existence of lane marks, roads dedicated to automated driving vehicles, etc.); geographical area (urban and mountainous areas, etc.); environmental conditions (weather, night-time limitations, etc.); speed range; other conditions that must be fulfilled for safe operation in the driving mode.

The vehicle shall always inform the driver (or person responsible for operation) or passengers about the operational status of the system in an unambiguous manner. For vehicles designed to operate only with no driver (e.g., driverless shuttles), a communication function shall be provided to send an emergency notification to an operation control center. Automated vehicles should be equipped with an on-board device that records the operational status of the automated driving system and the status of the driver to determine who was driving in case of an accident. Moreover, the vehicle shall be designed to protect the vehicle against automated vehicle hacking using state of the art techniques and must comply with EU data protection legislation.

5.9.3 Examples of the member states' legal frameworks

At the national level, there is a degree of scope for guaranteeing alternative national requirements and permitting exceptions for test operations. Different countries have introduced measures to ease tests of autonomous vehicles on their roads or have clarified the regulatory context to allow for tests, e.g., some countries grant authorization on a case-by-case basis, others are focused more on modifying national laws to facilitate vehicle testing in their territory. However, **in the EU there is no coordination between the legislation produced by different governments.**

In **Sweden,** the Vienna Convention of 1968, and the Swedish Road Traffic Ordinance (Ordinance) coexist. Now, the Ordinance considers the presence of a driver inside the vehicle, capable of intervening always, to be compulsory, as someone must always be legally responsible. Nevertheless, Swedish legislation does not categorically forbid the utilization of advanced driving systems to support the driver but points out some limitations. Due to the latter, automotive manufacturers will have to demonstrate that their automated systems will not affect basic driving tasks and allow the driver to always maintain control over the vehicle. According to the Ordinance, local authorities and municipalities are both authorized to issue special traffic laws and define regulations independently from national directives. In any case, special authorization is only granted for situations that always guarantee road safety.

In France, to support and boost the development of automated driving, the French Ministerial Council introduced a new legislative framework called "Pact" in 2018, which allows the expansion of technical testing and test driving all around the country from 2019. In 2020, it is expected to establish a suitable legislative regulation that would allow the use of autonomous public transport and delivery services under supervision and the circulation of 3rd level autonomous cars. The less developed 3rd level vehicles do the monitoring of driving situations for the driver but still need their assistance. 4th level vehicles are expected to be seen on the roads by 2022.

In Germany, the Autonomous Vehicle Bill was enacted in June 2017, modifying the existing Road Traffic Act defining the requirements for highly and fully automated vehicles, while also addressing the rights of the driver. The bill defines that fully autonomous vehicles must comply with traffic regulations, recognize when the driver needs to resume control, and inform him or her with sufficient lead time as well as at any time permitting the driver to manually override or deactivate the automated driving mode.

The legislation requires that a black box record the journey underway, logging whether the human driver or the car's self-piloting system was in charge at all moments of the ride. The driver will bear responsibility for accidents that take place under their watch under the legislation, but if the self-driving system is in charge and a system failure is to blame, the manufacturer will be responsible. Germany also aims to expand autonomous vehicle testing on the autobahn beyond the A9 highway in Bavaria, where it is experimenting with vehicle-to-vehicle communication via 5G mobile networks.

Belgian legislation allows prototypes to be tested on roads under the responsibility of car manufacturers, subject to permissions from regional authorities (as owners of the infrastructure) and the federal administration, which must approve the technology installed on the vehicle. Since Belgium ratified the Vienna Convention of 1968, Belgian law still required that all vehicles must have a driver. This hurdle was overcome by the Royal Decree of 18 March 2018, amending the Belgian Highway Code, such as to allow the Belgian Federal Minister of Mobility to deviate from all provisions of the Belgian Highway Code in the framework of tests with automated vehicles. Such deviation from the current applicable law is subject to conditions and must be granted only for a limited period.

Consequently, as of May 1, 2018, car manufacturers and technology companies operating in the autonomous vehicles market can carry out pilot tests on public highways without a driver, under the provision that an operator should be monitoring the car's trajectory remotely from a control room. Thus, for fully autonomous (without a driver) vehicles to be able to travel on Belgian roads, modifications to the Traffic Code will be required.

Countries already diverge significantly over the extent to which they protect the privacy of road users. Within the framework of data protection, the European Union adopted the General Regulation on Data Protection GDPR (went into effect on May 25, 2018, replacing the Data Protection Directive 95/46/EC). The General Data Protection Regulation (GDPR)[28] is the toughest privacy and security law in the world. Though it was drafted and passed by the European Union (EU), it imposes obligations onto organizations anywhere, so long as they target or collect data related to people in the EU. With the GDPR, Europe is signaling its firm stance on data private security at a time when more people are entrusting their personal data with cloud services and breaches are a daily occurrence.

The United States provides less protection at a federal level, although states including California have recently tightened their rules. Some countries including China place less importance on privacy because of a more communal approach. This means the data that AVs and other connected vehicles collect and transmit is likely to vary substantially from country to country. For those with strict data protection rules, vehicles will need to anonymize data and minimize what is passed on, while other jurisdictions may require AVs to tell the authorities where they are always.

Manufacturers will have to implement security features in advance ("privacy by design") in their products. In the absence of these protections, manufacturers incur heavy financial penalties. Many countries and jurisdictions now have some of the appropriate legislation and regulations in place to enable AVs, although much of the hard work on national implementation remains - including putting infrastructure in place, establishing data policies and protocols, and setting policies on licensing and insurance.

In the UK Self-driving vehicles could be allowed on roads by the end of 2021, the government has said (Criddle 2021). The Department for Transport confirmed automated lane-keeping systems (ALKS) would be the first type of hands-free driving legalized. The technology controls the position and speed of a car in a single lane, and it will be limited to 37mph (60km/h). The government

[28] `https://gdpr.eu/`

confirmed that drivers will not be required to monitor the road or keep their hands on the wheel when the vehicle is driving itself. But the driver will need to stay alert and be able to take over when requested by the system within 10 seconds. If a driver fails to respond, the vehicle will automatically put on its hazard lights to warn nearby vehicles, slow down and eventually stop. The Highway Code is now consulting on what rules will be put into new laws to make sure the technology is safely used. What happens if you fall asleep in a self-driving car? "This is a major step for the safe use of self-driving vehicles in the UK, making future journeys greener, easier and more reliable while also helping the nation to build back better," said Transport Minister Rachel Maclean.

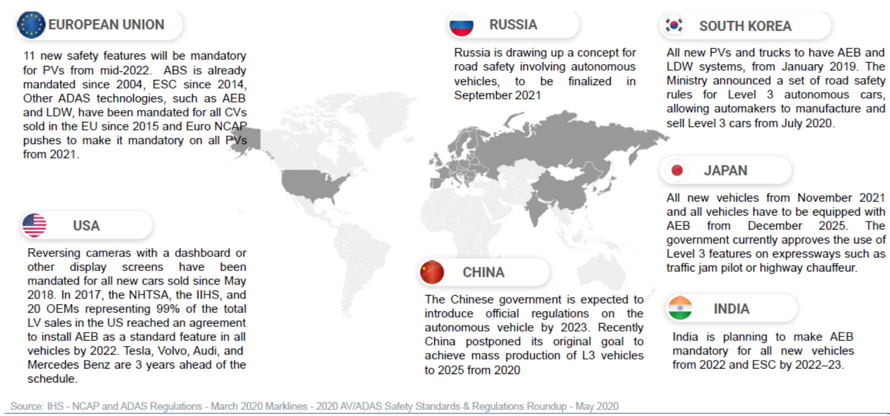


Figure 5.6: Source VALEO

5.10 Accident Repair Costs and Liability - New Modern Solutions

As we have already mentioned, the vast majority of road accidents are due to human inattention or error. The risk of accidents with artificial intelligence at the wheel should therefore decrease. In case of an accident, which is unfortunately always possible with an autonomous car, the repair costs will be significantly higher than with a conventional car. The advanced technology integrated in the bumpers, headlights, engine and dashboard is indeed extremely complex and expensive. The frequency of accidents will be lower, but the repair costs will be higher. Insurers will have to take this into account when calculating car insurance premiums.

Insurers are faced with multiple IT and ethical questions for the time being: Who will be responsible in case of an accident with an autonomous car? In this case, there will not be a "driver" but a "user". Will the user be responsible? Or will it be the manufacturer? Or the IT company that provided the technology? At this stage, the answer to the question of liability is not yet clear. What if the car is hacked? How will an autonomous car react to several simultaneous dangers? Is the driver or the manufacturer responsible in case of an accident? What about liability in case of an accident? These are all issues that need to be clarified before transforming car insurance as we know it today. However, several avenues are already being explored. In the current system, damages are paid by the insurer of the responsible party, a practice that does not seem to be sustainable in the future. Various alternatives are currently being studied. One idea that is often heard is a system where your damages are paid by your insurer, regardless of who is at fault[29]. This would not only allow claims to be handled more quickly - no more discussions about liability - but also in a very simple and transparent way. Introducing such a system will, however, take time and a thorough adaptation of the legislation. The rules will have to be carefully considered when, in a transitional phase, autonomous cars and human drivers use the public highway together.

The first autonomous cars will soon be on our roads. This will mean many changes for insurers, but they are ready to take up the challenge and offer new, more modern solutions: The formulas we know today (third party, third party + and comprehensive formulas) will have to be rethought in order to correspond to new uses. Expensive claims are bound to disappear, according to a KPMG study, 30,000 hospitalizations in France would be avoided thanks to autonomous driving. However, policyholders will have to cover themselves in case of theft, fire or vandalism. The debate should also focus on the ownership of the data collected by the vehicles. In the event of a claim, insurers could demand data to determine the conditions of the accident[30].

There is a talk mainly about **"no-fault liability"**. In the case of an accident involving two autonomous cars, the drivers would be compensated in equal parts by their respective insurers. Other solutions would consist in entrusting the insurance directly to the manufacturers. In any case, the question of car insurance for autonomous cars remains open for the moment[31]

The opinion of the high Patronage Committee experts regarding EU legislation

Etienne Jaqué: *Technology is often faster than regulation.*

Michael Grandfils: *I think, for regulations you still have quite some work to be done. I am thinking especially about the Vienna convention, which is normally foreseeing people that there still needs to be somebody into an autonomous vehicle when you are on a public road. This is how it is interpreted by most countries at national level and the issue here, of course is you do not have a business case for actual deployments today.*

Francesco Ferrero: *I think there are different approaches in different parts of the world. So typically, Europe is a prudent, let say geographical block. So, if you think of Tesla for instance, you can use in the United States more advanced functionalities of the Tesla, autopilot, than you can use in Europe. This is*

[29] http://www.allianz.be

[30] https://www.assuronline.co

[31] https://www.assurpeople.com/assurance-auto/59-la-voiture-autonome-va-t-elle-bouleverser-le-monde-de-l%E2%80%99assurance-auto

entirely a legislative problem. The technology is the same. I think that it is in line with the European approach to be extremely careful in the introduction of new technologies and that the people would react badly if accidents involving autonomous cars start to happen. So, I tend to think that this approach is justified here, you know.

German Castignani: *In terms of technology, we are now clearly able to deploy level 3. There are at least 3-4 brands that are ready to deploy level 3. There is enough regulation and legislation, liability mostly, not only legislation because the legislation gives the framework to drive but then who is liable in case of an accident? Up to level 2 it is clear who is liable. After level 3 it is more complicated. If you disengage completely then how can you share the liability between the OEM and yourself?*

Frédéric CHRISTEN: *I guess here in Europe we need better legislation. At least for Germany I know that we will have this year in 2021 a new law coming out for L4 Vehicles. So, I think they are closing the gap to the US;*

Bram HENDRIX: *What is happening now with the Green Deal, the regulation is pushing the developments. We need to reach a level of decarbonization, and the regulation helps. With smart mobility and autonomous driving, it is not so easy, no one can say 'we need to have 30% of cars at level 4', this is not the case. We need regulations to push the technology. Secondly, when you have a Level 4 car it is not possible to go on the road. I can tell you from my contacts in the government in my country (Netherlands) that they are thinking about it, but they are still very few. That needs some investment from the government's side and compromises between public and private sectors. Here is where we play a role and you as a university play a role, to make that possible. For now, governments are talking with themselves and the industry is talking with themselves.*

M. Friedrich: *The French legislation, in my opinion, is 100% against the industries since always. It's a real break, meaning that people, indeed, workers, are all well protected. We have a lot of advantages, we have a lot of things, but then it kills the job. We talk about deindustrialization. I think that the first phenomenon of deindustrialization is there. It is the legislation itself.*

5.11 Ethical principles - Moral Dilemma

With the rapid development of artificial intelligence have come concerns about how machines will make moral decisions, and the major challenge of quantifying societal expectations about the ethical principles that should guide machine behavior; To address this challenge, MIT deployed the Moral Machine, an online experimental platform designed to explore the moral dilemmas faced by autonomous vehicles. This platform gathered 40 million decisions in ten languages from millions of people in 233 countries and territories[32].

Autonomous vehicles will cruise our roads soon, necessitating agreement on the principles that should apply when, inevitably, life-threatening dilemmas

[32] `https://www.moralmachine.net`

emerge. The frequency at which these dilemmas will emerge is extremely hard to estimate, just as it is extremely hard to estimate the rate at which human drivers find themselves in comparable situations. Human drivers who die in crashes cannot report whether they were faced with a dilemma; and human drivers who survive a crash may not have realized that they were in a dilemma situation.

As emphasized by former US president Barack Obama[33] consensus in this matter is going to be important. Decisions about the ethical principles that will guide autonomous vehicles cannot be left solely to either the **engineers or the ethicists**. For consumers to switch from traditional human-driven cars to autonomous vehicles, and for the wider public to accept the proliferation of artificial intelligence-driven vehicles on their roads, **both groups will need to understand the origins of the ethical principles that are programmed into these vehicles**[34].

In other words, even if ethicists were to agree on how autonomous vehicles should solve moral dilemmas, their work would be useless if citizens were to disagree with their solution, and thus opt out of the future that autonomous vehicles promise in lieu of the status quo. Any attempt to devise artificial intelligence ethics must be at least cognizant of public morality[35]. This experience illustrates **there is no such thing as an universal ethics** [Petit2021].

A question of choice arises concerning accidents involving autonomous cars. Already today autonomous vehicles undertake decisions that used to be a human monopoly; *For example, suppose two kids chasing a ball jump right in front of a self-driving car concludes that the only way to avoid hitting two kids is to swerve into the opposite lane and risk colliding with an oncoming truck. The algorithm calculated that in such a case there is a 70 percent chance that the owner of the car - who is fast asleep in the back seat - would be killed. What should the algorithm* do? This raises the question of whether to save a pedestrian rather than the driver, for example, or a child rather than an adult. This question calls for moral principles to be considered in the parameterization of the algorithms of these cars and in their acceptance by society[36]. Which means that when designing their self-driving car, Toyota or Tesla will be transforming a theoretical problem in philosophy of ethics into a practical problem of engineering [Harari2018].

Elizabeth Joh noted that automatic traffic stops are fairer than police officers, as the freedom of the latter "to make choices in enforcing the law can have harmful effects because enforcement may be discriminatory and arbitrary" [Joh2007]. Ryan Calo famously wrote that "the traffic light does not care about

[33] `https://www.wired.com/2016/10/president-obama-mit-joi-ito-interview/`

[34] Shariff, A., Bonnefon, J.-F. & Rahwan, I. Psychological roadblocks to the adoption of self-driving vehicles. Nat. Hum. Behav. 1, 694–696 (2017)

[35] Edmon Awad, Sohan Dsouza, Richard Kim, Jonathan Schulz, Joseph Enrich, Azim Shariff, Jean-François Bonnefon and Lyad Rahwan, "The Moral Machine experiment" (2018) 563 Nature, 59-64 (`https://www.nature.com/articles/s41586-018-0637-6`)

[36] Véhicules communicants, délégation de conduite et responsabilités juridiques Michèle Guilbot, IFSTTAR

black or white, only red and green"[37].

5.12 Environmental and societal issues

Environmental and societal wellbeing is one of the seven key requirements identified by the Independent High-level expert group of experts on artificial intelligence set up by the European Commission (hereafter HLEG)."In line with the principles of fairness and prevention of harm, the broader society, other sentient beings and the environment should be also considered as stakeholders throughout the Artificial Intelligence system's life cycle. Sustainability and ecological responsibility of AI systems should be encouraged, and research should be fostered into AI solutions addressing areas of global concern, such as for instance the Sustainable Development Goals. Ideally, AI systems should be used to benefit all human beings, including future generations.

Sustainable and environmentally friendly AI. Jérôme DE COOMAN highlights that AI systems promise to help tackle some of the most pressing societal concerns, yet it must be ensured that this occurs in the most environmentally friendly way possible. The system's development, deployment and use process, as well as its entire supply chain, should be assessed in this regard, e.g. via a critical examination of the resource usage and energy consumption during training, opting for less harmful choices. Measures securing the environmental friendliness of AI systems' entire supply chain should be encouraged.

Social impact. Ubiquitous exposure to social AI systems in all areas of our lives (be it in education, work, care or entertainment) may alter our conception of social agency, or impact our social relationships and attachment. While AI systems can be used to enhance social skills, they can equally contribute to their deterioration. This could also affect people's physical and mental wellbeing. The effects of these systems must therefore be carefully monitored and considered.

Society and Democracy. Beyond assessing the impact of an AI system's development, deployment and use on individuals, this impact should also be assessed from a societal perspective, taking into account its effect on institutions, democracy and society at large. The use of AI systems should be given careful consideration particularly in situations relating to the democratic process, including not only political decision-making but also electoral contexts." [DECOOMAN2020].

Automated vehicles could reduce transportation energy use by up to 90% or increase it by more than 200%, according to a Department of Energy (DOE) study. That's a big difference: more than a quarter of greenhouse gas emissions come from the transportation sector, according to the Environmental Protection Agency (EPA). "The impacts, if you look at full vehicle automation could be huge," says Jeff Gonder, a transportation researcher at the National Renewable Energy Laboratory[38] and [Moussa2020].

[37] Ryan Calo, "Code, Nudge, or Notice?" (2014) 99(2) Iowa Law Review, p. 781

[38] NREL, `https://time.com/4476614/self-driving-cars-environment`

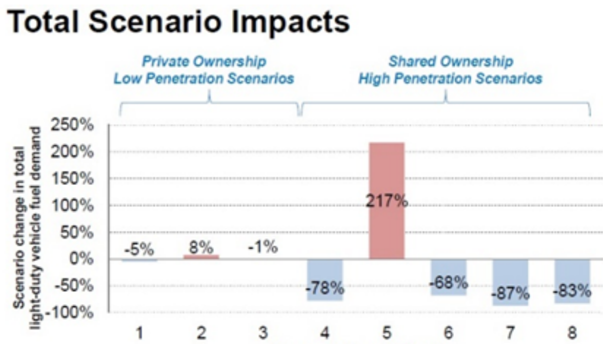


Figure 5.7: Environmental Impact Scenarios, source Austin Brown1, Brittany Repac2, Jeff Gonder1 1. National Renewable Energy Laboratory 2. University of Maryland, College Park, July 2013.

- Scenario (1,) is subject to 10% privately owned penetration with significant energy savings under the Peloton effect, this scenario leads to a -5% demand reduction.
- Scenario (2) explains the increase in fuel consumption related to an increase in distance traveled, with a 10% penetration in private ownership.
- Scenario (3), summarizes the combination of the two scenarios (1+2).
- Scenario (4), results from scenario (1) followed by a 90% penetration of shared and light autonomous vehicles, this combination leads to a decrease in demand of about -78%.
- Scenario (5), combines the results of scenario (2) and any possible identification of increased fuel consumption (more travel due to very fast travel) at a penetration rate of 90%, this scenario shows a fairly significant increase in fuel consumption.
- Scenario (6) is the result of the electrification of shared autonomous vehicles at 90% scale, which can lead to a 68% decrease in fuel consumption.
- Scenario (7) results from the identification of any potential energy savings, it would be the combination of the result of scenario (4) and (6).
- Scenario (8) is the sum of all the possibilities considered.

These different scenarios give us an overview of the impact related to the deployment of autonomous vehicles in the future, the improvement of the energy performance of the autonomous vehicle is not enough, because the energy intensity is in most scenarios improved as a result of incentives with a strong influence on the behavior of the users, which subsequently leads to a reduction of energy consumption. Hence the need to consider energy impacts in the deployment plan of autonomous vehicles.

Indeed, the results of these analyses lead to ecological consequences, namely greenhouse gas emissions in the transport sector, which are closely linked to fuel consumption, mobility demand, and the type of motorization. The more fuel we consume, the more we pollute; the more we use electric motorization of renewable origin, the less we pollute [Moussa2020].

Saujot, Brimont, and Sartor (2017) identify at least 6 different potential rebound effects related to autonomous vehicle development:

- The first rebound effect is related to urban sprawl, as more pleasant, restful, or productive transportation could induce households to move farther away from their place of work;

- The second rebound effect is linked to the fact that the autonomous vehicle could become a real place to live, if the equipment installed in it makes it possible to work, talk with friends or rest, and therefore generate an increase in the distances traveled. Renault is already presenting its autonomous vehicle prototype as a "rolling living room";

- The third rebound effect is linked to the fact that, depending on the parking policy of local authorities, vehicle owners could be encouraged to leave their vehicles unattended while they carry out their activity or to send them to park further away, in free parking lots or at the "driver's" home.

- The fourth rebound effect concerns the transport of goods. The autonomous vehicle would reduce the cost of delivery, and the purchase of products online could increase considerably;

- The fifth rebound effect is related to economic activities. The autonomous vehicle could cause the appearance of mobile businesses, circulating autonomously, if this becomes more profitable than paying for a commercial space in town;

- Finally, the individual or shared autonomous vehicle (robot-taxi) could compete with public transport and weaken its economic model, leading to a modal shift in favor of the autonomous vehicle [Moussa2020].

In addition to these rebound effects, the authors consider the risk of new inequalities in access to mobility depending on the development scenarios (more expensive private cars, expensive robot-taxis limited to certain cities, lanes reserved for autonomous vehicles, etc.) and the risk that the autonomous vehicle could complicate the sharing of roads between different uses (pedestrians, bicycles, etc.) to the detriment of soft modes[39].**Several technological bricks that go into the construction and use of the autonomous vehicle lead to an enormous environmental impact.**

[39] Autonomous vehicles: what role in the ecological transition of mobility? Anahita Grizoni, March 2021

5.13 Commercialization of autonomous mobility services

5.13.1 Private autonomous vehicles

Despite the hype and the lights that are currently concentrated on shuttles and robotaxis, there is another whole sector of autonomous driving with its own particularities, the private autonomous vehicles. McKinsey & Company share an interesting figure, reproduced here below, containing the customers' point of view on side activities during AD.

Interestingly, the side activities related to high level of autonomous driving (e.g., level 4), like sleeping, working or reading, receive very little expectations while most of the value for side activities are concentrated on having a more concentrated discussions or to look out the windows that are already achievable with level 2. Consequently, highly distracting side activities, which are only possible with Level 4 systems, account for only a small share of what consumers would like to do.

