Artificial intelligence in road transport

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Cost of Non-Europe report on artificial intelligence in road transport

Annex

Artificial intelligence is a key enabler for autonomous vehicles that potentially provides European citizens with economic, environmental and social benefits. However, a the absence of a relevant European framework around liability, data protection, cybersecurity and protection of users creates costs of non-Europe in terms of economic output and employment. It also generates other costs, in particular around data protection and privacy, which can influence fundamental rights for European citizens.

This study is annexed to the Cost of non-Europe report entitled Artificial intelligence in road transport, published by EPRS.

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Executive summary

In the transportation sector, artificial intelligence is most often associated with autonomous and semi-autonomous transportation. These new modes of transportation should reduce traffic congestion, fuel emissions, air pollution and driving costs. They should also lower the number of road accidents, improve safety and address companies' needs of transportation under extreme conditions. Of all the modes of transport impacted by artificial intelligence (AI), self-driving vehicles are the ones experiencing major advancements.

To excel in the field of artificial intelligence, the European Union (EU) needs to ensure that the correct 'enablers' are in place to see it thrive. This includes infrastructure, such as roads and enhanced connectivity (such as 5G), the appropriate funding of priority research areas as well as an appropriate regulatory framework. This regulatory framework should further promote innovation ecosystems, **making permits uniform** across the EU so that industry can more easily apply its innovations on a large scale. It should also clarify **issues of liability** that could cause consumers and businesses along a value chain to avoid the technology.

The costs of non-Europe in this sector have the potential to be substantial from an economic, environmental, social, and fundamental rights perspective.

The regulatory framework includes rules that apply both specifically to the sector as well as those that apply more generally

A number of the legal instruments apply directly to the road transportation sector and artificial intelligence. These recently implemented instruments cover safety and liability as well as the deployment of intelligence transport systems. In addition, other more general rules that apply to the sector can be placed into six categories:

- Empowering consumers. Rules that help to balance information asymmetries and other market failures as consumers interact with businesses that are providing products and services in relation to connected automated driving.
- Empowering business users. As with empowering consumers, these are rules that address market concerns of businesses along a value chain.
- Security and data. Rules that address issues around the security of road transportation, in particular around data protection and privacy.
- Liability rules. Rules that address who is responsible for failures and accidents within the road transportation sector, both from a business and consumer perspective.
- Data governance. Related to the security and data category, rules that address how data should be handled by providers.
- Intellectual property. Rules related to protecting the rights of intellectual property.

The primary legal and regulatory barriers revolve around horizontal rules

Recent changes to the regulatory framework that apply directly to autonomous vehicles (AV) mean that the main potential gaps remain the horizontal ones. Four gaps are of particular relevance, namely liability, empower users (consumers and businesses), cybersecurity, and data privacy.

Potential liability issues

The main challenge identified by scholars and lawyers relates to the adaptation of the liability framework to autonomous vehicles in particular and AI-based products and services in general. With regard to liability, two main alternatives are (i) fault-based liability and (ii) strict liability regimes. Fault liability and civil liability are not harmonised at the EU level. With respect to strict liability, harmonisation is limited to damages caused by defective products under the Product Liability

Directive (PLD). In addition, the Motor Vehicles Insurance Directive allows compensation for damages caused by motor vehicles (including autonomous ones). However, it does not harmonise the liability rules across EU Member States.

Potential issues empowering users

Autonomous vehicles and other applications of artificial intelligence often involve a 'black box' of sorts, which can reduce user trust in the technology. If users lack trust in the systems, it can influence uptake of the technology. Most of the transparency requirements related to the characteristics and functionality of products and digital content and services apply only in the Business-to-Consumer context. However, the same information asymmetry existing between a consumer and a trader may also happen between a professional user and a trader when dealing with technology-intense and sophisticated AV products and services.

Potential cybersecurity threats

Cybersecurity is another important challenge for AV. The Directive on Security of Network and Information Systems (NIS Directive) only applies to operators of essential services and a limited set of digital service providers. Thus, it is questionable whether car manufacturers have cybersecurity requirements under the NIS Directive, at least for AV that still require supervision. The General Vehicles Safety Regulation requires compliance with United Nations Economic Commission for Europe technical cybersecurity requirements but their adoption is still pending. Under the EU Cybersecurity Act, certification processes are voluntary unless provided otherwise by EU law or national law. Finally, in cases of the local processing of personal data, the General Data Protection Regulation (GDPR) and its security requirements may not apply.