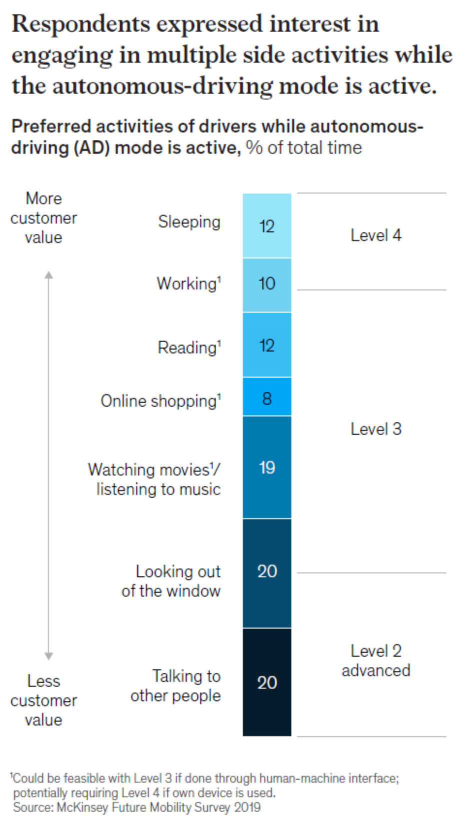


Figure 5.8: Side activities to autonomous driving.

As exhibited in the figure below, the share of new private vehicles (i.e., excluding robo-taxis) with Level 2 entry systems is expected to reach 47 percent by 2025. The Level 2 entry systems will become commoditized from 2022 onward as regulations and requirements for voluntary safety tests change. Overall, 64 percent of vehicles sold in 2030 will have some AD Level 2 or higher features.

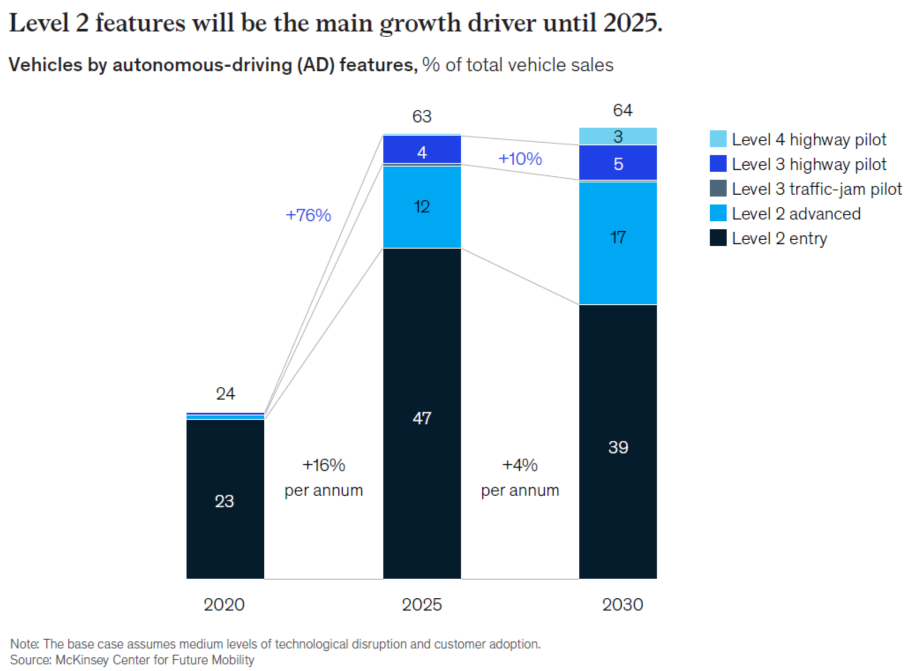


Figure 5.9: Base scenario for the growth drivers of private AV until 2030

5.13.2 Market Outlook

According to PwC Level 4 autonomy will be available by 2021 in people movers traveling at less than 50km/h. Though, there are still a lot of implications. The efforts to develop and implement ADAS software in vehicles have resulted in higher cost than originally anticipated, launch dates for high-level automated driving features have been postponed, sensors for ADAS systems are still far from being at target cost level, due to the small quantities being made. Furthermore, the legal side is also still unclear: the technical framework regulations of the UN/ECE (Economic Commission for Europe) are not yet fully in place: and the approval of Level 3 vehicles for assisted driving on motorways is still not defined.

In total, automated driving expansion seems to be delayed due to higher tech cost and limits on where automated vehicles can operate.

The opinion of the high Patronage Committee experts regarding Level 3, 4 and 5

Etienne Jaqué: *What happens in the future? Level 4 and level 5 will arrive, no doubt. After some experience in more controlled environments and public transport scenarios, probably any consumer may acquire level 4 or 5 vehicles for personal use. Even if 100% failsafe operation may not be achieved, which is true for any technology, adoption and acceptance will grow, supported by appropriate regulation. It is hard to predict how fast this transition will happen as many factors play a role, like cost, usage profiles, local infrastructure, etc...*

Michael Grandfils: *I would say not before 2030 and maybe later than that...*

Francesco Ferrero: *The level 4 is out there. I think that there are a certain number of vehicle makers that label their vehicles as level 4. If you take the latest NAVYA shuttle it is sold as a level 4, and other vehicles as well. The problem is level 4 means that it is completely autonomous in a limited environment and the extent to which these environments are limited is what you asked. If it is only working in level 4 on a private road environment, in completely straight and with no obstacles and then it is ok its level 4, but you would use it as a level 3 for 99% of the time, right? So that is the key question in my opinion, the extent to which you can get to level 4.*

Pierre Courbe: *Not before 2035 perhaps. Because it needs an implementation of costly dedicated the infrastructures in all the member states of Europe and the priorities are clearly not there. The priorities identified by governments are investing in public transport, investing in cycle lanes, and so on and I am not sure that they will also be able to invest in infrastructure dedicated to the use of autonomous cars. So, I am not sure that it will happen before that.*

German Castignani: *Technologically, Tesla is on the door of level 3. And level 3 is when you can take long disengagement from the vehicle and the car is taking complete action for you. BMW has this strategy for launching a real level 3 project in 2021-2022. If we go to level 4 It could be sharing or a dedicated fleet, delivery of parcels for example. There is a project now in Luxembourg for the autonomous shuttle with two lines, connecting the city center with two points. The first point is one that is not well connected now, a lot of companies are there. The other is inside the university campus. That would be a particularly good test for level 4 indeed.*

Frédéric CHRISTEN: *I guess we will see in the next year's first level 4 vehicles which means we have an operational design domain, which is limited, it will be only in a few cities in the beginning, maybe under certain weather conditions which are good. So, it doesn't mean that we will have in two or three years level 4, vehicles, at every corner. It is just, I guess, the first vehicle on the market but extremely limited.So, most of the companies or startups are concentrated in two or three cities e.g. in California, Florida, or Texas. So, it is assumed that in those cities we could see the first L4 vehicles. I do not know if you are more aware of it and I guess the level 4 will first start really with Urban services. So, the ridesharing or delivery services I guess will start in big* *cities. And not on the highway, so highway. I guess it is more the first systems for level 3 like the traffic jam*

Bram Hendrix: *Level 5 is just something without a steering wheel, without pedals, it goes automatically, and everybody can do what they want. That is utopia! Level 4 can be reached quite soon, not for all traffic systems of course. We will see a mixed traffic system in the next 20-30 years with Level 2, 3, 4 cars. And that is the most interesting period also, there will be mixed traffic and the question will be what to do with old timers? Are we going to kick them out? The same happened for example with other technologies in the past, like with the ABS, people thought 'ok, now I am safe' but there are always the other cars. driving or driving at higher speeds, until 130 kph. But level 4 I guess is more for urban applications;*

5.13.3 Effect of Covid-19 crisis

The coronavirus pandemic has had disruptive effects on the CAV value chain and impacted the operations of numerous Original Equipment Manufacturers (OEMs) in R&D and production during the first lockdown (e.g. Through delays in setting up pilots or trials and through cuts in investment to favor short-term cash management). Automakers had to delay their CAV R&D programs in order to improve their liquidity. Europe is well-positioned to take a leadership position in the market of CAVs, due to its strong legacy and innovation in Advanced Driver-Assistance Systems(ADAS) and Cooperative Intelligent Transport Systems. Many initiatives, supported by the EC, for large scale testing on public roads are already underway in Member States, and a legal framework for CAVs, including driving license equivalents for CAVs, has been reviewed in the Netherlands and Germany .

The health issues have reinforced the role of the autonomous vehicle in the transportation of goods in different ways: by using vehicles for deliveries of products in order to respect the containment and health measures, it has allowed to demonstrate the performances of the autonomous vehicle and to imagine the role that this type of vehicle could play in the years to come. The completely contained cities were an ideal training ground for vehicle manufacturers who were able to run their cars in some cases under facilitated but nonetheless real conditions.(Nasser Moussa, Prof. Pierre Duysinx, ULiege, Travail d'évaluation : Les véhicules autonomes l'avenir de la mobilité).

The Beijing Institute of Technology deployed an autonomous, 5G-powered vehicle to take the temperature of passersby remotely, and deliver packages. (An autonomous car specially designed to combat Covid-19 (siecledigital.fr). In Wuhan, small vehicles from the company Noelix (2.4 meters long and with an average speed of 20 km/h) have been used by local authorities to clean the streets and to transport essential goods to patients and residents in confinement (masks, food) and to hospitals[40].

[40] https://www.caradisiac.com/navettes-et-autres-engins-roulants-autonomes-collectivites-et-entreprises-pretes-a-saisir-les-opportunites-182686.htm

5.13.4 Development trajectory and compatibility with climate issues

In 2019, in an educational report, the CNRS stated that the autonomous vehicle would not reach the level of development necessary for driving in all types of situations before 2050. In 2020, the National Federation of Road Transport (FNRT), which was in charge of writing a report on the impact of the autonomous vehicle on employment, skills and training in the road haulage sector, states that their thinking shows that:

"Full (Level 5) automation is really not in the cards for tomorrow. And not just because of technological limitations. The absence of human intervention poses very concrete problems in legal terms, in terms of insurance and simply in terms of the model of sharing the road. In the report on the autonomous vehicle prepared by Idrac (2018), the authors consider the following timeline:

"- By 2020-2025, continued incremental innovations with an increase in the number of driving functions that can be delegated to the driver and gradual expansion of usage environments ; around 2030-2050: reaching a degree of near-total autonomy in any usage environment; beyond 2050: price reductions and gradual incorporation into fleets of vehicles in circulation[41].

5.14 Conclusions

Autonomous vehicles or self-driving vehicles aim to minimize the need for human drivers and look poised to transform everyday transportation. Fleets of AVs expand the scope of last-mile deliveries, reduce downtime, and aim to make public transportation relatively safer. For example, by reducing accidents caused due to driver fatigue or negligence. AVs are equipped with advanced recognition technologies, such as AI-enhanced computer vision to identify obstacles along the route.

Although many industry leaders expected autonomous vehicles to be commonplace on highways in the early 2020s, this doesn't seem likely. The enthusiasm in the industry has decreased during the last 2-3 years. Companies became aware that there is still a long way to go before solving all problems. Market introduction turns out to be not as fast as supposed. Return-on-investment is seen as critical. Despite the massive amounts of venture capital, self-driving car technology is still a long way off before they become available to people at a legitimate scale. Artificial intelligence is becoming more and more a part of everyday life and automobiles are no exception. However, autonomous vehicles require both the right legal and technological frameworks that are still missing at the time this report is written. The large-scale deployment is lacking and despite the fact that the different manufacturers are in competition to put the first fully autonomous vehicle on the road, there is a need for collaboration between these industries, the governments and the road users. => We can see

[41] The autonomous vehicle: what role in the ecological transition of mobility? March 2021, Anahita Grisoni

more and more partnerships to leverage the expertise and share the costs.

The conclusion of this study is that the technology is moving fast while the convergence on the infrastructure, the legislation and the exact role of autonomous driving in the mobility of the future is still evolving relatively slowly. Because of this, the large-scale deployment of autonomous vehicles will certainly be delayed for another decade. However, undoubtedly, autonomous vehicles will be an entire part of future mobility and the sooner the governments and the regulating bodies will tackle the problem, the better for the development of the industry and the sustainability of mobility. In the future we will see more and more partnerships to leverage the expertise and share the costs.

However, the success of CAVs also depends on many other factors as explained in this White Paper, such as public acceptance, costs and investments in technology and infrastructure.. It will be interesting to see how this regulatory aspect evolves and the effectiveness of double or triple safety systems to determine whether this segment of passenger transport can represent a relevant market for autonomous vehicles. However, as long as the human factor is involved in combination with a purely "digital" factor, there will be no such thing as zero risk.

Chapter 6

Last Mile Delivery Challenge

With the growth of e-commerce, which was significantly accelerated by the Covid-19 pandemic, the prompt and reliable delivery of goods to customers becomes one of the primary factors that customers take into consideration, and that can define the success (or lack thereof) of sellers, marketplaces, couriers, and logistics providers. The autonomous last mile delivery market is booming and is expected to have a compound annual growth rate (CAGR) of 24.4% between 2021 and 2030[1 2].

The market pressure for developing alternative solutions that are both convenient (for customers) and cost-efficient (for suppliers) is at an all-time high, and both marketplaces and providers of logistics services see it as a necessity to grow. The last mile is one of the most expensive elements of the delivery equation, representing over 50% of the total delivery costs[3]. Autonomous vehicles and robots are an obvious solution to this problem and can bring costs down significantly, from $1.60 to $0.06 per delivery[4], according to estimates, although they still face several challenges.

The logistics sector has a huge impact on the technological evolution of autonomous vehicles, and the latest developments in that domain are of numerous electric, robotic, and autonomous delivery projects, notably in the United States and Asia (JD.com, Dominos' Pizzas, Just Eat...). There are several autonomous delivery solutions that are at different stages of development, testing or rollout, such as aerial drones, autonomous vehicles (cars, vans, and trucks),

[1] https://www.alliedmarketresearch.com/autonomous-last-mile-delivery-market

[2] https://www.lmad.eu/last-mile-delivery-autonomous-vehicles-robots-urban-logistics%C2%B0https://www.lmad.eu/last-mile-delivery-autonomous-vehicles-robots-urban-logistics

[3] https://www.grandviewresearch.com/industry-analysis/autonomous-last-mile-delivery-market

[4] https://www.marketsandmarkets.com/Market-Reports/delivery-robot-market-263997316.html

and robots or droids. These solutions have the potential to revolutionize the last mile delivery market[5] and help providers improve customer satisfaction dramatically. They all solve some of the challenges of last mile delivery in urban environments, but still face several obstacles, including the fact that legislative frameworks are rather slow to adapt to new technologies and innovative last mile delivery solutions. In this regard, Europe is lagging the United States and Asia.

A 2016 McKinsey study[6] predicts that autonomous vehicles could make 80% of B2C deliveries in a decade. To realize the economic and service potential of this technological opportunity, it will be necessary to address many political, social, economic, and technical issues that will change the organization of the last mile logistics value chain.

In the "last mile of delivery", drones are used in several applications within logistics and delivery; Typically; drones are being trialed to fulfil the role of deploying and delivering goods and services. In the next 20 years it is expected that fully autonomous technologies will be fully commercial; Compared to the rest of the mobile robots in material handling and logistics, drones take up a sizable portion of this market. Bram Hendrix points out that "*Let us say for example you order a book, and your neighbor is ordering something too, it is possible that there are two mini trucks driving to your place and to your neighbor. That does not make sense. In my opinion there are going to be more hubs where the goods are collected and from there you go with e-bikes for example into the city. It will be more of a system than the individual approach that there is now. There is a lot of possible integration, it will be necessary. On the other hand, if one wants to order a book let us say at noon and have it delivered by evening that is totally stupid to think that you need it right now and not in 1-2 days. I talk to people from UPS and others, and they admit that 'it is totally stupid what we are doing but the customer wants it'. If we do not do it we will be the partner that loses. There must be a change of mindset, I think 95% of the time that we order something it is not totally necessary to have it the same day. If we change that it will make a huge difference.*

The US-based startup Udelv provides (www.udelv.com) autonomous vehicles for last-mile deliveries. It combines advanced AI algorithms and hyper-speed teleoperations for human-assisted guidance in unique situations. The startup's vans have a payload capacity of approx. 360 kg (800+ lbs) and reach speeds up to approx 100 km/h (60 mi/h). The vans deliver groceries from nearby stores and send out a push notification when the order arrives.

The pandemic has highlighted the potential for CAV adoption by logistics companies, delivery companies, and the foodservice industry, allowing for efficient and reliable transport of goods throughout the supply chain. For example,

[5] https://www.sciencedirect.com/science/article/abs/pii/S0968090X19309258

[6] How customer demands are reshaping last-mile delivery, https://www.mckinsey.com/~/media/mckinsey/industries/travel%20transport%20and%20logistics/our%20insights/how%20customer%20demands%20are%20reshaping%20last%20mile%20delivery/parcel_delivery_the_future_of_last_mile.ashx#:~:text=Autonomous%20vehicles%20including%20drones%20will,relatively%20small%20instant%20delivery%20segment.

COVID-19 tests were delivered in Florida by self-driving shuttles (O'Keane, S., 2020, Supervised self-driving shuttles are moving COVID-19 tests in Florida[7].

[7] https://www.theverge.com/2020/4/6/21209964/self-drivng-shuttles-covid-19-tests-florida-beep-jacksonville-navya

Chapter 7

Shared Mobility

Shared mobility refers to the behavior of people sharing various forms of transportation, such as cars, bikes, taxis and buses. The aim of encouraging shared mobility is to reduce carbon emissions and ease congestion on public roads, all the while, reducing travel costs for individuals. Shared mobility can also help solve our urban density problems, to the benefit of commuters and cities themselves. Travel times will be quicker on public roads, car parking will be freely available, and cities will be able to reclaim land to be used for other purposes.

The European Federation for Transport and Environment estimates that car share schemes remove up to 15% of private vehicles from the road. As a result, our journeys will become more sociable as we meet new travel companions and spend more time traveling with friends, family, and co-workers.

Shared mobility is a concept that appeared as early as 1948 in Zurich (Switzerland) under the name Selbstfahrer Genossenschaft, which can be translated as the "drivers' club". This club brought together people who decided by mutual agreement to contribute to the purchase and sharing of a car, which at the time was a so-called luxury item. Then in 1951, a French architect by the name of Jacques de Welles had the idea of deploying the first shared car project in Paris by making available Renault 4CVs and Vélo-Solex. This project was set up in response to traffic problems and congestion in the French capital. The avant-garde ideas of Jacques d'Welles were developed and quickly spread throughout Europe. Today, he is recognized as the forerunner of many mobility sharing services such as Mobility Société Coopérative which is the leader in the European car sharing market.

As defined in article L. 1231-14 of the French Transport Code, car-sharing is "the pooling of a vehicle or a fleet of motorized land transport vehicles for the benefit of users who are subscribers or authorized by the organization or person managing the vehicles. Each subscriber or authorized user may access a driverless vehicle for the trip of his or her choice and for a limited time. "But this definition can be completed by the fact that access to the vehicle is not constrained by schedules (24/7 availability) as in the case of a rental, as highlighted by the Center for Studies and Expertise on Risks, Environment, Mobility and Development (Cerema). Car sharing is therefore a mobility on demand that will allow its members to have access to a car without being the owners. To benefit from this mobility, individuals only need to pay for registration to the services (in some cases registration is not necessary) and then pay for their journey according to the distance covered and/or the time of use of the vehicle. Finally, it is important to know that car sharing often works on a self-service basis, meaning that there is no direct interaction with the rental company.

Over the last 10 years, car-sharing has become very popular, especially when you know that owning a car generates substantial annual costs and that a personal car remains unused 95% of the time. However, it is important to know that the concept of car-sharing encompasses several types of services that are differentiated according to the owner of the shared fleet, i.e. who owns the car-sharing vehicles. Thus the vehicles can belong to :

- to individuals, called **Peer-to-Peer (P2P) car sharing**. In this type of car sharing, individuals directly make their own car available to other users who are part of a community or association, for example. Thus, both parties are win-win since the user benefits from all the advantages linked to car-sharing that we will detail later and the owner will be able to amortize the acquisition and maintenance costs of his vehicle by receiving a remuneration for each use of a user.

- to companies, called **Business-to-Business (B2B) car sharing**. In this case, the company provides a fleet of vehicles for its employees. The vehicles can be owned directly by the company or can be the property of a car-sharing service that will be responsible for managing their organization and sharing. In some companies, Business-to-Business car sharing can replace the personal company car.

- to private operators, called **Business-to-Consumer (B2C) car sharing**. This is one of the best-known and most widespread forms of shared mobility. In this case, private car-sharing service groups rent their vehicles directly to individuals. This car-sharing can be divided into several types depending on the route. Thus, we distinguish :
  - loop carsharing in which the vehicle must be returned to the starting station.
  - The car-sharing in direct trace which allows him the vehicle to be deposited in another station.

With car sharing, individuals benefit from having the use of a private vehicle, without the costs and responsibilities of ownership. We can use the vehicle when we want and only pay for the journeys we make, with car sharing companies paying for fuel, maintenance, repairs, and insurance. The concept of carsharing started in Switzerland in 1987 and used a station-based model where vehicle use was recorded on paper and access to keys were gained through lock-boxes. The concept has since grown worldwide with initiatives growing rapidly in China and the U.S. According to shared mobility service Movmi[1], as of 2019, there were 236 carshare operators in 3,128 cities worldwide, each contributing to a more sustainable urban environment. Today, carshare initiatives use subscription-based models, making use of smartphone technology for bookings (www.automotiveworld.com).

Whereas *car sharing* shares the vehicle itself, *ridesharing* is about sharing the route. It works in a similar way to carpooling, where the driver picks up passengers on route to nearby destinations. One of the largest contributing factors to traffic congestion is simply the number of vehicles on the road. With ridesharing, the number of cars being used for daily commutes can be reduced, as the number of passengers per vehicle increases. However, in order for car sharing to have a positive impact on congestion, it needs to be embraced by commuters en masse, otherwise the number of vehicles on the road may actually increase[2] as the number of ridesharing companies grow. The concept of ridesharing dates back as far as 1605, when horse and carriage was used to taxi people around cities. Ridesharing as we know it today came to prominence around 2010, when UberCab was launched alongside its mobile app. Today, some of the biggest players in ridesharing include Uber[3], Lyft[4] and DiDi[5].

The US-based startup Launch Mobility[6] develops a platform for a range of shared mobility solutions. The platform LM Mission Control™ offers free-floating or station-based car sharing, advanced shuttle services, shared dockless scooters, keyless rental programs, and peer-to-peer shared mobility. The LM Mission ControlTM dashboard allows business users to manage their fleets. Further, their drivers use out-of-the-box or white-labeled apps to manage reservations or remotely access vehicles.

Bike sharing: The adoption of bike sharing schemes is on the rise globally. The market is predicted to grow[7] at a rate of 12.5% from 2018 through to 2026. Like car sharing, travelers access bicycles on an as-needed basis. Depending on the stipulations of the company, the bikes can be used for one-way trips, round trips, or within certain communities, like universities. The concept of bike sharing began in Amsterdam in the 1960s and was revived in the mid-‘90s in Copenhagen. The bike docking system that is widely used today was first adopted in France in 1998. With the rise of technology, bike sharing programs have evolved so that people can reserve, collect, and drop off bikes easily. Some of the leading companies in bike sharing today include Uber's electric bike

[1] https://movmi.net/carsharing-market-growth-2019/

[2] https://www.theverge.com/2019/8/6/20756945/uber-lyft-tnc-vmt-traffic-congestion-study-fehr-peers

[3] https://www.intelligent-mobility-xperience.com/shared-mobility-explained-a-917833/uber.com/

[4] https://www.lyft.com/

[5] https://www.didiglobal.com/

[6] https://www.launchmobility.com/product

[7] https://www.smartcitiesworld.net/news/news/the-rise-of-bike-share-3257

scheme, Jump[8], Zagster[9] and GrabBike[10].

As described before, COVID-19 swept across the globe in a matter of months, jeopardizing lives, upending businesses, and setting off a worldwide economic slump. Consumers are intensely focused on health and have altered many long-standing habits and preferences to avoid infection. Within the mobility sector, this means that many passengers favor transport modes perceived as safer and more hygienic. Suddenly, private cars are in and shared rides seem to be out. Working from home is on the rise, again with the goal of preserving safety, while business travel and all the mobility services attached to it—flying, taxis, e-hailing are in low demand.

German Castignani agrees that *shared mobility was a trend before Covid, now social distancing is indispensable, how can you tell people to share the same car? It is a complicated situation for shared mobility.*

7.1 Towards a connected, autonomous and electric shared mobility?

Why not go even further by combining all future technologies related to the development of vehicles in car-sharing? In a futuristic world, we could see the appearance of a "super car" without an owner, operating in self-service without a driver, electric and connected. But this is far from being just a dream, since at the beginning of 2020, General Motors presented Cruise Origin, an autonomous, all-electric, shared car. By being shared, the user no longer buys a product but an experience.

Bought in 2016 by the General Motors group, the company Cruise specializes in the manufacture of software to be used for fully autonomous vehicles. It also advocates to users the importance of shared ownership over individual ownership in order to reduce the impact of the car on the environment, the number of accidents or congestion in major cities. The first vehicles produced by Cruise were electric and equipped with driving control algorithms and artificial intelligence for better safety and optimal driving assistance. The company recently presented their latest model, the Cruise Origin, which is revolutionary in the automotive world. It has been specially designed as an autonomous vehicle and does not contain any manual steering controls such as pedals or a steering wheel. Closer to the appearance of a shuttle than a car, it is entirely electric. Designed for ease of use and comfort, it has doors on both sides of the vehicle that open from the center like the automatic doors found in department stores. It also offers a large space for each user since the seats of the vehicle are facing each other leaving more room for our legs. In October 2020, the California Department of Motor Vehicles allowed the company to test 5 of its driverless vehicles on the streets of San Francisco until December provided that it does

[8] https://www.jump.com/
[9] https://www.zagster.com/
[10] https://www.grab.com/th/en/transport/bike/

not exceed 30mi/h and there is no thick fog or heavy rain. These tests are done with a Cruise employee who monitors the driving from the passenger's side and who can press a stop button in case of danger. **The tests are so far positive, suggesting that the connected, autonomous and electric shared car could become the shared mobility of tomorrow.**[11]

Figure 7.1: Interior and exterior images of the Cruise Origin (source: Honda)

The majority of shared transport modes are located in metropolises and their immediate surroundings, creating geographical inequalities in mobility. There are disparities between rural areas where shared mobility is not developed and urban areas where it is present in different forms. Taking the French territory as an example, rural areas are defined by the National Institute of Statistics and Economic Studies (INSEE) as all municipalities not under the direct influence of large cities and represent 70% of the territory's surface[12]. These 70% were home to 20% of the French population in 2018 or 13,394,000 people who had

[11]Duysinx Pierre, La mobilité partagée, Innovations et technologies
[12]https://www.insee.fr/fr/metadonnees/definition/c1034

no access to shared mobility[13]. Development there is impossible since it is not profitable with a population that is not large enough and dense enough. The same problem exists with small and medium-sized cities since they do not have a large enough population to develop a shared transport network. Thus, according to Le Figaro, shared mobility services are available since September in only 85% of French cities with more than 100,000 inhabitants[14]. And again according to INSEE only 15.2% of the French population lived in cities with 100,000 or more inhabitants in 2018[15]. Finally, the geographical inequality in relation to access to shared mobility is even greater, with nearly 57 million French people not having access to it. And this problem will affect all countries and prevent the massive development of this mobility across a territory due to lack of profitability.

There is also a problem with the motivation that pushes users to turn to this mobility, since the majority evokes the financial and practical aspect well before putting forward the ecological aspect and the stakes on the environment. When we know that 1 kilo of CO2 equivalent is emitted every 4 seconds by European cars alone and that 4.9 billion kilos of CO2 will be released into the atmosphere every year due to cars in Europe according to Planestoscope CO2 emissions from cars in Europe in real time by Planetoscope, we should perhaps review our collective priorities for a better future.

There are other examples of brakes or limits to the development of mobility, but I wanted to finish by talking about a current topic with "free-floating" which will pose problems in terms of public space and its uncontrolled invasion by operators, especially for non-motorized transport. In the big cities, we can observe disturbing parking on the sidewalk, particularly for soft mobility, bicycles that are broken and deteriorated or abandoned when the operator has gone bankrupt. No legal framework has yet been implemented in France to fight against this scourge which entails costs for the community. The cost of delinquency with investigations regularly opened for theft or damage to property, or costs related to the restoration of public space, particularly by removing abandoned bikes or scooters.

Ush is Belgium's first dedicated autonomous shared mobility provider[16]. Shared mobility will therefore have to find new solutions by innovating in order to develop and contribute to the energy and ecological transition.

7.2 Conclusion

With connected vehicles, new business models have come up that focus on shared mobility as an alternative to traditional vehicle ownership. This enables mobility-as-a-service (MaaS) and discourages unused vehicles. Such solutions

[13] https://fr.statista.com/statistiques

[14] https://www.lefigaro.fr/flash-eco/des-services-de-mobilite-partagee-dans-85-des-grandes-villes-francaises-20201020

[15] Les chiffres clés des collectivités locales tirée du rapport de l'INSEE, Recensement de la population, population municipale en vigueur en 2018 (millésimée 2015

[16] https://www.ush.be

meet the requirements of a city or a business without adding new vehicles, thus reducing waiting time for fleets and pollution caused by petrol or diesel vehicles.

Such fundamental changes are prompting mobility leaders to reimagine the future of mobility. They had already been adjusting their strategies to the emergence of ACES (Mckinsey) autonomous driving, connected cars, electrified vehicles, and shared mobility and now they are going even further for the pandemic's impact on consumer behavior, policy making, and regional economies.

Chapter 8

Future Mobility Systems

Autonomous-vehicle and drone technologies have been advancing steadily in recent years. The coronavirus pandemic serves to accelerate development of those innovations, particularly in a time when "no-touch" delivery options are highly desired.

8.1 Flying cars

Many of the world's largest aerospace and automotive companies are ramping up their interest in electric vertical take-off and landing (eVTOL, Figure below) aircraft design architectures recognizing it as a potentially disruptive new transport mode. Incumbent OEMs like Boeing, Airbus, Embraer, and Bell have ongoing eVTOL development programs. The major aerospace suppliers Raytheon, GE, SAFRAN, Rolls-Royce, and Honeywell, are all investing in eVTOL related technologies including electric and hybrid-electric powertrain components, systems for autonomous flight and advanced air traffic management systems. Furthermore, composite material manufacturers like Toray and Hexcel have been working with OEMs on the advanced lightweight materials required for several facets of eVTOL design. The automotive industry is taking an interest as well, with Toyota, Hyundai[1].

eVTOL aircraft presents opportunities for companies across numerous technology fields with significant challenges still to be addressed, especially in battery technologies to meet demanding high power, high energy density, and high lifecycle requirements. These trends are leading many to look at hybrid powertrain options with either existing turbine and piston engine or fuel cells. The demanding requirements of electric powered flight offer a promising market for developers of many cutting-edge enabling technologies such as lithium metal batteries, advanced composites, and axial flux motors.

Toyota invested nearly $400 million in eVTOL start-up Joby Aviation in January 2020, in a $590 million funding round that was joined by private fund

[1] IDTechEx "Air Taxis: Electric Vertical Take-Off and Landing Aircraft 2021-2041"

manager Baillie Gifford, which famously invested early in Tesla stock at $6 per share.

The UK is building the world's first airport for flying cars[2]. The Air-One facility will be open for just one month, and is a collaboration between government agencies, private-sector businesses, and the aviation industry. It has been developed by Urban Airport, with the involvement of the Urban Air Mobility Division of Hyundai Motor Group and Coventry City Council.

Source: Huyndai Motor Group

The whole concept of flying cars would have to be regulated, or there would be no end of mid-air collisions. The consequences of these would potentially be much worse than crashes on the ground since debris falling from the sky would injure and kill people. Indeed, every mid-air collision would almost certainly have fatal implications. It is hard to see how members of the public would be allowed to simply purchase a flying car and drive it off the showroom forecourt. Finally, there are environmental issues, as some of the vehicles are likely to be powered by fossil-based fuels in order to achieve the necessary thrust[3].

8.2 Robotaxis

The Alphabet-owned autonomous driving technology firm Waymo is the first company that has launched a fully autonomous taxi service in Arizona US, in four suburbs of Phoenix-Chandler, Tempe, Mesa and Gilbert. from December 2018. Before the pandemic, the company was providing "1,000 to 2,000 weekly rides in total, 5-10% of which were fully driverless."

[2]https://www.weforum.org/agenda/2021/02/uk-first-airport-electric-flying-cars
[3]https://theconversation.com/are-self-driving-cars-safe-expert-on-how-we-will-drive-in-the-future

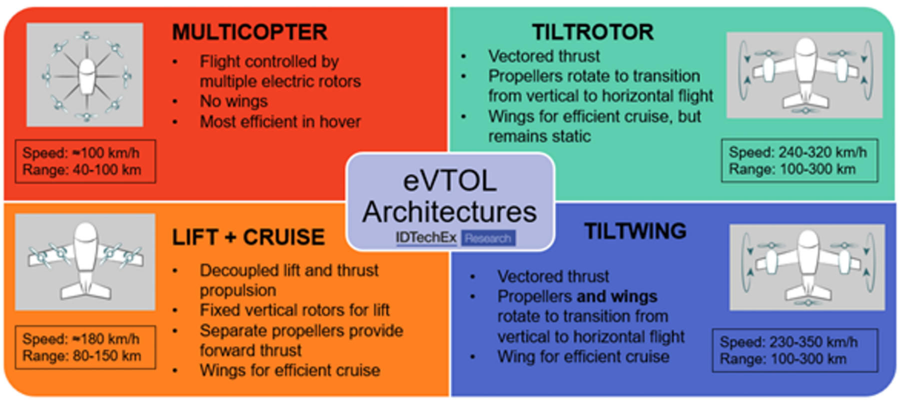


Figure 8.1: Source: IDTechEx "Air Taxis: Electric Vertical Take-Off and Landing Aircraft 2021-2041", Graphics: FEV.com

GM's Cruise and AutoX recently received the green light to launch self-driving robot taxi fleets to consumers in parts of the United States and China, respectively. Other companies have received permits to remove human drivers from their test vehicles and are not far behind.

A recent forecast from Ark Invest[4] suggests robotaxis will offer the cheapest method of transportation. The cost to travel in robotaxis is expected to be less than half that of a personal car and over 10 times cheaper than a traditional taxi ride [5].

According to Research and Markets[6], the market for MaaS is expected to reach $1.8 trillion, one-fourth of the entire transportation industry, by 2028. The MaaS market will get even bigger in the 2030s, when robotaxi adoption is expected to really take off.

According to Bloomberg, the fleet of robotaxis is expected to grow 6,300% between 2030 and 2040, from 334,000 to 21.3 million.

A small number of international players (Waymo, Zoox, GM / Cruise, Uber / Toyota ...) are aiming straight at a global market for robotaxis. They are looking to simultaneously capture the customer through the multimodal interface (which gives sense to Mobility as-a-Service) and building an unquestionable market power towards subcontractors (car and equipment manufacturers).

A development in direct competition with the historical mobility, depending on national components (highway code, safety standards, labor costs, etc.) but also resolutely local ones, each city in the world having its characteristics: important density, more or less developed and efficient public transport, more or less saturated road networks etc. The transport policy is in the hands of local authorities who intervene via public service delegations (PSD) to address the

[4] https://ark-invest.com
[5] https://banyanhill.com/
[6] https://www.marketsandmarkets.com

mobility needs, but also to handle issues such as pollution, congestion, traffic[7].

At the IAA trade show in Munich (2021), Mobileye - an Intel subsidiary - announced plans to launch a self-driving cab service in Germany in Munich and in Israel in Tel Aviv as early as 2022. This service will use a 6-seat electric vehicle model and will be done in partnership with Sixt, a car rental company.

For its robotaxis service, Mobileye has signed an agreement with the Chinese manufacturer Nio, which specializes in electric vehicles and will provide a 6-seat crossover in an autonomous version. At the launch of the service, the human being remains behind the wheel and responsible for the operation of the vehicle when the SuperVision system is activated. This system is based on two of Mobileye's EyeQ5 systems on a chip and uses 11 cameras and enables hands-free driving and self-parking capabilities. The service will launch in Munich in mid-2022 and aim for several dozen vehicles in 2023. The main reason for choosing Germany and Israel, then, is that the regulatory environment there is more favorable to autonomous driving. European expansion will therefore depend on the evolution of traffic laws in the various EU countries. To ensure safe autonomous driving, Mobileye is not limiting itself to a network of in-car cameras, believing that this is not safe enough. Mobileye is therefore working on a second layer of surveillance called the "redundancy layer" that should make autonomous driving truly safer than with a "passive" driver monitoring behind the wheel[8].

8.3 Shuttles

According to the report "Robot Shuttles and Autonomous Buses 2020-2040"[9], robot shuttles are an important reconfigurable form of transportation for goods and people that may even function as mobile offices, restaurants and more.. Primarily intended for intensive urban use, they are gated to never exceed a determined speed, typically in the range 50-60 kph. It all adds up to a new form of transport backed by both huge companies like Toyota and Baidu and startups, one having raised one billion dollars for the task. Their trials explore many possible applications, from empowering the poor and disabled, to viably filling in gaps in the transportation network and replacing very underutilized vehicles such as school buses and private cars, reducing congestion and cost. The major players developing autonomous shuttles are profiled below. While true level 4 autonomy does not currently exist, most companies discussed are at "level 4" in geofenced or controlled areas.

1. *NAVYA* is a French company founded in 2014 with more than 270 employees in France and the US. The company filed for IPO in Euronext Paris in July 2018 with 80-million-euro ($94 million) financing and the company

[7] `https://www.ykems.com/en/new-mobilities/`

[8] `https://www.moniteurautomobile.be/actu-auto/mobilite/mobileye-robotaxis-2022-allemagne-israel.html`

[9] Robot Shuttles and Autonomous Buses 2020-2040: IDTechEx, `https://www.idtechex.com/en/research-report/robot-shuttles-and-autonomous-buses-2020-2040/708`

achieved 19-million-euro ($22 million) revenues in 2018. The AUTONOM SHUTTLE, launched in 2015, is designed for a low-speed environment where there is a high frequency of travel. Currently, it is still operated at Level 3 autonomy where on-board safety operators are required. The shuttle is dedicated to the first and last-mile transportation and can carry up to 15 people. It is suitable for underserved areas where full-sized buses might not be justified from a ridership standpoint, or areas that are too tight to get around. The shuttles can operate on open roads in cities or private sites such as campuses, business parks, airports, industrial parks and hospitals - anywhere where people are taking lots of trips from half a mile up to two miles. NAVYA's strategy is to build small autonomous shuttles with a $300,000+ price that can be amortized over time by municipalities, campuses and large corporate parks working on smart city projects.

2. *EasyMile* is a French high-tech start-up founded in 2014 with over 180 employees. The main product, EZ10, was designed from the ground for autonomous driving (no steering wheel). The EZ10 was launched in 2015 and 110 units have been sold to date. The company is generating some revenues (relatively small) from selling the shuttles. Apart from selling the EZ10 shuttles, the company also licenses its in-house autonomous driving software to other companies.

3. *2getthere* is a spin-off company of Frog Navigation Systems, which was founded in 1984 to deliver automated guided vehicles (AGVs) to factories. The company became an independent company focused on autonomous vehicles for passenger transport in 2007, with a HQ in the Netherlands and was acquired by ZF Group, a German auto parts maker, in March 2019, which is one of the largest automotive suppliers. Its business model is to sell the complete transportation system: vehicles and operation systems including a supervision system for fleet management, passenger interface, charging infrastructure and communication infrastructure.

4. The Chinese tech giant *Baidu* was founded in 2000 and specializes in internet-related services and products, and AI. The company started the development of autonomous vehicles in 2013. The company has negotiated 50 partners to sign up for the development and purchase of the new autonomous buses Apolong. The volume production of the autonomous minibus Apolong is in partnership with Chinese vehicle manufacturer King Long who designs and manufactures the vehicle. In July 2018, Baidu announced its 100th Apolong, marking its ability to commercialize its autonomous shuttle buses.

5. *Yutong* is a Chinese manufacturer of commercial vehicles, especially electric buses, headquartered in Zhengzhou, Henan. As of 2016, it was the largest bus manufacturer in the world by sales volume. Yutong showcased their pure electric shuttle in March 2019 during a forum in Hainan, China,

transporting attendees at the conference venue. The autonomous shuttle integrates the U-Drive AI platform developed by UISEE, which uses sensor fusion and deep learning algorithms as well as a cloud-based vehicle management system. The 5m-long shuttle has 8 seats and can go up to 40km/h in a closed environment. The shuttle is equipped with a set of sensors including 3 lidars, radars, cameras, and ultrasonics. In May 2019, Yutong started a pilot project on 5G intelligent transportation, running 5 shuttles on an island district in Zhengzhou in collaboration with China Unicom and China Mobile.

Figure 8.2: Shuttles in Greece; source `https://www.idtechex.com/`

8.4 Drones

Drones, until just a few years ago, were synonymous with military UAV (Unmanned Aerial Vehicle). These were large gasoline powered entities capable of running surveillance missions and firing weapons. Drone revenues for commercial use applications have increased over the past four years. This is due to the increase in use cases as markets such as human carrying and search and rescue have increased in maturity. This has all changed since 2012 onwards[10].

The major market use cases for drones have continued to be mapping and agricultural use cases. This is because the regulations surrounding drones limit their applications in other use cases such as delivery, where drones cannot be flown over built-up areas etc. in many countries.

[10] IDTechEx, Autonomous Vehicles, and Drones in Logistics, Warehousing, and Delivery 2020-2040

There has been an overall increase in the revenue generated by the drone market over the past four years, driven by the need for simpler, quicker, and easier methods to measure and fly and inspect a range of structures and areas. Now drones are considered professional drones, born out of consumer ones. These drones represent an amazing diversity of sizes and shapes.

Drone delivery is in use for medicine and post disaster humanitarian aid. During the times of a public health emergency, such as the COVID-19 pandemic, UAVs, i.e., drones, can offer many advantages[11].

Not only can they ensure minimized human interaction, but they can also be used to reach otherwise inaccessible areas. China, the first country to face the wrath of the COVID-19, has made great use of drone technology to counter the COVID-19 outbreak. Taking that as inspiration, several countries around the world have joined forces with numerous researchers and innovators to find ingenious ways of using drones to fight the COVID-19 (refer to Fig. below).

Figure 8.3: Source IEEE

Human carrying is still primitive in all aspects. There are concerns related to the airframe safety and reliability, sensing approaches are not complete and satisfying, and almost nothing is done for software. There have been some examples, but regulations have restricted their use case in real life applications.

[11]A Comprehensive Review of the COVID-19 Pandemic and the Role of IoT, Drones, AI, Blockchain, and 5G in Managing its Impact, IEE

Chapter 9

Micro Mobility

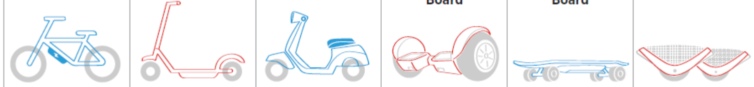
Micro mobility refers to short-distance transport, usually less than 8km. Increasingly, it is shorthand for the growing crop of bike– and scooter-sharing companies that are poised to remake the urban landscape. Micro Mobility is not a new concept throughout Europe. In fact, European cities are some of the first to offer shared bicycles as a public service, in addition to already high ownership levels; As described above, the global pandemic has transformed the way people think about travel, including micro mobility.

Today, micro mobility is a relatively ambiguous term that has no commonly agreed definition. SAE International created a set of terminology for describing micro mobility vehicles to address the lack of a common vocabulary. Its taxonomy includes three key criteria: fully or partially powered; curb weight up to and including 500 lb. (227kg); top speed up to and including 30 mph (48km/hour). Bram Hendrix underlines: The Internet of Things is growing and growing of course and that will also be the case for the mobility sector, it goes more digital, especially in cities. It is not easy in cities because there is limited space, technology limitations, it is going to be a mixed environment for many years. But the IoT world will quickly go all over the place, everything is connected, in 5 years it will be quicker than we think. During the last 50 years we put a lot more cars in cities, that is not nice, there is pollution, there are accidents, now we try to give the cities back to bicycles, to pedestrians, that is also happening out there.

According to the Mckinsey Survey[1] the use of micro mobility stands to increase—by 9% for private micro mobility and by 12% for shared micro mobility—compared to pre-pandemic levels. For 2030, a boost of 5 to 10 percent in the number of passenger-kilometers traveled is predicted. This increase will come from several trends: First, people are now more willing to use micro mobility; in addition, average trip distances could increase, as observed during the COVID-19 crisis, leading to a higher revenue per trip. Moreover, higher awareness about personal hygiene and physical distancing might encourage consumers to use mi-

[1] The future of micro mobility: Ridership and revenue after a crisis, 2020

TYPES OF POWERED MICROMOBILITY VEHICLES[1]



	Powered Bicycle	Powered Standing Scooter	Powered Seated Scooter	Powered Self-Balancing Board	Powered Non-Self-Balancing Board	Powered Skates
Center column	Y	Y	Y	Possible	N	N
Seat	Y	N	Y	N	N	N
Operable pedals	Y	N	N	N	N	N
Floorboard / foot pegs	Possible	Y	Y	Y	Y	Y
Self-balancing[2]	N	N	N	Y	N	Possible

[1] All vehicles typically designed for one person, except for those specifically designed to accommodate additional passenger(s)
[2] Self-balancing refers to dynamic stabilization achieved via a combination of sensors and gyroscopes contained in/on the vehicle

Figure 9.1: A graphical summary of Micro mobility

cro mobility, rather than public transportation, for short trips. Other trends relate to private-car usage. This form of transport could increase in cities as the next normal as people practice physical distancing to prevent transmission of COVID-19. Overall, private cars are seen as a safer mode of travel, especially when compared with public transit. As noted earlier, cities might enact measures to disincentivize and regulate private-car ownership, such as instituting higher parking fees, taxes, and tolls. They might also invest more in biking infrastructure or even repurpose whole streets to incentivize micro mobility use. Finally, consumers could become more aware of the value of sustainable and noise-reducing transportation modes after experiencing them during lockdowns. Micro Mobility might thus emerge as a leading option for riders who want to protect the environment.

There is going to be a tangible need for more vehicles circulating to keep up with newfound micro mobility demand and infrastructure, especially in the untapped markets that giant mobility companies have avoided. There is an appetite for micro mobility and the market is responding with solutions. Micro mobility is not a panacea for sustainable transport. There must be clear rules on where micro mobility can operate and how (e.g. speed limits and priority). Clear rules for road users must be supported by suitable infrastructure, including separate pathways, smooth road surfaces and informative signage. It is generally agreed that legislation is required for micro mobility solutions to work in harmony with conventional transport. But with the right governance and legal framework, it can play an important role.

9.1 Bikes and E-bikes

Cities are offering greater support for biking Worldwide. The lockdown has driven new citywide policies. One major result is an increased focus on bicycle lanes. In Europe for example: Milan has announced that 35 kilometers of streets previously used by cars will be transitioned to walking and cycling lanes after the lockdown is lifted. Paris will convert 50 kilometers of lanes usually reserved for cars to bicycle lanes. It also plans to invest $325 million to update its bicycle network. Brussels is turning 40 kilometers of car lanes into cycle paths. In Denmark, for example, 90% of the population owns a bike while just 56% own a car[2].