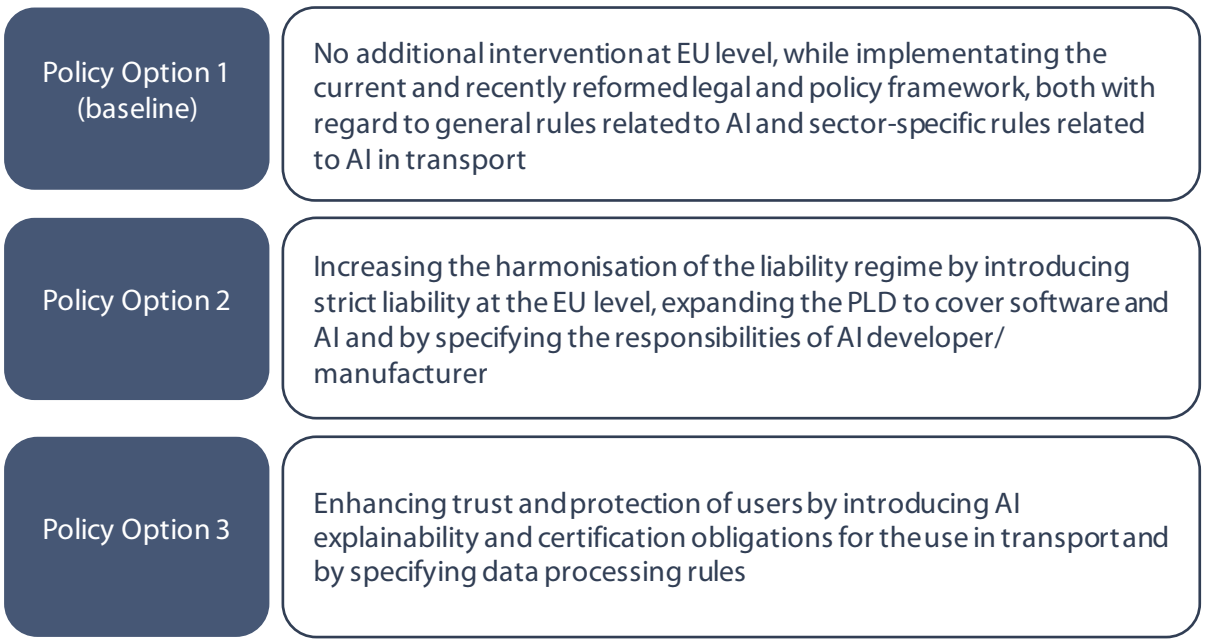
Potential issues around data protection and privacy

AV have the potential to collect more – potentially invasive – personal data. In particular, using voice and face recognition technologies presents significant risks for fundamental rights as the collection and usage of these data may occur without person's knowledge and/or full understanding. In this regard, the GDPR may only apply if the processing is carried out to uniquely identify the person. Following this interpretation, biometric data may be collected and processed by autonomous vehicles without users' consent. At the same time, Recital 10 of the General Vehicles Safety Regulation states that 'advanced emergency braking systems, intelligent speed assistance, emergency lane-keeping systems, driver drowsiness and attention warning, advanced driver distraction warning and reversing detection systems should function without using any biometric information of drivers and passengers'.

Addressing the potential issues identified

Given these policy gaps, a number of policy options were identified. One of the suggested policy options is the baseline that includes all relevant and recently adopted legislation. While other policy options suggest specific actions to address the potential gaps and barriers. The policy options are summarised in the diagram below:

Figure 1: Proposed policy options



Source: Authors.

The cost of non-Europe

The cost of non-Europe refers to the costs borne by the EU citizens, public organisations, businesses due to the identified potential gaps and barriers. The suggested Policy Options 2 and 3 address the identified gaps to various extent, while Policy Option 1 proposes no additional intervention at the EU level. Therefore, the cost of non-Europe are calculated as benefits that Policy Option 2 and 3 bring individually over Policy Option 1.

Table 1: Estimated direct cost of non-Europe, in 2030, EU-27

	Lower bound	Upper bound
GDP (million euros)	€231 097	€275 287
Employment (million persons)	5 181	6 147

Note: the lower bound (upper bound) estimate refers to the benefits that Policy Option 2 (3) brings additionally to Policy Option 1 as quantified using a computable general equilibrium (CGE) model.
Source: Authors.