European cities such as Barcelona, Berlin, and Rome have also closed off streets to cars for bikes, scooters, and pedestrians. Across Europe broadly, the bicycle market was estimated at nearly $14.8B in 2016 and is expected to grow at an annual growth rate of 5.5% until 2022. Europe's car market, for comparison, is expected to grow by just 1.7% until 2024, according to the European Cyclists Federation. The French city of La Rochelle launched a bike-sharing program back in 1974 and is still in use today. The Velib in Paris, replaced in 2018 by the Velib Metropole, was one of the biggest public bike-share programs outside of China. It has since become the model for a properly implemented bike-share system.

JCDecaux, the largest outdoor advertising company in the world, was the foundation of many self-service bike rental schemes that offer thousands of bicycles across many European nations today, including Paris, Brussels, Dublin, Luxembourg, Vienna, and Valencia.

9.2 E-scooter

The rise of micro mobility is giving rise to the fastest-growing mode of transport ever documented: electric scooters (e-scooters). These e-scooters are just one of a growing range of shared micro mobility options in cities across Europe, the US and Asia. Within a year of operation, electric scooters have become a mainstream part of daily travel for citizens in metropolitan areas all over the world, available in 626 cities in 53 countries, according to the NUMO mobility alliance. And just two years after launch, no fewer than 300 million trips were made globally, and expansion is predicted to continue[3].

Shared e-scooters offer users a quick, convenient and environmentally friendly way of taking shorter journeys across city centers. Their app-based, on-demand capability and shared provision have proven to be a boon for consumers, cities and the environment benefit as well.

E-scooter operators have come together to form a new coalition, Micro Mobility for Europe (MMfE), which has launched on February 2021, Comprised of eight founding members (Bird[4], Bolt, Dott, FreeNow, Lime[5], TIER, Voi[6] and

[2] https://www.cbinsights.com
[3] https://www.ey.com/en_gl/automotive-transportation/how-micromobility-is-moving-cities-into-a-sustainable-future
[4] https://www.intelligenttransport.com/transport-articles/112179/swappable-batteries/
[5] https://www.intelligenttransport.com/transport-news/116120/lime-e-moped/
[6] https://www.intelligenttransport.com/transport-news/116018/voi-e-bikes/

Wind), the coalition aims to contribute to the development of a coherent policy framework in Europe, which it hopes will ensure micro-mobility solutions flourish in European cities and support the rapid transition to zero-emission urban mobility. Members of MMfE operate in over ten EU countries across more than 100 European cities. More and more local authorities are working to integrate micro mobility into their transportation ecosystem. MMfE claims data generated by micro-mobility providers helps cities to better understand, regulate, and plan for traffic flows, use of public infrastructure and space as well as necessary changes to improve road safety and mobility services in line with future mobility needs.

In Europe, there are around 20 million users of e-scooters and it is estimated that the micro mobility market could be valued at over €100 billion by 2030. By comparison, the car-share market across the whole of Europe was estimated at half a billion in 2017[7]!

In March 2018, Daimler and BMW merged their urban mobility companies into a single holding company. The company includes Hive, an electric kick scooter rental company that operates across Europe. Other competitors include Ford-owned Spin, which began its expansion into Europe in June, and Voi, which recently partnered with ride-hailing app Free Now, another subsidiary of the Daimler/BMW holding company, to expand its reach. In addition, many US-based companies have flocked to the European market as well, including Lime and Bird.

So far, Lime has deployed its fleets across 20 countries in Europe but had to suspend operations amid Covid-19. In May, Uber offloaded Jump, its electric bike sharing unit, to Lime — lobbing nearly 80% off Lime's valuation in the process. Bird started its Europe launch in Paris in late 2018 and quickly became popular, with over 50,000 rides after only 2 months. In January 2020, Bird acquired German rival Circ. Its scooters can be found operating across Portugal, Belgium, the UK, France, Austria, Spain, and Switzerland, though have also largely been pulled due to the coronavirus crisis.

Singapore-based startup **Beam**[8] on e-scooters to promote shared mobility in the Asia-Pacific region. Their scooters use an aviation-grade aluminum frame and are customized for sharing, safety, reliability, and durability. Users discover the nearest Beam scooter on the app and park it in visible public spots after the ride. Further, the micro-mobility platform offers a sustainable alternative to short-distance rides and helps regulate traffic flow in.

The **French manufacturer CITROEN is presenting the CV20, an electric "skateboard"** capable of carrying all sorts of capsules for the most varied of follies. The CV20 consists of a large module with four spherical wheels developed by Goodyear and designed to be driven by electric motors. The CV20 is completely autonomous. Modules that can be adapted to any use are grafted onto the four cylinders of this platform. r. Each of them was the subject of a partnership with players totally foreign to the world of mobility: Accor Hotel

[7]`https://www.eltis.org/resources/case-studies/rise-micromobility`
[8]`www.ridebeam.com`

via its Pullman and Sofitel brands, and JCDecaux[9].

Figure 9.2: Source CITROEN

9.3 Challenges the micro mobility world face

While the micro mobility trend continues to grow worldwide, there are still several challenges hindering complete adoption, including limited infrastructure, lack of regulation, citywide prohibits, and theft: (www.cbinsights.com)

9.3.1 City Infrastructure

If a city lacks the proper infrastructure such as sufficient bike lanes, adoption of shared bicycles and scooters becomes difficult and even dangerous to the public. This is one reason micro mobility has yet to take off in countries within Africa, as well as in India.

9.3.2 Regulation

As bikes and scooters remain a relatively novel concept, most cities do not have proper regulations in place for how these programs can run, leaving governments scrambling to figure out how to deal with the sudden appearance of fleets of bikes and scooters popping up around their cities. With this massive influx of companies rushing to establish their own ride-share systems within a city,

[9] Citroën ne fait rien comme tout le monde, même lorsqu'il s'agit de réinventer la mobilité. (autotrends.be), https://magazine.autotrends.be/fr/actualit%C3%A9/nouvelles-voitures/Citroen-ne-fait-rien-comme-tout-le-monde--meme-lorsquil-sagit-de-reinventer-la-mobilite

various cities have begun discussing laws to regulate the establishment and usage of these bike and scooter systems.

However, while some cities are celebrating their successful launches, others are banning these companies from operating, citing safety out of concern for the chaos they bring to the streets. The Chinese government has been creating new regulations to help control the emerging micro mobility market, including punishing individuals that leave shared bikes outside of permitted areas or vandalize the bicycles.

Some European cities like Paris are banning them on sidewalks as cautionary steps to prevent scooter collisions with pedestrians. Barcelona has taken the extra step to ban the use of shared electronic scooters completely.

9.3.3 Vandalism and theft

The vandalism and theft of bikes and scooters has become a major barrier to many new micro mobility companies. This may not be as damaging for larger companies (that can afford to redesign their hardware) as it is for smaller startups that could be driven out of business as a result. For example, Gobee.bike, a dockless bike-share service, had to abandon its efforts in France[10] completely in February 2018 as it saw thousands of their bikes damaged or stolen. For the same reason, it had already ceased services in Brussels earlier in the year.

In addition, 80% of bikes from Paris's Velib bike-share program have been reportedly stolen or damaged — some have been even found on black markets in Eastern Europe and northern Africa.

9.3.4 Weather

For cities with harsher climates, like those in northern Europe, adoption of shared bikes and scooters is not as viable. In the rain and snow, conditions become dangerous and accidents skyrocket. Plus, demand simply decreases when it is too cold to use unenclosed vehicles. Many scooter sharing companies are moving towards offering more durable fleets to make riding safer in inclement weather. Skip has even been giving away branded winter gloves and hats to its users in Washington, DC during the cold winter months. But ultimately, when weather conditions are too severe, shared scooter and bike companies might be forced to take their fleets off the streets and potentially lose precious profits.

9.3.5 Conclusion

Despite challenges, the future of micro mobility looks bright. As with any emerging industry, micro mobility companies offering the relatively new service of shared bikes and scooters to the world have some bumpy roads ahead as they face numerous challenges across the space.

[10] `https://www.theguardian.com/world/2018/feb/25/gobeebike-france-mass-destruction-dockless-bikes`

Covid-19 has accelerated the potential consolidation of the space, but also driven demand in a time where one-rider, open-air transportation solutions are highly desirable. Of course, much of this is dependent on geography, and whether cities or urban settings can accommodate these methods of transportation successfully.

But with an increasing number of investors pouring enormous amounts of capital into the micro mobility industry, we can expect to see more bicycles and scooters on the streets of cities all over the globe moving forward.

The opinion of the high Patronage Committee experts regarding micro mobility

Damien Ernst: *Well, they will be bikes. Maybe electrical bikes. Even if you are not in great physical shape, you know, to go on a bike and it is for sure these micro mobility things still are there. Yes, and then autonomous vehicles, but the key components will be a Google Maps type of approach for selecting, you know the different Mobility services that you need to combine for making a trip; The integrated approach will become excellent and I think it can go from micro mobility to autonomous vehicle, train, bike, an airplane, everything integrated into a single chain and you see that all the numerical platform for doing so, they are more or less already ready.*

Michael Grandfils: *You've seen that in a lot of cities. I was in Paris not so long ago. It is crazy, you see the change that has happened. So yeah, I think they are going to be out of that, and I think it is good.*

Francesco Ferrero: *micro mobility vehicles, people are a bit afraid even though I do think that they are less afraid now, than six months ago. So, it is now becoming a bit, let us say, less stressful to use a shared vehicle with the necessary precautions, on the other hand, you know, you can buy your own scooter. It does not cost a lot of money. So, there are also a lot of people who are using public transport for instance that are opting today for a scooter or bike. So, this contributes to an overall increase of micro mobility. So, the two types are playing, countering, let us say roles in every place. Then this proportion to balance can be different. It has any local problem, of course, depending on the average distance from job to work, the type of roads that are connected, it is difficult to generalize.*

Chapter 10

Industry 4.0 (the fourth industrial revolution)

The integration of the Internet of Things (IoT) in manufactured products offers precise traceability and data feedback to optimize production management, logistics and product use. The auto industry has already embraced Industry 4.0., however, many auto companies have not yet completely exploited the technology to establish connected facilities. But considering the vast potential of IoT, it is expected that by the end of 2022, more than 25% of automotive plants will turn into smart factories. Also, as more and more consumers are looking for greater connectivity with their automobiles, the auto industry is poised to make a dramatic shift.

Over the past 50 years, the automotive sector has invested billions of dollars in enterprise systems, automation solutions and advanced product technologies. Nonetheless, in some respects, automotive companies remain a slow follower to data and technology companies that are defining the competitive landscape of the Fourth into speed connectivity, and machine learning that have enabled the digitization of the physical world, transforming insights optimized actions. Now, these well-capitalized tech players are entering the automotive sector, and traditional automakers—saddled with legacy infrastructures and product portfolios—are Industrial Revolution—Industry 4.0. These technology companies have developed low-cost computing, struggling to keep pace.

Industry 4.0 might influence back shoring processes in two major ways : First, factor cost advantages of offshoring locations could be neutralized through positive productivity effects induced by Industry 4.0. Second, the promise of more flexible manufacturing processes might provide incentives to move more production closer to key buyers, for example, the automotive industry in the EU (Ancarani, Di Mauro and Mascali, 2019), although these effects need not hold for all (high-tech) industries. While the effects of Industry 4.0 applications on location decisions might also go both ways, thus not necessarily benefitting Europe via-ávis Asia and the US, we do believe that semiconductor production in Europe likely stands to benefit from technological developments related to Industry 4.0.

10.1 Semiconductors

Semiconductors are found in almost all electronic devices. They are the basis for chips, memory cards and processors. This market is growing very rapidly, with a doubling in value over the past 20 years. According to the Semiconductor Industry Association (SIA), the sector's global turnover has reached $439 billion in 2020.

The automotive industry today is highly dependent on semiconductors because of the many applications of electronics in our cars. Deloitte estimates that electronics will account for half the cost of a new vehicle by 2030. Semiconductors alone will cost $600 per vehicle by then, up from $312 in 2013.

If technological developments can further erode the production cost advantage of Asian countries with established chip production, the increased flexibility in manufacturing and shorter lead times expected from new production processes should favor (re-)location of semiconductor production capacity to the EU. What is more, policies to strengthen European regional value chains in the semiconductor industry could show substantial synergies with missions outlined in the Horizon Europe program.46 For example, the mission to achieve climate-neutral smart cities would benefit as new tailor-made products and applications could be developed and produced faster and more sustainably with a strong local semiconductor industry. Importantly, considering possible supply chain disruptions caused by geopolitical rivalries (as exemplified by US trade restrictions on China) in the future, it would be in the EU's interest to maintain —or further develop—state-of-the-art semiconductor manufacturing capacity within the union. (European Parliament, Impacts of the COVID-19 pandemic on EU industries).

The European (EU-28 plus continental Europe) chip industry generated around USD 30 billion in sales per year over the last decade, directly supporting roughly 200 000 jobs and, indirectly, up to 1million through its applications and services (ESIA, 2020b). European semiconductor companies have a market leader position in terms of sales in discrete (42 %), with Japan and the US following behind (at 25% and 23 %, respectively). 40 European firms are also specialized in sales of Analog ICs (a subcategory of ICs) and hold a global market share of 22% in this category. Europe is only surpassed by US-headquartered companies with a share of two-thirds of the market (SIA, 2020). Generally, European companies have embraced the 'More than Moore' trend and are well-positioned in these technologies (Decision, 2020). 'More than Moore' products are categorized by a diverse mix of (semiconductor) devices where the design and the integration in embedded systems (for professional end-users e.g., in automotive, industrial, and healthcare sectors) is often more important than a state-of-the-art fabrication plant. Europe is well equipped with wafer fabs from previous generations of semiconductor production that can still be used to produce 'More than Moore' products (ibid.). Roughly 37 % of semiconductors produced in the EU are supplied to the automotive industry, with a further 25 % produced for other industrial applications. Consequently, specialized EU firms are also global leaders in automotive semiconductors with a global market share of 29 % in 2019 (ESIA, 2020b).

Companies including German Bosch, American-Dutch NXP Semiconductors, Swiss-headquartered STMicroelectronics and German Infineon are also expected to benefit from increasing digitalization across the automotive sector (Deloitte, 2019). (European Parliament, Impacts of the COVID-19 pandemic on EU industries).

Infineon Technologies, headquartered near Munich, Germany, but located throughout Germany, Europe and the World is the leading firm in the production of discrete semiconductors (Infineon, 2020).

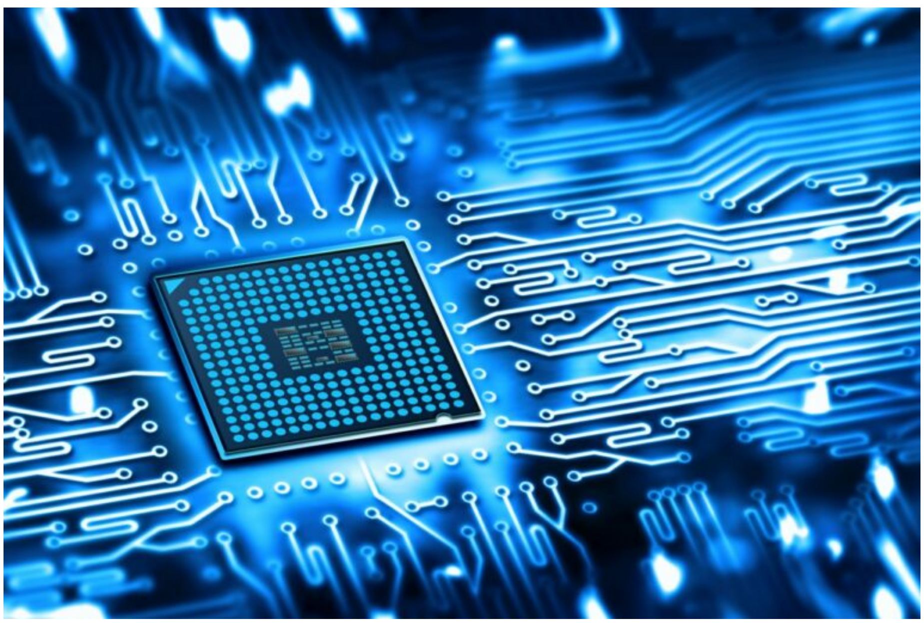


Figure 10.1: Source Bosch

10.2 industry 4.0 and sustainable manufacturing

Sustainable manufacturing is seen from various dimensions depending on its purpose and application; however, the widely accepted dimensions among the industrial participants are Environment, Society, Economy, Technology, and Performance Management. Of the mentioned dimensions, Environment, Society, and Economy are regarded as the 'three pillars' of sustainable development and are often known as 'Triple Bottom Line' (TBL). Currently, industry experts and researchers are utilizing industry 4.0 technologies to address challenges and issues related to TBL of sustainable manufacturing. For instance, environmental challenges such as climate change, resource depletion, and environmental protection will be addressed with industry 4.0 technologies. This brings a new perspective to industry 4.0, which was traditionally looked at digitizing operations and reaping benefits. However, for this to be realized, there should be complete coherence and convergence of industry 4.0 technologies. The below exhibit 3, shows the important technological enablers of the fourth industrial revolution, which is expected to play a significant role in achieving sustainable manufacturing of the future[1].

Transformation of a manufacturing unit into an intelligent factory requires both horizontal and vertical integration, wherein, all the production areas and distributors and customers are integrated. The seamless integration, provided by industry 4.0 technologies and Information & Communication technology platforms, increases the transparency of the production processes and supply chain activities, thus helping optimize all the energy and resources. Such connected operations produce vast amounts of data with regard to every aspect of manufacturing. When all such data are transformed into useful information, it will play a key role in developing strategies from environmental, societal, and economic perspectives.

Concerning the environmental dimension of sustainable manufacturing, industry 4.0 helps in reducing waste generation through its streamlined manufacturing process and effective recycling and remanufacturing initiatives. For instance, transparency in any manufacturing operation or process increases significantly by incorporating different types of sensors. Such sensors also provide valuable information including behavior, usage, failure models, performance indicators, emissions, performance under stress, etc., of the product throughout its life cycle. Such information is used to develop better products and processes using various simulation systems, to mitigate negative effects on the environment, without damaging its competitiveness. Such integrated systems also help in monitoring and managing losses incurred in the product life cycle, both in its manufacturing and usage stages. Hence, with complete transparency, manufacturers can design new products that are both competitive and environment friendly, achieving sustainability.

From an economic point of view, industry 4.0 facilitated by IoT, Artificial Intelligence, Machine Learning, Machine Vision, and Data Analytics, enables the development of equipment at much lower costs through efficient use of energy and resources. Manufacturers are continuously exploring ways to reduce their operational costs involved in manufacturing activities. However, challenges such as waste generation (arising out of both manufacturing and maintenance activities), decreased productivity, and increased energy consumption always set back the strategies developed by the manufacturers to reduce costs. With proper implementation of industry 4.0 technologies, manufacturers will be able to view

[1] `https://www.futurebridge.com/industry`

the optimized and non-optimized processes in their value chain. Such solutions will enable manufacturers to right-size their facilities, workforce, resources, and provide a view of process loopholes that can be optimized, reducing operational costs involved in manufacturing and increasing their productivity. Apart from these, strategies such as the utilization of new and cleaner technologies for manufacturing and the use of 3D printing will also help manufacturers reduce waste generation.

Concerning the social dimension of sustainable manufacturing, industry4.0 helps develop better products, which in turn benefits the society on the whole. Apart from this, numerous better jobs will be created, wherein the overall skill sets of labor will be on an improved scale. As promotional offers, several manufacturers are expected to provide incentives to consumers who are willing to return their end-of-life products to assist in recycling and remanufacturing activities (see Fig. 10.2).

Industry 4.0 technologies are expected to play a significant role in driving sustainability in industrial manufacturing. Manufacturers are keen to understand the benefits of industry 4.0 to transform themselves into a smart factory aligned with sustainable goals.

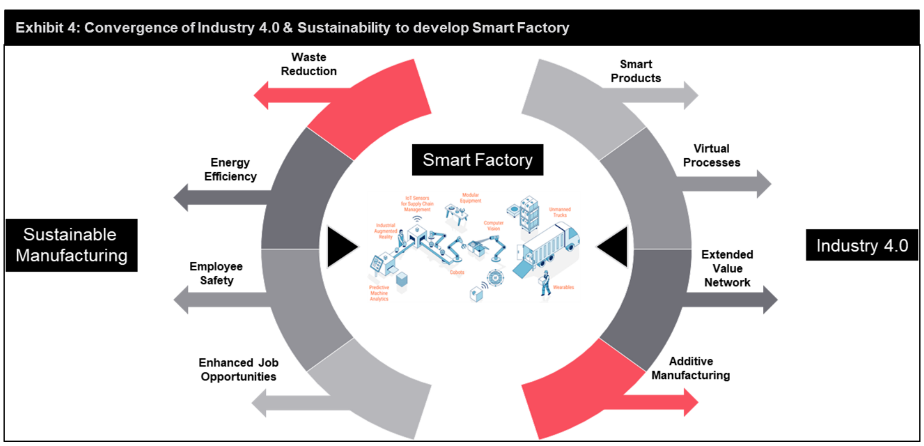


Figure 10.2: Source : http://www.futurebridge.com/industry

Industry 4.0 is leading to a shift in the relative importance of electronic and information technology know-how in the development of new vehicle components, attracting new players to the industry as lateral entrants from these fields. In addition the need to cope with increasing complexity in production while maintaining a greater variety of technology and at the same time competitive costs is an optimization task [wemoveit].

Mr Marc FRIEDRICH CEO, Fonderie Lorraine S.A. shares an interesting opinion: *Predictive maintenance, for example, is a real area that interests us a lot. We are not there yet. There are several problems in this area, in particular: the sensors are not all efficient and all good, the communication protocols, there* *are not yet on-board sensors and standardized communication protocols on these elements. This will come with the G5 with somewhat standardized communication sensors. All machines are different, everyone is trying. And after the Big Data, that is to say that you are going to record millions and millions of data that you are going to store somewhere, hesitate to destroy your stored data, but you don't really know how to exploit them because you have to put intelligence behind 1/ to get something out of it, 2/ to determine the state of your machine. At what point do I say that my machine is good and at what point do I say that it is drifting. All of that, there's a lot of things. So, this is a theme, for example, that would interest me a lot to advance in this area because we have relatively high maintenance costs on... It's very capital-intensive, our tool, and the maintenance costs are relatively high. So there is something to be done for remote maintenance with all our accounts, with all our machine suppliers. We have remote maintenance there too for data protection, we have no machine that is open. We connect the machine with a cell phone and that machine the day we do remote maintenance and we last, all these software that are all our machines are duplicated virtually. That means that a machine falls in one hour. We can reload a whole other computer to plug it in, put it on and restart. In one shift we can reboot, reconfigure a whole machine, reboot because it is completely duplicated. And we have software behind it that is WatchDog which, every night, compares what we have in the machine. Did we have the record from the day before? And if no one has declared, a modification must not be in the base of the machine and if there is a modification, it comes out with a report of something. This means that someone has intervened on the machine or has modified something that could be dangerous for production. Or maybe a virus got into that kind of thing. Even worse for a company of our size, with a good engineer in the industrial IT department, we can do this kind of thing. It's not unattainable at all, whereas there are many things that are unattainable for us. But working in these areas, a company of our size, is not. It's not unattainable, but you have to know where you want to go.* ***You can't do everything at once. You have to make a diagnosis and choose two or three themes where you want to go.***

10.3 Artificial Intelligence (AI)

As the great wave of digital technology breaks across the world, Artificial Intelligence (AI) creeps increasingly into the very fabric of our lives. Artificial Intelligence (AI) is general use technology and, therefore, of key importance for technological developments. Artificial intelligence technologies such as machine learning[2], deep learning, and computer vision find applications in robotic automation within the automotive industry. These guide self-driving cars, manage fleets, assist drivers to improve safety and improve services such as vehicle inspection or insurance. Robotics has been characterized as the intelligent connec-

[2] https://www.startus-insights.com/innovators-guide/5-top-machine-learning-startups-impacting-the-automotive-industry/

tion of perception to action in engineered systems. Automotive and electronics have been the major industry sectors for robotic use; Robotics coupled with converging mobile technologies are especially transforming industry in Asia, which has dominated the ramp-up of robotics use and with China being the primary contributor. But demand for greater productivity, mass customization, miniaturization and shorter product life cycles has also driven growth for robotics worldwide, especially in Japan, Germany, Korea and the US.

Moreover, AI is central in the field of mobility and autonomous driving and can also be applied in healthcare and medicine for the diagnosis and prevention of diseases. Across these applications, the availability, quality, and integrity of data is a major challenge.

The AI value chain can be divided into three elements: raw materials, hardware, and software. In terms of raw materials (i.e. access to data), European companies cannot compete with large American and Chinese competitors such as Alphabet, Facebook, Baidu, and Alibaba. (European Parliament Impacts of the Covid Impacts of the COVID-19 pandemic on EU industries),

Jérôme DE COOMAN highlights that the GDPR aims to ensure the free movement of personal data, but under some conditions that protect EU citizens. The same goes for non-personal data. The EU also promotes free movement of non-personal data through Regulation (EU) 2018/1807 of the European Parliament and of the Council of 14 November 2018 on a framework for the free flow of non-personal data in the European Union. All this belongs to a European policy aiming at achieving trust in AI systems. The European Commission's Communication "Building Trust in Human-Centric AI" makes this crystal clear. The European AI systems are heralded as "trustworthy" since 2018 (Cf. HLEG's draft ethics guidelines (2018) and Ethics Guidelines (2019)).

The AI value chain has not been impacted by COVID-19 due to its digital nature. In fact, as highlighted in Section 1.2.8, spending on AI is actually expected to increase. Nevertheless, the pandemic had impacts on AI development. The need for quick decision-making in the crisis sped up the development of AI solutions. Before the crisis, it took three to four months from initial conception to production deployment. During the crisis, some solutions were developed within one week. Increased uncertainty because of emotionally driven responses (e.g. stockpiling of toilet paper) and fast policy changes, as well as lack of historical data, also led to more dynamic algorithms that rely initially more on models than data175. In this regard, AI has been applied for diagnosis, public health, clinical decision making, and therapeutics. It has the potential to support our efforts in addressing pandemics. However, the need for quick decisions and insufficient data also brings limitations and dangers such as the risk of bias and unreliable predictions176. The EU's ambition is to provide a safer and more ethical alternative in AI. While the EU has no big tech companies, there are various SMEs and a growing number of start-ups. Higher consumer trust in Europe due to its strict privacy rules could benefit these companies. Moreover, the proposed EU Data Governance Act aims to improve data availability through the reuse of public sector data. Finally, other regions seem to also favour a more regulated approach, leading to EU privacy policies being exported to other regions of the world (e.g. in California) 178. However, the UK's departure from the EU is a challenge for the EU's ambition. The UK accounted for 57% of EU AI firm's funding in 2019, and without the UK, the EU's relative standing in AI investment is expected to drop in the coming years.

Indian startup RevitsOne[3] offers an AI-powered fleet-management software that is suitable for fleets of varying sizes. The startup's vehicle management system provides insights into speed, running vitals, and health information. Drivers benefit from Voicera ID, a voice-based virtual assistant that helps them keep track of the information they need. Additionally, the onboard speed recorder limits the speed to discourage dangerous driving behaviors.

The US-based startup Apex AI[4] enables automotive companies to implement complex AI solutions. Apex.OS runs on automotive electronic control units (ECUs) and offers robust, reliable, and secure APIs to develop autonomous mobility solutions. ApexAutonomy offers modules to build 3D perception, localization, and control to enable autonomous vehicles. Lastly, MARV.Automotive is a configurable and extensible data management platform that reliably transmits data from the vehicle to the cloud.

10.4 Digital Twins In Automotive Sector

The term "digital twins" refers to a new principle that is gaining importance in the development of complex hardware/software systems. In general, it refers to a **virtual representation of the real system**. This model serves to simulate the functional interactions of the parts, saving time and money by avoiding unnecessary redesign cycles and enabling considerably better optimization of the overall system design[5].

While still relatively new to the area of automotive development, the digital twin concept has been used for years in the field of industrial automation. The system modeling approach already is in widespread use in automotive, particularly with the goal of verifying the system behavior, but the digital twin represents a significant addition. Digital twins typically have a longer lifetime and greater efficiency compared with a classic system model since they can be re-used at multiple points along the entire product lifecycle. Use of the digital twin as a virtual prototype typically already starts in the planning phase for the product development, allowing more effective exploration of the design space and supporting architectural decisions. In the following step, the digital twin serves as a communication tool at the interface for system implementation. In the form of an executable specification, the resulting model can be shared with internal developer teams and external contractors. It acts as the gold standard reference for the implementation phase, ensuring clear communication and avoiding errors due to misunderstanding of the specification. In the ideal case,

[3] `http://www.revitsone.com`
[4] `https://www.apex.ai/`
[5] `https://semiengineering.com/`

the tests for checking compliance with the specification values are provided at the same time to ensure a consistent test concept from the very start.

These digital mock-ups also can be sent to customers for integration into a larger system landscape. IP remains protected thanks to an abstract model, which does not contain the details of the actual implementation. For example, software developers can receive virtual prototypes of hardware that is either still in development or should not yet be shared in detail. These familiar system development approaches can be implemented very easily with a digital twin. Finally, the digital twin remains useful even beyond the development phase. Data from operation of the real twin in the field can be played back on the virtual twin to improve the quality of the model, and future development work on the product will profit from a more accurate representation of reality.

Some of the approaches described above already are employed in the development of automotive systems. Due to the many safety-critical systems in a vehicle, several binding requirements apply to the development process for automotive electronics. The digital twin can help guarantee that these requirements are met. For example, the responses of the system to possible faults must be investigated and evaluated in advance. A virtual prototype is perfectly suited for injecting and simulating faults.

The major providers of commercial development environments for integrated electronic systems are working intensively on approaches to virtual prototyping. One area of note here is chip development, where emulator solutions and high-performance FPGA platforms are offered. However, the digital twin approach captures more relationships at the system level. Another important aspect is the interaction of electronic components with multi-physical effects, such as in the case of mechanical components or changing thermal conditions. Such a complex digital twin must be capable of integrating sub-models of quite different origins. This requires a powerful, open interface, such as provided by an FMI (Functional Mockup Interface), which permits the integration of models based on completely different mathematical principles, description languages and abstraction levels.

10.5 The Birth of Constant Optimization

One future challenge lies in expanding the digital twin from its initial functional focus to include non-functional properties. This could allow optimization of the power consumption of the complete system in various operating models, for example, as well as open the possibility of investigations of safety and reliability. The sheer number of test kilometers required to ensure the safety of highly complex assistance systems and automated driving functions will be enough to make virtual development with digital twins indispensable in the future.

A digital twin is a virtual double of a product, a machine, a process or of a complete production facility. It contains all the data and simulation models relevant to its original. Digital twins not only enable products to be conceived, simulated, and manufactured faster than in the past, but also to be designed with a view to improved economy, performance, robustness, or environmental compatibility. The virtual twin of a product can also accompany it like a digital shadow through all the stages of the value chain – from design through production to operation to servicing and even recycling. It seamlessly and ideally links together the **three Ps: product, production, and performance.**

Figure 10.3: Source Siemens A prime example for digitalization in industry: Amberg Siemens' plant in Germany is one of most state-of-the-art plants worldwide.

Today, modern production facilities do not simply exist in the physical world. Everything that is crucial for their functioning – whether it is milling machines, assembly line robots, automated warehouses, or even air conditioning or lighting systems – sends signals to on-site computers and servers, continuously creating an instant inventory of its current state. This not only helps operators at control panels to know what is happening in their factories. They can also use this information to improve productivity, ensure safety, and adjust to new requirements. There is one tool we have today, though, that facilitates this process of continuous optimization.

10.6 Additive Manufacturing, biomaterials

3D printing helps the automotive industry in three primary ways[6]. Firstly, it enables rapid prototyping with 3D printed models that accelerate the design and testing phases of production. Secondly, it allows manufacturers to print spare parts to match their requirements. Lastly, additive manufacturing of composite materials leads to automotive parts that are lighter, stronger, and more durable.

3D printing is particularly suitable for the small-scale production of high-precision and geometrically complex parts. The importance of biomaterials lies in the fact that, as renewable raw materials, they can overcome the problem of scarcity of conventional raw materials.

They are followed by autonomous driving and lightweight construction for automotive manufacturing. Battery technology is also well positioned, although some experts believe that Germany has lost out because some Asian countries dominate in this area.

Swiss startup 9T Labs[7] employs additive manufacturing to produce carbon composites for use in the automotive industry. The startup's design software Fibrify optimizes fiber placement and automates equipment production with additive fusion technology to mass-produce carbon fiber products. The 3D printed composites are more affordable, lightweight, dimensionally stable, corrosion-resistant, and also offer increased strength and stiffness.

Italian startup Moi[8] combines thermosetting composite materials and 3D printing to manufacture high-performance parts for the automotive industry. Moi uses continuous fiber manufacturing (CFM) technology, robotic intelligence, and digital fabrication to deposit fibers. As a result, the solution is easily scalable for producing composites for panels, frames, and interior components. The startup also serves other industries, such as aerospace, construction, and biomedical.

[6] https://www.startus-insights.com/innovators-guide/automotive-industry-trends-10-innovations-that-will-impact-automotive-companies-in-2020-beyond/

[7] https://www.9tlabs.com/product

[8] https://www.moi.am/#technology

Chapter 11

Digitalization of Mobility Services

The welfare of our societies depends on digital technologies. Businesses are under pressure to ensure the trustworthiness and security of their organizations, their products and their supply chains. The responses from industry and governments are often innovative but also fragmented across supply-chains and borders. The lack of a shared vision for digital product security is compounded by gaps in cybersecurity capacity and the absence of a clear pathway towards cybersecurity implementation. Industrial and technological capabilities and capacities are considered crucial elements for the international competitiveness of the EU economy vis-à-vis the increasingly geopolitical strategies employed by the US and China. Such technological capabilities and capacities are essential elements for successfully tackling grand societal challenges such as the green transition as outlined in the European Green Deal.

Technological sovereignty in high-tech industries, and in particular in digital technologies, is increasingly considered a critical element of strategic autonomy, as the competitive position of EU companies is generally regarded as lagging behind that of the US and increasingly also of Chinese competitors. What is more, in their quest for technological supremacy, the latter two countries have recently engaged in ring-fencing key technologies including semiconductors through, amongst other things, reshoring policies. The EU has only just started to react to these developments, arguably with policies that are modest in scope and scale. (European Parliament, Post Covid-19 value chains:options for reshoring production back to Europe in a globalized economy).

Although digitalisation had long been underway before the outbreak of the COVID-19 pandemic, the crisis will likely catalyze further investment in digital technologies. As humans are vulnerable to the health impacts of pandemics, more automated production processes and logistics can help increase the resilience of production during public health crises. The use of robotics and production automation has been growing, particularly in the industries most exposed to international competition, such as those in automotive, computer and electronics sectors. Against the background of both COVID-19 and the continuously sinking investment costs of robots, the trend towards automation could be reinforced by companies in the near future (Marin, 2020, European Parliament, Post Covid-19 value chains: options for reshoring production back to Europe in a globalized economy).

The car of tomorrow is designed to be powered by electric drivetrain, to drive autonomously, to operate in a fully connected and digitalized environment and to deliver mobility as a service (MaaS). One could characterize it as a true computer on wheels. It becomes clear that the role of automotive electronics increases significantly, and the software-driven car emerges. Consumers have increasingly embraced new mobility options and apps over the last decade. Advances in automotive technology will allow us to enjoy our travels and make our journeys safer. However, for all the benefits they can bring, advances in technology and connectivity applied to the automotive sector carry the same risks as our phones and computers. This is one of the major issues facing manufacturers. Threats such as invasion of privacy, security breaches and data theft are at the heart of the transportation industry's concerns. Vulnerabilities in the software could compromise the physical security of passengers as well as that of other users. The creation of the Automotive Information Sharing and Analysis Center (Auto-ISAC), the development of key cyber security roles for manufacturers and suppliers, the widespread adoption of the standards established by the National Institute of Standards and Technology (NIST) Cybersecurity Framework, and the consensus on best practices are all evidence of the industry's determination to protect its customers. (European Parliament, Post Covid-19 value chains: options for reshoring production back to Europe in a globalized economy).

Launched in 2020, the Geneva Dialogue on Responsible Behavior in Cyberspace gathers some of the world's leading ICT companies as well as companies active in critical infrastructure, operational security and cybersecurity services. It aims to cultivate a corporate ecosystem geared towards security and trust (https://genevadialogue.ch).

Great Region OEMs must seek European and international cooperation at an early stage. Suppliers who are particularly strong on combustion engines will result in stagnating or shrinking markets with a high degree of rationalization or the need for relocation. The conversion of the vehicles from electro-mechanical individual components to complex integrated systems with digital interfaces for further developments and customer requirements in the field of automation and digitization is changing the previous development environment and division of labor in the vehicle industry. OEMs are partly on the supply of new products or improved functionalities, such as e.g. apps and sensors in order to be able to and have to compete against new providers to adapt their product development processes.

The field of sensor technology is becoming increasingly important, especially with the background of autonomous vehicles. The Great Region has recognizable competencies in the supplier area. Due to the margin pressure of the OEMs on the production side, there is an increased relocation and cost pressure in the direction of Eastern Europe and especially Asia (dumping). There is potential here in the collection, preparation and analysis of data (big data), creation and operation of databases for commercial vehicles and mobile machines (smart farming, value-added services in logistics), the linking of sensor data with mobile machines (interface management e.g. in viticulture) and innovations in the field of new mobility behavior. The prerequisite for this is to understand data as a resource that is transmitted via the sensors in intelligent vehicles. The advantages and disadvantages within the economy must be clarified and weighed up. To take this step towards a digital ecosystem of intelligent vehicles, Great Region can do data infrastructure and digital services continue to focus on test track operations for autonomous vehicles and the settlement of start-ups with digital business models in the urban regions of the country. Especially for start-ups and young growth companies in the vehicle and mobility sector; In the Great Region, there is a noticeable lag and potential for catching up in comparison to other federal states and metropolitan areas, which have a larger and more visible scene of dynamic young companies. Questions need to be clarified in this context: data sovereignty, data protection and the effects of digital services on markets in the automotive industry [wemoveit].

200 to 300 million lines of code are included in the new models of vehicles: +300% in the last 15 years, +30% in the last 5 years. Navigation systems require about 20 million lines of code. Level 5 autonomous driving would involve potentially up to 1 **billion lines of code.** The rate at which "digital" functionalities are being developed is accelerating and translates into an increased need for **software development.** [AlixPartners2021].

11.1 Connected mobility

By 2030, almost all new cars will have some level of connectivity, enriching the experience for car drivers and riders while opening new avenues for businesses to create value. **A Connected Vehicle** is referred to as a motor vehicle equipped with technologies that allow it to continuously exchange data with its environment. The connected car market is the world's third largest market in terms of growth, behind the tablet and smartphone markets. Connected cars, which link up with the smartphone or one' s own home, have already been available for several years. Yet the connectivity regarding the surrounding area and other road users (Car2X) for the realization of autonomous driving functions will be further expanded and spread in the future. The market potential of autonomous driving functions will rise to almost €36 billion in the next two years, the strongest increase among connected car services.

In an urban context, the connection with public transport is also a key element to ensure that mobility is flexible and sustainable. An integrated and fully connected mobility through smartphones is a key success factor. 80% of German customers would pay for digital services. Moreover, vehicles without connectivity will be perceived as increasingly unattractive for customers. The data collected in the services relating to safety, navigation and infotainment will offer great added value through data sales and customer personalization and will push automobile and technology companies.

Nowadays, vehicles come with a tamper-proof digital identity that differentiates them from other vehicles in the network. This enables easy tracking of vehicular data for various use cases such as insurance, driver safety, predictive maintenance, and fleet management. Sharing vehicular data helps not just the individual customer, but overhauls the entire mobility ecosystem. (www.tartus-insights.com)

British startup V2X Network[1] offers vehicle-to-everything (V2X) platform for autonomous transactions that combines geo-networking and caching to enable low latency real-time communication. The platform runs on distributed ledger technologies (DLTs) and allows for a high degree of scalability. The startup uses enterprise-grade encryption in order to provide users control over their data to enhance security and privacy measures.

Israeli startup NoTraffic[2] develops an AI-powered traffic signal platform that digitizes road infrastructure management and connects drivers to the city roadways to manage various traffic-related challenges. The data of all road users is streamed and processed in real-time to empower smart mobility. The solution also serves as the base for additional services such as micropayments and micro-mobility

The impact of digitalization on the future of international production remains to be seen and will depend on the type of digital technology considered: With respect to the impact of digitalization on employment, most experts agree that the effects on employment when production is restored in combination with investments in digital production technologies will be positive but limited to the host country, while, of course, negative for the country of origin, i.e., the country of production before reshoring. Similarly, the types of jobs created by digitalization will be qualitatively different, requiring workers to acquire new digital skills. This makes digitalization particularly challenging for less-developed countries, limiting their possibilities.

11.2 Mobility as a Service

Mobility as a service – MaaS for short – is the concept of shifting transportation solutions to an on-demand service. Mobility as a Service uses shared data and a digital interface to efficiently source and manage the provision of transport related services into a seamless offer which meets the mobility requirements of people. MaaS is not an Application. MaaS is a distribution model for mobility services. From a consumer perspective MaaS is typically delivered via an Application but from a regulatory and market perspective MaaS is an **ecosystem**[3].

Originally from Finland, the concept of MaaS is quite recent. Although the

[1] `https://www.v2x.network/#platform`

[2] `https://notraffic.tech/how-it-works/`

[3] *Mobility as a Service*, webinar 27.05.2021, Webinaire CFDD & SPF Mobilité et Transports, International Transport Forum

generic idea of a combined mobility assistant can be traced back to 1996, it was not until 2013 that MaaS took its current form through a pilot project in the Swedish city of Gothenburg followed by the creation of MaaS Global, the first MaaS operator resulting from a Finnish research programmer. Although MaaS was initially largely driven by the intelligent transport systems industries, many public authorities have taken up the concept today. MaaS is currently mainly used in urban areas because its implementation requires an availability and combination of services that is difficult to find in peripheral and rural area [Lebas2021].

According to the MaaS Alliance, "Mobility as a Service (MaaS) puts users, both travellers and goods, at the core of transport services, offering them tailor-made mobility solutions based on their individual needs. This means that, for the first time, easy access to the most appropriate transport mode or service will be included in a bundle of flexible travel service options for end users.

Statistics suggest that 55% of the global population is living in urban areas currently, and estimates suggest nearly 68% of the population will be living in urban areas by 2050. The rapid pace of urbanization is already leading to traffic congestion. Mobility as a Service model may come across as a better option for managing traffic congestion through efficient use of the existing public and private transport infrastructure. The direct need for efficient solutions to move traffic in a faster, less expensive, and convenient manner in smart cities is poised to drive the MaaS market growth through 2027[4].

There are four objectives of MaaS, as follows[5]:

1. Seamless and efficient flow of information, goods and people both locally and through long distances;
2. Globally scalable door-to-door mobility services without owning a car;
3. A better level of service than the private car; and
4. An open ecosystem for information and services in intelligent transportation.

Instead of individuals owning and operating their own vehicles, MaaS providers offer transport options when and where the user requires them. In much the same way that Netflix and Spotify provide convenient access to TV, movies, and music, MaaS provides convenient access to a wide range of transport options to get around our current and future cities. Rideshare apps (Uber) and peer-to-peer rental services (GoGet, FlexiCar) and micro-mobility services (Lime Scooters, Jump Bike) are all current examples of MaaS solutions.

MaaS is a data-driven, user-centered paradigm, powered by the growth of smartphones. To work effectively, MaaS would require the following conditions: widespread penetration of smartphones on 4G/5G networks; high levels of connectivity; secure, dynamic, up-to-date information on travel options, schedules, and updates and cashless payment systems.

[4] `https://www.globenewswire.com`

[5] `http://eutravel.eu/Conference/wp-content/uploads/2016/10/INLECOM_EUTRAVEL.pdf`

To enable these conditions, a diverse range of actors would need to cooperate: mobility management players, telcos, payment processors, public and private transportation providers, and local authorities with responsibility for transportation and city planning. There should also be a thoughtful integration of physical infrastructure that enables transfer between transportation services, such as bus and subway interchanges, or bike and car sharing spaces at stations. Transportation planners should think through how the various modes link up.

An important factor in making MaaS a success will be getting all of the players to work together. Private sector participants might join the movement in search of profits, while government agencies could seek the public policy benefits that stem from reduced congestion: higher productivity, better air quality, fewer traffic accidents, and a smaller urban footprint for parking. Participants will gain these benefits only if they collaborate. The European Union has created the MaaS Alliance, a public-private partnership that facilitates information-sharing among players. The Figure below illustrates the MaaS ecosystem including the technology components.

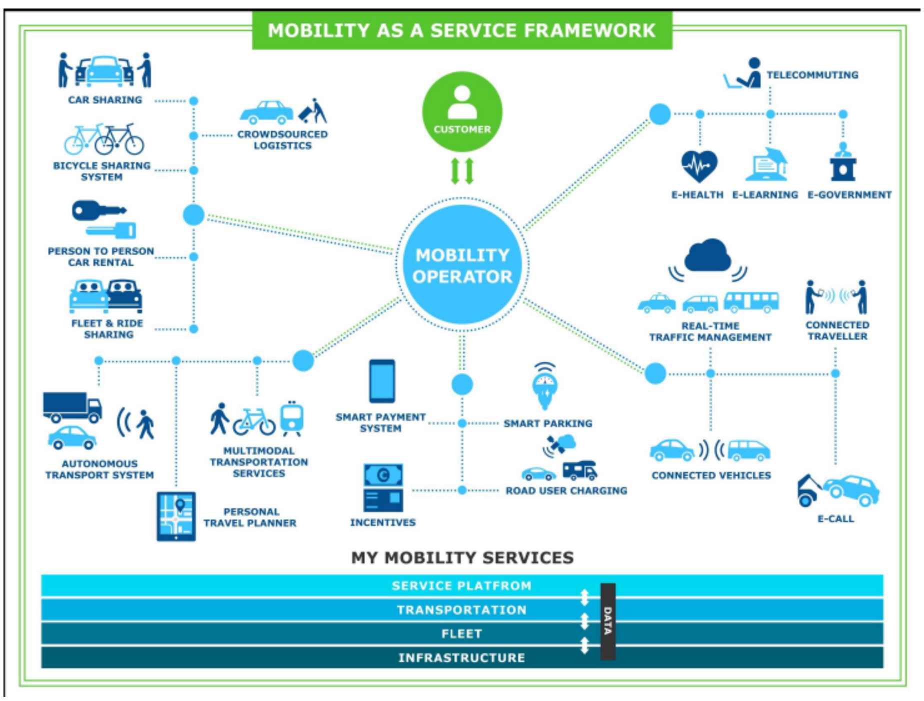


Figure 11.1: National Aging and Disability Transportation Center(http://www.nadtc.org/)

Europe is estimated to be a major regional ground for the Mobility as a Service (MaaS) market, contributing to a revenue of EUR 106.8 billion by 2027. The robust growth can be attributed to the presence of leading vendors including

Yandex, Gett, Blablacar, MyTaxi, and Uber[6]. Key players operating in the global Mobility as a Service (MaaS) market Whim App, SkedGo Pty Ltd., UbiGo AB, Moovel Group GmBH, Uber Technologies, Inc., Lyft, Inc., Ola, Splyt Technologies Ltd., Shuttl, Transit Systems Pty Ltd., Qixxit, Beeline Singapore, and Smile Mobility.

In 2019, ReachNow, a multimodal platform that integrates various mobility services, launched its MaaS platform in Japan by the 'Izuko' app. The application offers access to trains, rental cars, bikes, buses, and on-demand ridesharing, along with tickets for tourist attractions. In the same year, Citymapper, a public transit app and mapping service, launched a pass that enables users to travel by different modes of transport, including buses, trams, trains, Citymapper's Ride service, and Santander bikes with one pass with a weekly subscription.

As mentioned before, autonomous cars are a quickly evolving technology; Autonomous self-driving vehicles are expected to be used for ride-sharing purposes and would create immense opportunities for MaaS. For instance, Waymo already has driverless cars picking up passengers, while in January 2020, General Motors' self-driving car unit, Cruise, unveiled a prototype electric vehicle for its planned autonomous ride-sharing service. Ford has also indicated that it will have a self-driving fleet ready for ride sharing by 2021. MaaS, with autonomous cars, will require strong IoT backup since accessing all services will require connected vehicles and devices. Wi-Fi, 4G, GPS, Bluetooth, and 5G (upcoming) will play a vital role in MaaS. With the growing number of connected devices, ride sharing will be accessible to a larger user base in the future than it is today (https://www.marketsandmarkets.com).

Electric Mobility as a Service (eMaaS) is also gaining pace in the market. It combines highly innovative technologies and new business models to create conditions for large-scale adoption of electric vehicles. The use of electric vehicles not only reduces carbon emissions but also lowers noise and air pollution. It can also be cheaper to run per mile and reduces dependency on fossil fuels. Encouraging consumers with attractive subscriptions for multimodal transportation can create new opportunities in the MaaS market.

Mobility as a Service could help to shift focus from offering transport (moving something from A to B) to offering mobility (being able to move about freely and easily). But just as mobility is about more than the existence of many modes of transport, MaaS (especially in its more highly integrated forms) is more than a technical interface (e.g., an app) overlaying (a subset of) available modes. Although physical and digital infrastructures are clearly necessary to provide MaaS, a tech-led approach is not sufficient to understand how and why people make choices to use a service or a mode, nor to design MaaS services to meet people's needs. Mobility also relates to the quality of the transport experience; that it is accessible, affordable, efficient, safe, sustainable, etc., but what is "affordable enough" (for example) differs from person to person. Here one can also consider mobility, or the capacity to be mobile, sometimes more narrowly viewed as a personal capacity (related to e.g. physical or financial factors),

[6] `https://www.globenewswire.com`

and sometimes more broadly viewed as a general capacity (also affected by e.g. technology and telecommunications systems)[7].

The motor vehicle is at the center of a digital system: Vehicles are increasingly becoming a platform for data, services and interfaces, resulting in new value chains. In addition, the automotive industry is becoming interesting for newcomers from the software industry, which means that new partners must be integrated into the value chain. The risk of dependency on service providers from outside the industry at the expense of companies from the automotive industry [wemoveit].

Specific applications and total connectivity allowing the convergence of digital technologies with the classic business models of Auto

- mobility as a service (MaaS)
- autonomous vehicle data,
- artificial intelligence,
- connectivity across modules.

By 2025, more than 95% of new vehicles are expected to be "connected" in Europe and the United States, and more than 85% in China[**?**, **?**].

The opinion of the high Patronage Committee experts regarding Mobility as a service

Etienne Jaqué: *I always like the comparison with the smartphone. The phone itself is useless without a service contract. In the end, what you pay for is connectivity while the phone is a way for the providers to attract customers. Cars seem to go the same way: You buy mobility, the car comes as part of the service which includes other things like a charging card, maybe parking and so forth. This opens opportunities for flexibility, for example by swapping cars depending on the planned use (office, business trip, family trip). There is already a good learning curve with light mobility devices and a number of things yet to be improved.*

Michael Grandfils: *The trends are getting closer and closer to that. We still have a long way to go. So, what are the trends you see is first a proliferation of mobility offers, micro mobility and all those things which I think are good things to give more choices to citizens. So that is the first trend. A second trend is the term API. Like, you know, creating a link between two different IT systems. The one is it is really a way you conceive these days more and more like, you know IT software and some. Like historically things were a lot closer and these days like you try to be a lot more call it back API first really there is on APIS to allow interconnection between different systems from different providers and so on. And so, I think that trend is a positive trend, so you are getting more and more possibilities of connections between systems. It is especially valid for new mobility. So typically, and public transport, it is a bit less than anything*

[7] `https://www.itf-oecd.org`, International Transport Forum (ITF)

because they have more legacy IT systems, but they know it is a big trend and are progressively investing to make it more feasible.

Francesco Ferrero: *Well, I think that the great big trends that affect mobility are electrification, shared mobility and autonomous mobility and the combination of the three in all the different forms is what is shaping mobility. And at a technological level, I think that is all the things that you can do to solve a part of the current problem. Today the problem is that you use a very heavy vehicle that occupies a lot of space to move around one person and there are inefficiencies in that. So, one of the technologies that are revolutionizing this is electrification because electric vehicles can be more efficient from the thermodynamic point of view and simpler for the mechanics. The autonomous and shared vehicles can increase the average utilization of the car for one hour per day to up to 10 hours per day because the car will be used by more than a single person. And the first thing is micro mobility. So, if you reduce the weight and the size of the vehicle, there is a big gain that can serve a very good segment of the demand.*

Pierre Courbe: *The main concern with smart mobility is that it offers a technological answer to societal problems. I always take the image of what happens in a community or let us say, well, when you are in the office, there is always a kitchen where you have a coffee machine and some dishes and so on. Generally, nobody is cleaning the dirty cups. But you will always find someone who has the "good" idea: to buy a dishwashing machine. Well, when the machine is there, you won't see any real change. One needs to put the cups in the dishwasher, to run the dishwasher, to remove the dishes, ... and nobody likes nor wants to make it. So, it is a technological answer to a certain social and psychological problem. In my opinion, smart Mobility is the same thing: it offers a technological answer to psychological and sociological problems.*

Jean Pierre Heijters: *There are 2 main topics. Autonomous driving and mobility as such. We have projects on data and artificial intelligence. We see a change towards mobility as a use. A lot of people are not buying a car, but they are buying mobility. In cities like Amsterdam, it is better to share, rent, and lease your mobility than to own a car. It is normal to have a bike. Younger people are looking for the use of mobility and older people want to own mobility. In the countryside it is normal to own mobility whereas in city centers to use the mobility. In several projects we deal with the mobility use as a complete program to travel from A to B, even with the information needed on the trip, where you can rent a car, bike, etc. There are a lot of apps. Also, to have a smart system to charge your EV, garages where you can park, free spots and so on.*

German Castignani: *Firstly, I would like to see a real MaaS deployment. Everything needs to be unified on a platform. If it is about monetization of the trips there are a lot of solutions, most of the cities now have one city pass and you can use all the transportation. Multi-modality is still a topic. Being able to move in a well-coordinated way from point A to point B, using 3 or 4 modes of transportation, including shared mobility, we are not there yet. It needs more integration, and I do not know if public transportation operators can do something there, I am not sure which are the main challenges there. We advance* *a lot in monetizing the trips, but multi-modality is still open…The more data the user can provide to the MaaS operator, the better the mobility can be for him. The main data needed is the destination, if further information as activities is provided, the reason that someone is going from A to B then a better service of mobility may be offered. The information on activities is an interesting factor to scale in mobility. To improve MaaS you need data and of course you need to comply to regulations, you need to see what you can get, which opt-out you must leave to the user, if this opt-out will limit your services, meaning 'do you depend on the data and opt-out is destroying your model', you need to consider these from the design phase.*

Bram Hendrix: *In cities where you are not the owner but the user of the car, this is going to happen, cities are getting bigger, there is limited space for cars, etc. But on the other hand, the car is the ultimate machine of freedom for people, one uses it for 2% of the day or less, but it gives a lot of freedom. Ownership will still be the case for a lot of people. In cities it is not doable to pay to have a space for a car so MaaS will go there rapidly, especially through those platforms that make it quite easy to use the right mobility whenever you want.*

M. Friedrich: *I see that more and more young people would be ready to share a vehicle, to use it only when they need it the rest of the time. Public transportation, things like that. The longer trend. More and more people are living in cities or near big cities. So, yes, public transport has to take over. And shared mobility the day you need a car.*

11.3 Safety of personal data

Security has always been central for the protection of confidentiality, integrity, and availability of personal data. With the increasing use of online and mobile applications, the advances of analytics and the Internet of Things, the need for data security is more important than ever, considering the risks of new exposed system vulnerabilities and cyber-attacks, as well the vast opportunities for data combination and end users' tracking.

Still, security is not just about the application of one or more measures and no security measure alone can provide an adequate protection level for personal data. On the contrary, security for personal data needs to follow a thorough and continuously monitored framework of controls, both technical and organizational, appropriate to the nature of the data processing and the associated risks[8]. Due to the EU Agency for Cybersecurity (ENISA) ENISA's very scope and objectives, security is its core operational objective in several areas, including personal data.

What kind of data must be shared in MaaS? The opinion of the high Patronage Committee experts

Francesco Ferrero: *The key point in Mobility as a service is that you need to know almost in real time the complete mobility offer. So, all the potential*

[8] https://www.enisa.europa.eu

transport modes that I can choose to go from A to B at this moment and a good forecast of their reliability so if there is a disruption of the service you are picking and you need to know the pricing for each of those the probability offers. So, these are the key data that you need to have. And the key is real-time because if you do not have real time, then the experience becomes poor because you tell me okay, you can go from A to B with this combination of buses, but then you get to the first stop and then you see that you are delayed in that you have lost your correspondence. And now you must wait 25 minutes for the next bus to come and so you do this once and then you forget to use Mobility as a service. And this is the reason for which the people are still driving the car. The alternative is not convenient enough, but there is a chance that you can get to a reasonable compromise between the two.

Etienne Jaqué: *Data is blessing and curse in one. We benefit tremendously from the availability of information and we love to share our stories, but we are also uncomfortable when our privacy is infringed. Data protection rules are supposed to help but in most cases the end user does not know what he accepted when using his devices, including cars. It should be quite straightforward though. Probably you need to divide user data into three levels: The first level is relevant for safety and security. This data, appropriately aggregated and anonymized, must be made available to ensure safety and security free of charge with no option to withhold it. The second level of data is used for my own user experience, for example traffic information based on my current position or other personalized information. The user may allow or refuse the use of this data based on his preference. The third level is all other data that may be commercialized by others, with or without a direct benefit for the consumer who generates it. Depending on the application, the user may be invited to accept use of his data against certain benefits, for example a discount for a service. Clearly, it is not as simple as that but the challenge is to make it transparent in such a way that the end user is given the choice and understands the implications thereof.*

Michael Grandfils: *To me that is not a big deal, you need to have like, you know routing, which is generally easy to do these days, but you need to do it like ticketing. So typically, when you just have a mass application where you just have routing information and then as soon as you want to purchase a ticket for, so you must jump for another application that you do not already have... That is that is not great, in terms of user experience and multiple people staying in their car. So, I think I need both the routing and the ticketing information to make this work properly and I think that the sensitivity is of course, it is private data localization that we need to be careful there and cybersecurity risk exists. It is clear, but I am convinced, and I have a lot of things to prove that we can go around this. You just need to make the right type of agreements and have the safety measures in place and some to limit those risks. And so today if you look, we are working with a lot of private data and we are running some of the startups as operators. Some of them are aggregators and so there is a lot that changes B2B B2C that is working fine.*

Jacques HAENN: *We do deal with the subject of autonomous vehicles* *and everything that is also services. And applications related to new modes of operation, car-sharing, that kind of thing. Then the smart-grid. Today, energy companies are thinking about this and the first bi-directional charging stations are starting to come out. In fact, the energy companies are well aware that when the car, the car with battery, it will be very, very developed. You are going to have hundreds of thousands and tens of thousands, even hundreds of thousands of cars in the evening, which are going to be connected. So of course, it will not be necessary to charge all at the same time. The other interest is that finally, in winter, there is always a peak of demand around 7 pm in the evening. You will still have a lot of cars that will be there, plugged in with energy in stock. The energy companies will offer contracts to people. I'll buy back some of the electricity you have in your battery from 7 p.m. to 10 p.m. when I need it. But in the morning, when you go to work, your car will be charged again and you will have the charger, just by saying I need my vehicle, maybe a button to make the vehicle available quickly. But the idea is that you can actually use this energy storage that is finally sleeping. It's always the same. In a good industrial state, you buy a machine, you run it for an hour a day and then you fix it. I don't know any industrialist who invests in a machine that runs for an hour. Only individuals are able to do that. So it's true that this has potential. We call it power to the grid. So, in fact, it's to use this energy potential to be able to. So, of course, today, in winter, we do what at certain times we restart a coal-fired power plant that is there to be able to meet the peak needs. Moreover, in January 2022, the State has decided to close all French coal-fired power plants. There are three left and they will be closed. So it's a symbol. That's why the big projects are also about hydrogen, because it's the end, it's the aftermath of coal to convert. There is always the gas plant to be able to meet the peak. And we can imagine that it will be the cars in stock that will make the peak demands. The big advantage is that you can also tap into the energy supply where you need it. Because finally, the coal-fired power stations in France are distributed.*

11.4 Cyber threats in the automotive industry

A new society, "Society 5.0", where cyber and physical spaces are highly integrated, is emerging[9].

Any connected device can be subject to cyber threats. In fact, phones, laptops, connected objects ("Internet of Things") and even corporate databases are considered particularly vulnerable resources.

IT security giants and start-ups are active in the market for on-board protection of intelligent vehicles. The objective is to protect usage data, coming from functionalities such as GPS, air conditioning but also the start-up. They are also working on vehicle-to-vehicle and vehicle-to-infrastructure exchanges because the intelligent car is part of a road safety issue. In the future, the

[9] *Cyber/Physical Security Framework & Basic Frame for IoT Security Management, Toshikazu Okuya Director, the Cybersecurity Division, Cybersecurity Standardization Conference 2020)*

transmission of speed data between cooperating vehicles could, for example, help reduce accidents, and a system of certificates could authenticate them. We can also imagine an automatic management of intersections, but it would not be necessary for a smart guy to pretend to be the local red light to create accidents. In this case, it will be necessary to create certificates to recognize the so-called "public key infrastructures".

11.5 Legal Acts

11.5.1 Directive 2016/1148 on security of network and information systems (the NIS Directive)

Directive 2016/1148 on security of network and information systems (the NIS Directive) is the first horizontal legislation undertaken at European Union (EU) level for the protection of network and information systems across the Union. Cybersecurity incidents, in the form of cyber-attacks and even cyber warfare have not only been identified at expert level but have also frequently captured public attention and press frontpages. An EU response, in the form of the NIS Directive, was long overdue in view of the many EU values at stake.

The NIS Directive consists of 27 articles. Articles 1–6 set its scope and main definitions, including a further clarification regarding the identification of operators of essential services (article 5), as well as the meaning of significant disruptive effect (article 6). Articles 7–10 describe the national frameworks that need to be adopted by each Member State on the security of network and information systems. These frameworks include, among others, Member States' obligation to introduce a national strategy and to designate national competent authorities (including a single point of contract and the computer security incident response teams (CSIRTs), as well as the creation of the Cooperation Group. The cooperation mechanism is provided in Chapter III and more specifically in articles 11–13. The articles that follow (14–18) define the security requirements and incident notification for operators of essential services and digital service providers, respectively. The adoption of standards and the process of voluntary notification are dealt with in articles 19 and 20. Finally articles 21–27 include the Directive's final provisions.

ENISA is the European Union Agency for Network and Information Security. It is located in Greece (Heraklion Crete) and has an operational office in Athens. ENISA was founded by Regulation (EC) No 460/2004, whereas its current regulatory framework consists of Regulation (EU) No 526/2013. Since 2004, ENISA has been actively contributing towards warranting a high level of network and information security within the EU. ENISA's mission is to raise "awareness of network and information security and to develop and promote a culture of network and information security in society for the benefit of citizens, consumers, enterprises and public sector organizations in the Union "(Article 1 of ENISA's Regulation (EU) 526/2013).

Release of the two legal instruments, the NIS Directive and the GDPR, which we have stated above, largely coincided, the NIS Directive being published in July 2016 and the GDPR in April of the same year. However, the two law-making processes took place independently and in parallel [Markopoulou2019].

11.5.2 Digital Services Act & Digital Markets Act (in preparation)

On 15 December 2020, the European Commission unveiled the Digital Services Act[10] (DSA) and the Digital Markets Act[11] (DMA), two legislative proposals aimed at ensuring a safe, fair, open and accountable online environment. The proposals form part of the European Digital Strategy, whereby the Commission is aiming to develop and promote European digital standards in order to strengthen the EU's digital sovereignty[12].

Digital services include a large category of online services, from simple websites to internet infrastructure services and online platforms. The rules specified in the DSA primarily concern online intermediaries and platforms. For example, online marketplaces, social networks, content-sharing platforms, app stores, and online travel and accommodation platforms.

The Digital Markets Act includes rules that govern gatekeeper online platforms. Gatekeeper platforms are digital platforms with a systemic role in the internal market that function as bottlenecks between businesses and consumers for important digital services. Some of these services are also covered in the Digital Services Act, but for different reasons and with different types of provisions.

The Digital Services Act (DSA) modernizes the rules laid down by the previous eCommerce Directive 2000/31. Through this proposal, the Commission is seeking to rebalance the rights and responsibilities of providers of online intermediary services (including hosting services and online platforms such as online marketplaces, app stores and social media platforms) and their users. The DSA will apply to all online intermediaries offering their services in the European single market, whether or not they are based in the EU. The obligations applicable depend on the type and size of the online player concerned and may include:

1. measures to counter illegal goods, services or content online, such as a mechanism for users to flag such content and an obligation on providers to notify suspicions of serious criminal offenses or to suspend services for recipients that frequently provide manifestly illegal content;

2. greater transparency and reporting obligations, for instance regarding content moderation;

[10] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020PC0825&from=en
[11] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020PC0842&from=en
[12] https://digital-strategy.ec.europa.eu/en/policies/digital-services-act-package

3. new obligations on traceability of business users in online marketplaces, to help identify sellers of illegal goods;

4. effective safeguards for users, including access to an effective internal complaint-handling system.

Additional obligations apply to so-called "very large online platforms", i.e. online platforms with more than 45 million users. For example, these platforms will have to assess and manage on a regular basis the so-called "systemic risks" arising from the functioning and use of their services, i.e. the dissemination of illegal content through their services, negative effects for the exercise of fundamental rights and intentional manipulation of their service.

With the Digital Markets Act (DMA), the European Commission is seeking to complement existing competition rules in order to address specific challenges occurring in the digital sector. While competition law prohibits restrictive or abusive practices ex post, the DMA's approach is to minimize the detrimental structural effects of unfair practices ex ante[13].

In view of the considerable economic power of a small number of digital players, the European Commission is introducing new obligations and prohibitions for large online platforms that act as "gatekeepers" in the digital sector (online intermediaries, online search engines, online social networking, video sharing platform services, etc.). If adopted by the European Parliament and Member States, the final version of the DSA and the DMA will be directly applicable across the EU.

11.5.3 The Data Governance Act (in preparation)

On 25 November 2020, The European Commission published the Data Governance Act (DGA)[14] in response to the public consultation on the European Strategy for Data[15]. The consultation served as a means to gauge stakeholders' opinions on the data strategy (including open data, data sharing and data spaces), and as input for several planned initiatives around access to, and re-use of, data. A legislative framework on common European data spaces and an implementing act on a list of high-value datasets under the Open Data Directive[16] was part of the consultation as well.

The EU Public Consultation on the European Strategy for Data[17] received contributions from various stakeholders, including SMEs, EU citizens, business associations, academia, research institutes, as well as public authorities.

[13] https://www.debandt.eu

[14] https://ec.europa.eu/digital-single-market/en/news/proposal-regulation-european-data-governance-data-governance-act

[15] https://ec.europa.eu/digital-single-market/en/policies/building-european-data-economy

[16] https://ec.europa.eu/digital-single-market/en/european-legislation-reuse-public-sector-information

[17] https://data.europa.eu/en/news/public-consultation-eu-strategy-data

11.5.4 The Open Data Directive

As part of the European Strategy for Data, the **Open Data Directive** functions as a common legal framework for government-held data (public sector information) and is geared towards two key concepts in the European market (i.e., transparency and fair competition). Furthermore, the directive includes the adoption of a free-of-charge list of high-value datasets by the Commission. The consultation indicates that the need for these types of datasets is high among stakeholders. They will be labeled within a specific thematic categorization in the Annex to the directive and act as the building blocks for Artificial Intelligence solutions.

High-value datasets will become a more prevalent topic over the next few years and the Digital Governance Act as well as the Open Data Directive provide an initial framework for their arrival and implementation.

Europe requires a modern legal framework that ensures the safety of users online, establishes governance with the protection of fundamental rights at its forefront, and maintains a fair and open online platform environment.

11.5.5 Artificial Intelligence Act (in preparation)

The AI Act is based on the HLEG's Ethics Guidelines (2019) and the European Commission White Paper on AI (2020).

To regulate AI-related risk, the European Commission proposed a risk-based approach to regulation that distinguishes between high-risk and low or minimal risk. Jérôme de Cooman interestingly underlines that The Commission "identified two kinds of high-risk applications. The first ones raise high risk because of the sectors' particular characteristics in which they are used and – cumulatively – the particular way they are used. The second category recognized that, notwithstanding the particular sector concerned, "there may also be exceptional instances where, due to the risks at stake, the use of AI applications for certain purposes is to be considered as high-risks as such." (EC's White Paper, p. 18) The Commission's conclusion is interesting: only high-risk AI systems should be subject to mandatory requirements such as training data, robustness, accuracy and human oversight. Non-high-risk AI systems, on the other hand, would only be subject to a voluntary labeling scheme. "The White Paper makes clear that autonomous cars challenge the European liability regime.

"Under the Product Liability Directive, a manufacturer is liable for damage caused by a defective product. However, in the case of an AI based system such as autonomous cars, it may be difficult to prove that there is a defect in the product, the damage that has occurred and the causal link between the two. In addition, there is some uncertainty about how and to what extent the Product Liability Directive applies in the case of certain types of defects, for example if these result from weaknesses in the cybersecurity of the product. " (EC's White Paper, p. 13).

The Commission suggested that new safety risks related to autonomous systems - including autonomous vehicles - could be due to "flaws in the design of the AI technology " (Ibid., p. 12).

Such risks could however be handled through human oversight requirements, for example with a stop button (Ibid., p. 21). Even if the EC's White Paper on AI did not expressly state that autonomous vehicles are a high-risk application, it is clear the Commission envisioned that technology as such. If only high-risk AI systems should be subject to the requirements of human oversight and if human oversight is proposed as a solution to autonomous vehicles' flaws, then autonomous cars are high-risk application. This was confirmed by the European Parliament. In 2020, the European Parliament considered transport as a high-risk sector, and automated driving a high-risk use or purpose (European Parliament resolution of 20 October 2020 with recommendations to the Commission on a framework of ethical aspects of artificial intelligence, robotics and related technologies (2020/2012(INL)))

This Resolution was followed by the European Commission's Proposal for an AI Act in April 2021. In this document, it is unclear whether autonomous vehicles are still considered as **high-risks applications**.

Jérôme de Cooman underlines that there are two categories of high-risk AI systems. The first one comprises "AI systems intended to be used as safety components of products that are subject to third party ex-ante conformity assessment." The second one includes "other stand-alone AI systems with mainly fundamental rights implications that are explicitly listed in Annex III."

For convenience, let us start with the latter category, i.e., the AI systems listed in Annex III. It lists eight categories in which an AI system shall be qualified as high-risk. The first area is biometric identification and categorization of natural persons (1). Such systems are, in principle, forbidden when used for the purpose of law enforcement. It deserves to be questioned, therefore, whether they will be used in other fields as well. To the extent that this is the case, the high-risk AI systems regulatory obligations would apply to them. The second is management of operation of critical infrastructure such as road traffic or energy supply (2). The third is education and vocational training, including assessment required for admission to educational institutions (3)The fourth is workers recruitment, such as screening and filtering applications (4.a) as well as task allocation and performance monitoring (4.b). The fifth is access to essential public, e.g., eligibility for public assistance assessment (5.a), private services, e.g., credit scoring (5.c), including dispatching of first aid services (5.c). The sixth concerns law enforcement and encompasses individual risk assessment (6.a), emotion (6.b) or deep fake detection tool (6.c), evaluation of evidence reliability assessment tool (6.d), predictive policing (6.e), profiling (6.f) and data analysis allowing the discovering of hidden patterns and information (6.g). We note that the latter category is quite broad. The seventh is similar to the previous one, although in a migration, asylum and border control context, and includes emotion (7.a) risk assessment, verification of authenticity of documents (7.c) and eligibility to asylum and other procedures (7.d) tools. Finally, the eighth refers to factual and legal research and interpretation tools used by judicial authorities (8.a).It is worth noting that the European Commission will be empowered to amend this list (art. 7).

The first category of high-risk AI systems is much more complex to define, as it relies on numerous other EU secondary legislation instruments. There are two cumulative conditions to consider an AI system presenting high-risk.

The first condition is twofold. On the one hand, the AI system must be used as a product or a safety component of it (art. 6(1)(a)), i.e., a component that fulfills a safety function which failure or malfunction endangers the health and safety of persons or property (art. 3(14)).

On the other hand, the aforementioned product must be covered by one of the EU harmonization instruments listed in the Annex II. The twelve first instruments are part of the EU New Legislative Framework, i.e., machinery (II.A.1), toys safety (II.A.2), recreational craft and personal watercraft (II.A.3), lifts (II.A.4), equipment and protective systems intended for use in potentially explosive atmospheres (ATEX) (II.A.5), radio equipment (II.A.6), pressure equipment (II.A.7), cableway installations (II.A.8), personal protective equipment (II.A.9), gas appliances (II.A.10),medical devices (II.A.11) and in vitro diagnostic medical devices (II.A.12). Annex II adds seven other instruments of EU secondary legislation. They consist on approval and market surveillance of two- or three-wheel vehicles and quadricycles (II.B.2), of agricultural and forestry vehicles (II.B.3) and of motors vehicles and their trailers, including their systems, components and technical units, with an emphasis on protection of vehicle occupants and vulnerable road users (II.B.6). They also refer to marine equipment (II.B.4), rail system interoperability (II.B.5), and civil aviation security (II.B.1), including unmanned aircrafts and their engines, propellers, parts and remote-control equipment (II.B.7).

Per the second condition, an AI system will be qualified as a high-risk one when this system, either a safety component or a product, must be assessed by a third-party whose role is to evaluate the product conformity regarding the EU harmonization legislation listed in Annex II (art. 6(1)(b)). (Jérôme DE COOMAN,PhD Student - Research and Teaching Assistant Uliege, "Humpty Dumpty and High-Risk AI Systems, to be published April 2022).

With the German Research Center for Artificial Intelligence as well as the Fraunhofer Institutes for Experimental Software Engineering (IESE) and for Industrial Mathematics (ITWM) there are already strong and leading research players who test and develop the application of these new technologies for commercial vehicles, agricultural and construction machines [wemoveit].

11.5.6 Intellectual Property in Automotive sector

"Intellectual Property" or IP , is one of the most important and valuable sets of assets that a company can own. With innovation and technology evolving at a rate that itself is increasing by the day, and competition among automotive manufacturers and suppliers being as fierce and cutthroat as ever before, the protection and enforcement of IP is more important now than ever.

Investing €62 billion in R&D annually, the automotive sector is Europe's largest private contributor to innovation, accounting for 33% of total EU spending [ACEA2021c]. **Europe leads the world in patents for self-driving**

vehicles. The EU is by far the world's largest investor in automotive R&D.

As tech has started to become more commonplace in the automotive sector, with much of the focus relating to autonomous vehicles and communication – both between vehicles and the wider elements of the self-driving ecosystem – the patent portfolios of larger Tier 1 and Tier 2 suppliers have grown exponentially. This is because the sooner manufacturers and suppliers have patents in the development cycle with broad applications, the better positioned they are; everybody entering the sector is heavily engaged in patenting activity and competitors must do all they can to remain ahead of one another.

This trend of increasing patent activity reflects that a lot more money is being invested in R&D. It is also reflective of there being more disruption as newer companies enter the market, develop their own patent relevant tech, and compete with existing OEMs (original equipment manufacturer). Since automakers must need to keep up with competitors, OEMs are not just developing their own patents, but buying them through acquisitions and hiring specialists to boost further R&D, leading to even more patents.

It is not only Tier 1 and Tier 2 suppliers that are heavily engaged in patenting and other IP-related activity, either. The growing number of tech-led companies in the automotive space, including software developers, IoT solutions providers, and AI innovators, amongst others, are start-ups, and start-ups are traditionally more 'patent hungry'; they are highly geared and their business models require them to protect and monetize their IP whenever possible in order to survive and thrive. Again, this leads to more patents.

On the one hand, more companies entering the industry and innovating is a good thing. When companies innovate and file patents, they bring to market lots of new products, solutions, tools, processes, methods that automakers can then use to further their own R&D.

On the other, it means that there are more owners of relevant patents, many more than in the past, which leads us to one of the key challenges facing the automotive industry today: automakers that assemble, manufacture, and sell vehicles do not necessarily own, or have rights to, the tech that is key to their vehicles being developed and then functioning when on the road.

Much of the equipment driving today's autonomous vehicles is owned not by the automakers, but by IT companies, telecoms providers, and software developers. While some of this technology provides a competitive advantage (meaning that the patent owners perhaps have a claim to some of the automakers' revenues where it is used without a license) a lot of it will be used for communication, safety and security.

This is problematic because who is to blame if an autonomous vehicle's critical systems fail and lead to an accident, or worse? The automaker? The patent owner? The driver? Without clearly defined licensing models or a new way to manage IP rights in the modern automotive environment, there is no answer. Although the sector is working fine under its current sort-of "gentlemen's agreement", patent infringement claims, litigation, and battles in court are virtually guaranteed to follow if these agreements are not replaced by new, solid and unambiguous legal arrangements. In November 2019, BMW was sued in the U.S. for alleged patent infringement by Paice[18], a hybrid engine company, and The Abell Foundation, a not-for-profit organization that is a Paice investor. It is claimed that BMW used this IP in the design and manufacture of eight of its hybrid and plug-in vehicle models. Litigation is presently ongoing. Legal action taken against BMW by Paice, a tech-led company, should be taken as a clear sign that litigious activity is ramping up. Given that technology companies have traditionally been proactive when it comes to leveraging their IP assets and asserting their rights, the automotive sector should be prepared for more over the coming years.

If a patent war is looming, automakers could face serious and costly disruption if they are unable to rethink their IP strategies. While the introduction and adoption of autonomous and connected vehicles will depend on many factors, solving these complex IP problems will be key to ensuring that safe, efficient, trusted, and cost-effective vehicles can come to market. If IP challenges are not addressed, then this new technology will be delayed. Addressing the IP problems will not only support the automotive sector, either. As the IoT grows in size, 5G systems are rolled out, and more and more devices are connected to one another, similar challenges will be faced in these areas, too.

If the auto industry is able to find a solution now, it may become a model for the successful licensing of IP rights in the digital age[19]

11.6 Technological Challenges, Required Skills and Supply Chains

The most widespread vehicles utilized to increase manufacturing output and employment shares are a mix of innovation and industrial policies, which boost innovation and productivity of national and regional production systems. Strong innovative activities, tacit knowledge creation, administrative support, targeted public investment in infrastructure, research facilities and worker training schemes raise the attractiveness of investment and/or may tempt firms to reshore their productive capacities. These policies are expected to yield particularly high returns if they are linked to grand challenges and mission-oriented innovation (Mazzucato and Dibb, 2019) and tied to regional smart specialization strategies. In contrast to strong post-war intervention in industrial and innovation policies through its Ministry of International Trade and Industry (MITI), Japan appears to be less inclined to invest and coordinate industrial activity at the current economic juncture, preferring to focus on financial incentives and on increasing the competitiveness of its private sector.

The role of automotive electronics increases significantly, and the software-driven car emerges. Original Equipment Manufacturers (OEMs) have gained

[18] http://www.paicehybrid.com/automotive-news-bmw-sued-patent-infringement-hybrid-engine-technology/

[19] A New Way to Manage IP Rights in the Automotive Sector is Needed, February 17, 2020 by Luke James https://www.allaboutcircuits.com/author/luke-james

new revenue streams. Now vehicles allow their users to access stores and purchase numerous features and associated services that enhance customer experience, such as infotainment systems. By delivering aftermarket services directly to a car, the automotive industry monetizes new channels. Furthermore, these systems enable automakers to deliver advertisements, which become an increasing source of revenue. (European Parliament, Impacts of the COVID-19 pandemic on EU industries, Policy Department for Economic, Scientific and Quality of Life Policies Directorate-General for Internal Policies)

The development of new technology in automotive[20] creates a similar change as we observed in the mobile phone market. When smartphones equipped with operating systems had become a new normal, significantly increased the number of new apps that now allow their users to manage numerous services and tasks using the device[21]. But it is just an introduction to numerous business opportunities provided by connected cars. Since data has become a new competitive advantage that fuels the digital economy, collecting and distributing data about user behavior and vehicle performance is seen as highly profitable, especially when considering the potential interest of insurers providers.

Assembled data while used properly gives OEMs powerful insights into customer behavior that should lead to the rapid growth of new technologies and products improving customer experiences, such as predictive maintenance or fleet management.

Connected vehicles provide automakers and adjacent industries with a chance to establish beneficial co-operations, build new revenue streams, or even create completely new business models. The possibilities are delivered thanks to over-the-air communication (OTA) allowing us to send fixes, updates, and upgrades to already sold cars, provide new monetization channels, and sustain customer relationships.

The average lifecycle of a car is about 10 years. Today, automakers make decisions regarding connected cars that will go into production two to four years from now. For the cellular connectivity strategy to remain relevant over 12 to 15 years, significant challenges and assumptions need to be collaboratively addressed by OEMs, telematics control unit suppliers, and service providers. Automakers must manage software in the field reliably, cost-efficiently, and, most importantly, securely – not just patch fixes, but also continually upgrade and enhance the functionality. The availability of OTA updates reduces the burden on dealerships and certified repair centers but requires better and more extensive testing, as the breakage of critical features is not an option.

Cellular solutions need to be agile to be compatible with emerging network technologies over the vehicle lifetime, e.g., 5G to be the industry standard in the next few years. The chosen solution must deliver reliable, seamless, uninterrupted coverage in all countries and markets where the vehicles are sold and driven.

Solution developers must offer scalable, cost-effective ways to develop up-

[20] https://grapeup.com/customers/automotive/

[21] https://dzone.com

gradeable software that can be universally deployed across technologies, hardware, and chipsets. A huge focus must be put on testing the changes automatically on both the cloud platform side and the vehicle side.

As Connected Vehicles proliferate, the auto industry will need to adapt and transform itself into the growing technological dependency. OEMs and Tier-1 manufacturers must partner with technology specialists to thrive in an era of software-defined vehicles. As connectivity requires skills and capabilities outside of the OEMs' domain, automakers will necessarily have to be software developers. An open platform environment will go a long way to encourage external developers to design apps for vehicle connectivity platforms.

The consequences will be dramatic along the value chain (Figure 11.6):

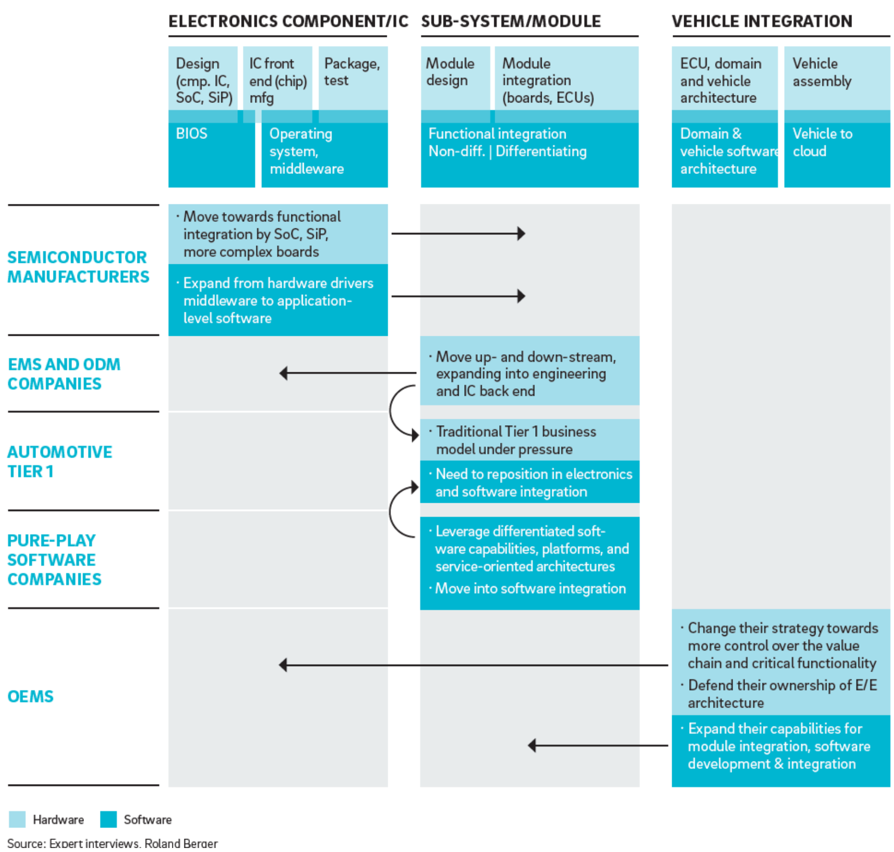


Figure 11.2: Chain reaction

OEMs are expanding their capabilities by adding significant resources for module integration, software development and even semiconductor design.

- Semiconductor players, who frequently control the largest share of the electronics bill of materials (BoM) in software-driven cars, are moving towards functional integration of their chips (system-on-a-chip (SoC), system-in-a-package (SiP), etc).

- Players in electronics contract manufacturing services (EMS, ODM) are expanding into engineering and integrated circuits (ICs), offering unparalleled scale advantages compared to other players.

- Software suppliers that were previously only minor players in the automotive market are now entering it all along the value chain, be it in middleware or at application level.

- Traditional Tier 1 E/E suppliers are under pressure from all sides. Their established business models are breaking apart and they risk becoming irrelevant. Furthermore, Tier 1s are at risk of getting stuck with traditional full front-line liability as an ECU and software stack integrator while losing control over multiple software components.

The coronavirus pandemic has had disruptive effects on the R&D decisions of companies. In many cases, the balance sheet capacity for increased investment has been damaged by the COVID-19 pandemic, and actual capital will be more constrained as a consequence of the pandemic. Since the outbreak of the pandemic, spending in the EU has been mostly focusing on healthcare and short-term measures, while the need to support industrial sectors to innovate is crucial as well. For this, it is imperative that national and European R&D public investments are aligned with private investments, and to set the EU industry on a path of sustainable growth is crucial. (European Parliament, Impacts of the COVID-19 pandemic on EU industries, Policy Department for Economic, Scientific and Quality of Life Policies Directorate-General for Internal Policies)

Information technology is becoming increasingly important for the automotive industry. Furthermore, Germany's dependence on foreign companies is problematic. It is necessary to develop IT competences and to achieve sufficient independence in this field.

German specialization in all areas of information technology is well below average in terms of patents and publications. However, it is not very realistic to expect Germany to catch up in a few years by investing more in research and development. These areas should be promoted by expanding the corresponding departments at universities or by increasing activities at non-university research institutions. However, first of all it is crucial to improve skills in the application of information technology in production. Finally, an essential element of strengthening IT in the economy is the development of the skills needed to apply IT in production [AWEXMunich2021].

Global supply chains bring together parts from production locations on different continents and enable production and value creation based on the division of labor. A reassessment of existing global supply chains and sales markets in terms of robustness and resilience is emerging in the wake of the Covid 19 pandemic. The trend towards global supply chains and the growing importance of emerging markets and in particular the Chinese market for established OEMs is leading to a relocation of production sites. On the one hand, this is due to the fact that new production sites are being established in markets of growing importance. Volkswagen Group China alone, for example, employed more than 95,000 people in eleven Chinese production facilities. On the other hand the establishment of global supply chains means that components are now routinely components that can now be produced on different continents and brought together in a single production facility. Thus, geographic location advantages such as proximity to a production site are disappearing or integration into a technological cluster become less important when comparable quality at a lower quality can be purchased elsewhere at a lower price. Suppliers are also increasingly outsourcing their production to countries with lower production costs. Within this framework, a reassessment of the robustness and resilience of global supply chains in worldwide crisis scenarios. The key factors will be the competitive cost structures and operational supply strategies of OEMs and major system suppliers will be decisive for the Grand Region vehicle industry [wemoveit].

Digital skills need to be expanded : There is no doubt that education and lifelong learning will be critical to building workers' resilience. Ensuring that everyone can benefit from the economic opportunities in the new digital economy should be a key priority for Europe, and the focus for schools and programs should be on the development of both technical and soft skills. According to one study by the European Commission, 42% of Europeans still lack basic digital skills. The European Commission is fully aware of the challenge and has proposed a new European Skills Agenda as well as a "Pact for Skills", mobilizing stakeholders to create better training opportunities. For example, the AI School network that Microsoft has developed in France with Simplon, where job seekers from a variety of backgrounds can embark on a free, intensive seven-month course, during which they learn AI development skills, followed by 12 months of employment at participating companies. This network has expanded to 39 schools since 2018 and has trained 750 students. When it comes to sustainability Technology companies can help through their own sustainability commitments and, perhaps even more importantly, by enabling other sectors to achieve their goals through the use of digital tools and solutions [SMITH].

The speed of the decline of the combustion engine vehicle will have a measurable impact on the automotive industry, with risks linked to the speed of the transition speed of the transition: re-sourcing outside France and threshold effects amplifying the impact on jobs: A decline of 46,000 to 87,000 jobs in 2030 for traditional players is estimated for the different scenarios, i.e. 15% to 30% of the 2019-2020 workforce, including 16,000 to 33,000 for suppliers [AlixPartners2021].

The opinion of the high Patronage Committee experts regarding the required skill set in the industry and new players other than the automotive industry businesses

Francesco Ferrero: *You must think today that making a car is mainly a mechanical job and you move into a dimension where it becomes closer to providing software and connectivity. And so, it's a completely different skill set. And this is the reason for which you see that the traditional car makers are now* *struggling and the new ones doing much better..., there will be opportunities for new players because you are creating a new industry. Let us say that this service is based on aggregated mobility data. So, you need all sorts of aggregators, interpreters of this data. People that can extract value.*

Michael Grandfils: *So, I think yes, you will have more players and by the way, like OEMS are backing up, backing off a bit. I think they realize it's a more complicated than what I thought and just having the money is not enough and especially because of also covid and electrification had to invest a significant amount of budgets in you know, in setting up like electric vehicle factories and so they're kind of backing up but you have, I think some other private players getting into that space and that the well-known one, like companies like Uber, VIA now, which is another startup, I think also active in on demand transport. You do have some public sector companies.*

Etienne Jaqué: *I think the best way to look at it is to count the number of ICT related job advertisements or new startups in the field of ICT. There is infinite opportunity and need for innovation, however in many cases solutions are developed individually and there is no real common standard. Count the number of apps you have on your smartphone and determine how many of them really do the same thing, just in a different context. If you sit in a new car, do you navigate intuitively through all the functions of the glass cockpit or do you feel like everything is, not necessarily better, but just different to your previous car. Does your software work as reliably as your mechanical systems ? The dynamics of the ICT business may not be the best solution for cars that, even if more and more connected and smart, ultimately still serve the transport function and must be safe and sustainable before entertaining their users.*

Pierre Courbe: *In fact, it is already visible. New key actors are Google cars and so on. The car is seen by them not as a means of mobility but as a perfect means to make money the way they are common with: big data and advertisement. In an autonomous car, you'll get one person "captured" and you can have a communication targeting this person. That is a prisoner, locked up in a car with nothing else to do than listen to what these new actors want to tell him. New actors like Google are not at all mobility solution providers. For them, it is just a way to make business, but their main aim is not to offer mobility solutions. It is something else.*

Jean Pierre Heijsters: *Employees more skilled in ICT are needed than in hard techniques, like mechanical engineering. That is still important, but you cannot survive without enough knowledge of ICT. That will be a main skill and a lot of companies must invest in that.*

Michael Effing: *So I think the biggest change in our industry will be the* ***change to the software****. That need for software is the most important need. And so, software Engineers with the OEMs will be needed. A lot of all, the big OEMs are installing software centers with maybe a couple of thousand new engineers just working on what Tesla already has done. But now in a much larger scale to get updates for any feature via the Internet to have a lot of, let us say data available and that the car will be used as a mobile, I do not know, data gathering system etc. So that is now, the challenge, they cannot find enough* *highly qualified software engineers*

Michael Friedrich: *made an interesting point sur Dumping: I think that there is a reduction in employment. And personally, in all the new developments, public transport has to take over and share mobility the day you need a car. That will reduce the number of vehicles on the road and also the number of vehicles produced. ...**International dumping**; we are facing it with China. Very, very clearly we are not at all severe enough somewhere, with, with dumping and China, for example. The Eastern countries have a cheaper labor force, but everything else, access to energy, access to aluminum. They buy on the world market. So we're getting there. ... The buyer thinks he has done his job well. But it's the quality that suffers or the production that suffers. I would say to our principals: be careful, do not neglect the hidden costs. Do a full cost analysis? Yes, because it is a lot. . Unless you are not told the truth...*

Jacques HAENN: *We risk having a problem of manpower in this subsidiary, and so I attended a meeting at EURES, a working group of the Grande Region where there is Wallonia, Luxembourg, Saarland, the Grand Est. There are employ*ment services and all that which work on the jobs in tension between our countries, especially in the cross-border aspects. So, of course, there are border workers who go to Luxembourg more than the other way around, but it is also in relation to training that we try to think in a judicious way. And so, they have just taken into account the studies of France Hydrogen to look closely at these jobs in tension. And in the meeting, the French person who presented to the others, he already crossed that there are on the 17, there are already 15, metier already identified in tension. Yes, apart from the hydrogen sector. So, this means that we are adding tension where there is tension.

11.7 Smart Cities

In 2050, two thirds of the world population will live in towns, consuming over 70% of energy and emitting just as much greenhouse gases. As city populations grow, the demand for services but also pressure on resources will increase. This demand puts a strain on energy, water, waste, mobility, and any other services that would be essential to a city's prosperity and sustainability. A smart city is a place where traditional networks and services are made more efficient with the use of digital and telecommunication technologies for the benefit of its inhabitants and business. A smart city goes beyond the use of information and communication technologies (ICT) for better resource use and less emissions. It means smarter urban transport networks, upgraded water supply and waste disposal facilities and more efficient ways to light and heat buildings. It also means a more interactive and responsive city administration, safer public spaces and meeting the needs of an ageing population[22].

The emergence of smart cities is creating a highly connected infrastructure that is a perfect enabler for connected autonomous vehicles (CAVs). Driverless cars, trucks and buses can be intrinsically connected to vital information

[22] `https://ec.europa.eu`

that reduces traffic and makes driving on roads safer. And CAVs will in turn enable smart cities by providing extensive value to the city's economic, social and sustainability goals. Cities are now using connected networks and cloud technologies to link these data sources to each other, to in-vehicle sensors such as GPSs, and to cloud-based data sources for weather data, street conditions and more. The next step is to combine these connected data sources with sophisticated data analysis and artificial intelligence (AI) capabilities for an interconnected system that can power smart decisions on a scale as big - or as targeted - as the city requires[23].

From Grenoble to Anvers, cities around the world are remaking themselves as "smart cities." These communities are taking advantage of a huge range of innovations in governance, urban planning, economic and social programs while using technology to create environments that are safer, more sustainable, and more efficient. The convergence of connected communities with autonomous transportation promises to deliver significant improvements in safety and convenience as well as new economic opportunities. What is making all this possible is a set of instrumental technologies that are just now reaching maturity. The internet of things (IoT), AI and machine learning, autonomous driving systems and big data analytics are coming into their own, united by highly connected networks that collect and share data across the city's infrastructure, often in real time.

To meet their overarching goal of providing a better quality of life for their citizens, smart cities must address a multitude of issues, including the social requirements of a growing population, economic and environmental sustainability, and public safety.

11.7.1 Astypalea: the first smart, sustainable island in Europe

Astypalea is on course to become a smart, sustainable island. In the coming years, the island wants to switch to smart sustainable mobility and completely modernize its energy system. Volkswagen and the Greek government signed a memorandum of understanding to this effect last November.

Herbert Diess, CEO of the Volkswagen Group, said: "Astypalea will be a future lab for decarbonization in Europe. We will be researching in real time what motivates people to switch to e-mobility and which incentives are needed to transition to a sustainable lifestyle. The learnings will help to accelerate the transformation towards sustainable mobility and green energy in Greece. Worldwide, climate protection is gaining enormous traction. Volkswagen has been driving this change, offering the full range of sustainable mobility – from cars, to charging to sustainable energy solutions. Astypalea can become a blueprint for a rapid transformation, fostered by the close collaboration of governments and businesses."

[23] https://social-innovation.hitachi/

Prime Minister Kyriakos Mitsotakis said: “Greece is on a mission to transform our economy and society into “Greece 2.0”, by leading the green revolution and harnessing the latest digital technology. Our plans are bold. Astypalea will be a test bed for the green transition: energy autonomous, and entirely powered by nature. This beautiful island is a central pillar in that transition, and I am enormously grateful to the local community for their continued support for the project. Our unique partnerships with Volkswagen, one of the world’s most dynamic and innovative car companies, and with the brilliant research teams at the Universities of the Aegean and Strathclyde, will give us vital insights that will help us to create incentives for change on our journey to a cleaner, greener and more sustainable future. Together we will harness the wind and the sun to power that brighter future.”

Scientists from the University of Strathclyde in Scotland and the University of the Aegean in Greece will be monitoring and systematically evaluating the transformation on Astypalea. The study will focus on the people of Astypalea and their attitudes towards the transformation. A series of surveys will examine the general views on e-mobility and the readiness to switch to an electric vehicle, providing a deeper understanding of the key levers and barriers of the transformation. The final results of the study will be made public and can help to accelerate the switch to e-mobility in other regions.

Over the next five years, Astypalea will be transformed into a smart sustainable island. Mobility will be electric, powered by locally produced green electricity. New mobility services like car sharing and ride sharing will replace the existing basic bus service. The goal overall is not only to improve mobility but also to reduce the number of vehicles on the island by about one third. (Astypalea: Kick-off for transformation to smart, sustainable island (volkswagen-press.be)

11.8 Block chain

Different varieties of block chains exist : Some are public (any individual can use them),others are private. Some are permission less (any individual can help validate transactions); others are permissioned. Different variants regularly appear while others are abandoned. “Natural selection is daily and hourly scrutinizing, throughout the world, every variation, even the slightest; public permission less block chains are immutable infrastructures. Block chain finds multiple applications in the automotive industry. These include sharing vehicle data over a secure network for connectivity and shared mobility solutions such as ride-hailing, urban transportation, and deliveries. Moreover, it finds application in verifying the supply chain of spare parts or making sure that the raw materials and spare parts are sourced exclusively from legal and trusted sources. (Thibault Schrepel, VU University Amsterdam; Stanford University’s Codex Center; University Paris 1 Panthéon-Sorbonne; Smart Contracts and the Digital Single Market Through the Lens of a “Law + Technology” Approach, European Commission, October 21, 2021)

Figure 11.3: Source - Greek City Times

British startup Cube Intelligence[24] develops a block chain-based security platform for autonomous vehicles. The startup's technology utilizes hash codes to block malicious attacks or hacking attempts on autonomous cars and connected cars. The hardware used gathers real-time data on mobility and emissions. Additionally, Cube Intelligence offers ride-hailing and valet parking services for AVs, as well as smart parking management systems.

Israeli startup DAV[25] offers a decentralized autonomous vehicles platform based on block chain technology. The platform allows autonomous vehicles to discover AVs, service providers, or clients around them. The vehicle-to-vehicle (V2V) communication is either on-block chain, with smart contracts, or off-block chain using DAV's protocols. The startup develops protocols for drone charging networks, drone flight planning, and open mobility.

The immutability of block chains proves central in terms of cybersecurity. It means that block chains have no single point of failure, i.e., hacking a single copy of the ledger has no impact on the other copies. In addition, block chain visibility ensures the transparency of the data used in AI systems. Such accessibility will prove helpful for auditing the databases used to train and operate AI. Moreover, one cannot modify block chain ledgers without leaving a trace. No single user will thus be able to delete data, e.g., as one may be tempted to do in case of AI malfunction to hide the roots of the problem.(Thibault Schrepel, idem).

[24] https://cubeint.io/#cube
[25] http://dav.network/

11.9 Internet of Things (IoT)

In the automotive industry, IoT enables secure communication between vehicles as well as vehicles and infrastructure components. The technology improves road safety, solves traffic congestion, and reduces pollution and energy expenditure with better fleet management. Startups and emerging companies develop advanced sensing technologies to gather more data about the vehicle as well as allow the vehicle to understand its surroundings. The technology also automates payments for fuel and tolls.

Operating from Germany and the US, EcoG[26] is a startup offering an IoT-based operating system and platform for EV charging. The startup provides manufacturers with tools that make the development and maintenance of EV charging infrastructure simple, fast, and scalable. It also allows operators to integrate services and micro services in the chargers to make the charging process profitable. In addition, the solution works with any EV charger and enables new features to be shipped throughout the network.

Canadian startup KonnectShift[27] provides IoT solutions to optimize fleet and asset management. The startup develops Konnect – GS01, an automatic electronic logging device (ELD) to continuously track vehicular health. The solution includes route planning and optimization for real-time dispatch, advanced analytics to enable alerts regarding driving, vehicles, and fuel, predictive maintenance alerts to reduce downtime, as well as developing driver management apps.

[26] https://ecog.io/

[27] https://konnectshift.com/

Chapter 12

Building up expertise in growth areas for the Great Region

In order for the automotive industry in the Great Region to be able to benefit from the technological change and the opportunities that come with new drive technologies and artificial intelligence which we have described above in detail, the Great Region needs to build up its expertise in relevant growth areas. Especially the future topics such as **autonomous driving, alternative drive technologies and digital services** offer promising long-term potential and the future competitive and innovative strength of the vehicle industry in the Great Region. The same also applies to the competencies in the area of production systems for the vehicle industry. In particular, **networks and cooperation between relevant stakeholders** (companies, institutes, universities) from the respective fields of technology play an important role in terms of knowledge transfer. Intermediaries such as the Commercial Vehicle Cluster have the function to identify competencies within the vehicle industry in the Great Region, to determine their relevance and new interfaces, and on this basis to relevant companies and scientific actors within the state and beyond its borders. In addition, it is essential for the Great Region vehicle industry to exploit its potential. Great Region vehicle industry with regard to the **combination of existing competences with new technologies (including the breadth and diversity of drive technologies), approach and political support** are necessary. This is particularly important for the Great Region with its value-added potential in commercial vehicles ranging from battery-electric drives to (hydrogen)-fuel cells, hydrogen combustion, synthetic fuels and hybrid drives to meet the differentiated requirements of vehicle applications [wemoveit].

Preparation for the Electric Vehicle is at the heart of the German industrial strategy. Government support prioritizes bottom -up approach with regional or product/process-based "**innovation clusters** "as core designers/implementers of new training concepts. Example: the e-mobil BW in Baden -Württemberg and it's Spitzencluster Elektromobilität Süd- West New electromobility -specific programs being added to strong preexisting vocational training and apprenticeship programs [AlixPartners2021].

In addition, a further and targeted expansion of **research and development** capacities is required and development capacities in the central growth areas of importance for the location (including alternative drives and autonomous driving) is of great importance. This expansion of expertise should focus on the increase and professionalization of (semi)public capacities (state and federal federal government) personnel, development laboratories and institutes in the future-oriented fields of the Great Region (especially alternative drive technology with fuel cells, hydrogen-based drives and the production and storage of synthetic fuels). In addition to the strengthening and further development of existing application-oriented institutes (including basic-funded research facilities of the federal government and the state), in specific areas, the targeted establishment and strategic development of new institutions can be effective. The expansion of capacities for applied research and development in the Great Region should be linked to the new applications and cross-sectional technologies that offer potential for commercial vehicles and mobile machines and to create an opportunity-oriented testing ground for new products and innovations that provide the Great Region location with a strategic advantage.

In this context, existing networks and intermediaries have the opportunity to promote the transfer of knowledge across the boundaries of sectors and industry segments and to provide guidance and coordination for the joint development of systemic innovations in the further development of corporate innovation management. The Great Region also needs to build up capacities in this area, for example with regard to storage technology. The technological megatrends and upcoming innovation pushes not only affect individual areas of the vehicle industry, but are also having a broad impact. Against this backdrop, it is particularly important in the Great Region to involve the Great Region's many small and medium-sized supplier companies in the development of competencies, diversification and innovation management. In addition to large corporations and hidden champions, young, high-growth companies will take a central role. Disruptive business models and a sharpening of the profile in the area of digital services are increasingly being taken up by young founders and can set dynamics and new technologies that are not yet foreseeable today. On the one hand, the Great Region has the opportunity to initiate creative ideas for new product developments.

On the other hand, there is the challenge of enabling young growth companies to develop the process quality needed to integrate new developments into the business processes of established companies. The automotive industry in the Great Region has the opportunity to cooperate with young growth companies and digital business models and to provide new impetus for existing products and fields of products and areas of expertise of established companies in conjunction with complementary service products. A lively start-up scene with networking events, a strong digital connection, the embedding in a distinctive scientific landscape and an extensive range of leisure activities (work-life balance) are decisive drivers for the formation of start-up clusters in this context.. Through a targeted provision of start-up scholarships, support for access to venture capital, and **accelerator programs in the knowledge and skills and competence centers in the state (companies, universities, non-university research institutes) can make a contribution to the targeted promotion of start-ups** and to strengthen the Great Region as a business location in core areas of the automotive industry, as well as complementary and flanking growth fields (spatial clustering) [wemoveit].

Policymakers, in conjunction with associations and business partners, should accordingly increase the presence of the Great Region automotive industry. It is much more important to promote the Great Region as a location for the automotive industry with innovative products, leading companies and hidden champions in the perception of skilled workers. IN addition to securing the general supply of skilled workers, this also serves to fill key positions (production, development) in important future fields of the automotive industry as well as the settlement of new companies (e.g. IT companies, young companies/ founders). Competencies in automated driving, drive technology or digital interfaces, which play a central role in the future further development of an innovative location and future value creation, can thus be attracted more strongly and the range of services and expand the range of services offered by the vehicle industry in the Great Region. As a concrete measure in this context, the visibility of the automotive industry in the Great Region should be increased in cooperation with intermediaries (including chambers of industry and commerce, associations, employment offices) and the HR departments of companies seeking skilled workers. English-language messages and content (including brochures and image films) can promote the state's innovative products, successful companies, high quality of life and expertise in the automotive industry [wemoveit].

The presentation of innovative pilot and demonstration projects can also contribute to increasing the visibility of the Great Region. The strengths of the state in the automotive industry should thus generally be communicated more strongly beyond the country's borders. Within the state, this can also contribute to the maintenance of existing companies and prevent an exodus of young graduates and skilled workers in rural areas. Innovations and developments that combine existing competencies with future growth areas, can be exploited with the right framework and secure growth and employment in the industry sector, even against the backdrop of high transformation pressure. The attractiveness of the location is of central importance here. **Short delivery routes, an attractive infrastructure, technology-oriented education and training opportunities, close networking of the players and an effective public image of the automotive industry** in the Great Region are key levers for exploiting the full potential and specific opportunities for the Great Region to develop them strategically in a targeted manner [wemoveit].

According to the study of Alix Partners [AlixPartners2021], **the reduction of labor costs, support for investments and training appear to be the priorities for the automotive sector in France**: Support that is stable over time and not ad hoc that can be planned in a business plan.

Chapter 13

Conclusions-recommendations

The COVID-19 crisis has been, in many ways, a defining moment for mobility. Except for the damage and disruption, it has shown, for the first time in practical terms, that mobility could be quite different in the future. It has caused society to reflect and reassess its values and priorities highlighting the importance of issues such as **health, hygiene, the environment, and home life, as well as speed, convenience, and consumption.** Furthermore, the crisis leads consumers to re-assess their needs and allows for a potential acceleration of the green agenda. Despite the decline in the demand for new vehicles, the impact of the pandemic on the demand for electric vehicles seems to be much less severe. The pandemic acted as an accelerator of digitalization. It is also creating new opportunities for growth in the sector of autonomous vehicles. This also affects the positive forecasts for the rebound of the batteries supply chain. Overall, the pandemic has increased the awareness of the benefits of the digital and green transition, which needs to be coupled with investments and political drives (European Parliament, Impacts of the COVID-19 pandemic on EU industries).

European automotive suppliers still concentrate a large share of their sales in Europe. The premium market has been driving the sector's economic growth in recent months. The investments are large, as suppliers have to respond both with innovative solutions and with new requirements regarding ecology and sustainability in the supply chain. These challenges are leading to a repositioning of the automotive supplier market. Grand Region is a particularly competitive market with a high number of automotive players, from research to marketing. **There are many opportunities for business development, networking or trade fairs.**

The corona crisis has confirmed the need for the automotive market in the Grand Region **to invest more in digital and electric motor technologies in order to remain competitive on the international stage.** We have seen that the crisis has had the effect of potentially accelerating trends, such as changes in city topology, more e-commerce, more flexible working, increased health and safety requirements, healthier mobility modes, greater acceptance of new mobility forms and an increased need for more flexible, resilient, and human-centric mobility solutions which depend heavily on digital technologies.

The switch to battery-electric drives is a very strong one technological change in engine technology: Formerly important components (e.g. gearboxes and exhaust systems) are less in demand. Hybrid drives with smaller combustion engines can represent temporary interim solutions. There are new components for it (especially batteries), which reduces the added value of the established components. This lightweight vehicle construction is playing an increasingly important role in vehicle construction. Here the Great Region in the supplier area with leading companies (e.g. in production plastic components) rely on existing competencies. This transition will establish major changes, new collaborations as well as a change in value chains in the Great Region.

We need to mobilize new public policy levers for employees and regions; A new era of mobility, where all Europeans can access affordable transport solutions that are: **Green & Clean, Smart & Efficient, Safe & Reliable** [ACEA2021c].

In the wake of the pandemic, government incentives have encouraged the use of **carbon-neutral solutions and stimulated the development of EVs**. Another shift arising from the pandemic, consumers are increasingly turning to digital channels—from convenient food deliveries to streaming services—and they now expect mobility players to expand their online offerings.

Mobility leaders will now have to **reimagine the future of mobility**. Strategies were already in adjustment due to the megatrends described earlier and now they must go even further to account for the pandemic's impact on consumer's behavior, regional economies and new policy making.

The European automotive sector has recognized strengths that need to be further developed and the automotive industry is already aware of this. The direct consequence of the shortened vehicle life is the continuous adaptation of vehicle models. This will put greater pressure on the development time for these vehicles. The target is to move from 3 to 5 years to a development time of 2 years. But car manufacturers have already shown that this is achievable. **The development of the full range of electrified propulsion will be necessary to offer adapted mobility solutions**; Increasingly shorter design times and price pressure will require a high level of automation of the manufacturing lines with a high level of human-machine interaction.

The weaknesses of the European automotive sector lie mainly in software engineering and data processing, for which few solutions are developed by European manufacturers. However, whoever masters the service offer will master the value chain and take the biggest profits. The threats are clearly the loss of brand value and major investments to develop new service offers. On a purely technical level, the challenges are significant, but European manufacturers have already reacted. On the other hand, on the consumer service offer, everything remains to be done. If the European automotive sector wants to counter giants in the field such as Google or Amazon, IBM, major efforts must be made. Employees more skilled in ICT, SOFTWARE engineering are needed than in hard techniques, like mechanical engineering. That is still important, **the European automotive industry will not survive without enough knowledge of ICT. That will be a main skill and a lot of companies must invest in that.** We have to ensure that the European auto industry remains a strong global & competitive player.

Suppliers and car manufacturers will need to adjust to much shorter development cycles and improved **recycling methods.** New sales models will compete and converge with new operating models, autonomous driving algorithms will communicate with central transport systems, and electricity suppliers will attract new customers by advertising traction and current battery capacity.

Traditional brands will expand their areas of business, new brands and competitors will attack traditional automobile companies. To maintain its global leadership position in the global automotive industry, European Original Equipment Manufacturers need a compelling vision for the European automotive industry in 2050.

The vehicle industry in Grande Region covers a large part of the highly competitive or displacement-shaped segments (including diesel/ combustion technology, standardized mechanical components) but also **must be present in areas that are future-oriented and growth segments can be designated (including lightweight construction, software / infotainment**).

The biggest change in the automotive industry will be the change to software, the challenge to find enough highly qualified **software engineers.** The pressure on the workforce will be severe. Automakers must become data managers and mobility service providers as well as vehicle assemblers.

In autonomous driving the major challenges are not technological. It is more about collaboration between partners because autonomous driving is not something that only the government or only industry can do. We need the collaboration between the industry and the road owners, the infrastructure and it is about deployment. **Technologies for car-to-car or car-to-infrastructure communication already exist but deployment is still lacking**. We saw in the past years a lot of projects and pilots, but the next step is deployment.

Electric drives, automated driving, and mobility services – these are the areas that will determine whether the automotive industry in the Great Region will continue to shape mobility in the future or whether these new business opportunities will go to others. **The connected, autonomous and electric shared car could become the shared mobility of tomorrow.**

The COVID-19 pandemic seems to accelerate the growth of the electric vehicle market, as firstly consumer behavior is changing towards more private mobility instead of public mobility to reduce infection risks, while at the same time, regulators are intensifying activities for climate protection in the mobility sector. Moreover, recovery measures linked to the green transition are incentivizing investments in this sector.

Autonomous vehicles need their own ecosystem. Carmakers, fleet operators, power providers, insurance companies, and logistics sectors all have to play an important role. Close cooperation between governments and private actors in new mobility markets is imperative. All have to know where they want to go. **They can't do everything at once. They have to make a diagnosis and choose two or three themes where they want to go.**

Recovery from the Covid-19 crisis offers a singular chance to **combine economic development with shifting mobility behavior and scaling up low-carbon technologies**, while increasing opportunities for citizens by improving access through **better mobility solutions**.

The role of the PME in the Great Region is to **bring new ideas for new solutions.** It's a mix of all the solutions. To that end, this white paper **concludes** that it is a great opportunity for the European automotive industry and more specifically in the Great Region to **reinvent itself**; There are still challenges on a technological level but the most important key is the **collaboration between all stakeholders.** It is imperative that national and European R&D public investments are aligned with private investments, and to set the EU industry on a path of sustainable growth is crucial.

There is a need for investing more in research and development. These areas should be promoted by expanding the corresponding departments at universities or by increasing activities at non-university research institutions.

The automotive sector is a sector where everything is interconnected. **In order to develop mobility, we need to develop production, to realize the energy transition. It's not going to be a single solution**. **But in the end, we need everyone to work together on this important notion of ecosystem and we will succeed.**

Nomenclature

ACEA: European Automobile Manufacturers' Association

AD: Autonomous Driving

ADAS: Advanced Driving Autonomous Systems

AI: Artificial Intelligence

AV: Autonomous Vehicle

BSG: Boston Consulting Group

BEVT: Battery Electric Truck

CASE: Connectivity, Autonomous driving. Shared mobility, Electrification

CAV: Connected and Automated Vehicle

COVID-19: Coronavirus Disease 2019

CH4: Methane

CNG: Compressed natural gas

CO2: Carbon dioxide

DAV's protocols: An extension of the HTTP/1.1 protocol

DGA: Data Governance Act

ECU: Electronic Control Unit

EFI: Electronic Fuel Injection

EMS: Electronics manufacturing services

eMaaS: Electric Mobility as a Service

e-fuels: Electrofuels or (synthetic fuels)

EV: Electric Vehicle

EVI: Electric Vehicle Index

ENISA: European Union Agency for Network and Information Security

ET Emission Trading System

EU: European Union

FCH: Fuel Cell Hydrogen

GDPR: General Data Protection Regulation

GHG: Greenhouse Gas

HAD: Highly Autonomous Driving

HEV: Hybrid-Electric Vehicle

ICT: Information and Communication Technologies

ICEV: Internal Combustion Engine Vehicle

IEA: International Energy Agency

IEW: Inter-Environnement Wallonie

IP : Intellectual Property

IoT: Information and Communications Technology

LCA: Life-Cycle Assessment

LEV: Low-Emission Vehicle

LH2: Liquid Hydrogen

LNG: Liquefied natural gas

MAAS: Mobility As A Service

MQB: Modularer Querbaukasten, or modular transversal toolkit

MMfE: Micro Mobility for Europe

NIS Directive: Directive 2016/1148 on security of network and information systems

ODM: Original Design Manufacturer

OEM: Original Equipment Manufacturer

OTA: Over-The-Air communication

PAE: Pôle Automobile Européen (Project)

PME: Petites et Moyennes entreprises/ SME: Small and medium-sized enterprise (FR)

PHEVs: Plug-in Hybrid Electric Vehicles

RoO: Rules of Origin

R&D: Research and Development

SAM: Shared Autonomous Mobility

SIA: Semiconductor Industry Association

SoC: System-on-a-Chip

SUV: Sport Utility Vehicle

Tier1: System suppliers

TEN-T: Trans-European Transport Network

TCO: Total Cost of Ownership

TRL: Technology Readiness Level

TWh: Terawatt-hour

ULEV: Ultra Low Emission Vehicle

UNCTAD: United Nations Conference on Trade and Development

V2I: Vehicle-to-Infrastructure

ZEV: Zero-Emission Vehicle

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