On this basis, several policy options were developed to conduct a cost of non-Europe analysis to quantify the potential net benefits. In other words, we assessed quantitatively and qualitatively net costs, resulting from the lack of EU action. The policy options were put forward and assessed in terms of their benefits and costs, feasibility and impacts. The table below summarises the benefits (and costs) of each of the proposed policy options. Overall, the preferred policy option is Policy Option 3 enhancing trust and protection of users. While feasibility of this policy option is lower than focussing strictly on the liability regime, consumer trust and cybersecurity remain key to uptake. Additionally, given that these are horizontal issues influencing more than just the road transport sector, there are additional costs of non-Europe that are not captured in this analysis, which need to be kept in mind when taking this policy option path.

Table 2: Summary of policy options assessments

	PO 1: baseline/ no additional intervention at EU level	PO 2: Liability regime	PO 3: Trust and protection of users
New enabler targeted	n/a	• Road infrastructure • Technology • Liability and insurance • Research, development and innovation policies	• Road infrastructure • Technology • Ethical framework for AI • Liability and insurance • Research, development and innovation policies
Innovation potential	+	++	+++
Security and safety of the vehicle	++	++	++
Cybersecurity of the vehicle	+	+	+++
Increased consumer trust	+	++	+++
Improved legal certainty	+	+++	+++
Feasibility of implementing a policy option	+++	++	+
Proportionality and subsidiarity	+++	+++	+++

Notes: feasibility, proportionality and subsidiarity are ranked from low (+), medium (++) to high (+++).
Source: Authors.

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List of acronyms and abbreviations

5G-PPP	5G public private partnership
ABS	anti-lock braking systems
AI	artificial intelligence
AI HLEG	High-Level Expert Group on Artificial Intelligence
AMSVR	Approval and Market Surveillance of Vehicles Regulation
ANN	artificial neural networks
API	application programming interface
AV	automated/ Autonomous vehicles
B2B	business to business
B2C	business to consumer
BCO	bee colony optimisation
CAD	connected and autonomous driving
CAM	connected and automated mobility
CAV	connected and automated vehicles
CCAM	connected, cooperative and automated mobility
CEF	Connecting Europe Facility
CGE	computable general equilibrium
C-ITS	cooperative intelligent transport systems
CoNE	cost of non-Europe
COVID-19	coronavirus disease
CRD	Consumer Rights Directive
CSIRTs	computer security incident response teams
DCD	Digital Content Directive
DCSG	Directive on certain aspects of contracts for the sale of goods
DEP	Digital Europe programme
DIH	digital innovation hubs
DSM	digital single market
EATA	European Automotive-Telecom Alliance
ECD	E-Commerce Directive

EDPB	European Data Protection Board
EDR	event data recorder
EEA	European Environment Agency
EGNOS	European Geostationary Navigation Overlay Service
ENISA	European Union Agency for Cybersecurity (former European Network and Information Security Agency)
ESIF	European Structural and Investment Funds
EU	European Union
EV	electric vehicle
GDP	gross domestic product
GDPR	General Data Protection Regulation
GPS	global positioning system
GPSD	General Product Safety Directive
GVA	gross value added
GVSR	General Vehicles Safety Regulation
HEV	Hybrid electric vehicle
ICT	information and communication technology
InfoSoc	information society
IoT	internet of things
IRU	International Road Union
ITF	International Transport Forum
ITS	intelligent transport systems
MaaS	mobility as a service
MID	Motor Vehicles Insurance Directive
NIS	network and information systems
OBD	on-board diagnostics
OECD	Organisation for Economic Co-operation and Development
OEM	original equipment manufacturer
OES	operator of essential services
P2B	platform to business
PLD	Product Liability Directive

R&D	research and development
R&D&I	research, development and innovation
RED	Radio Equipment Directive
SAE	Society of Automotive Engineers
SME	small and medium-sized enterprise
STRIA	strategic transport research and innovation agenda
UCPD	Unfair Commercial Practice Directive
UK	United Kingdom
UNECE	United Nations Economic Commission for Europe
US	United States
V2I	vehicle-to-infrastructure (communication)
V2N	vehicle-to-network (communication)
V2V	vehicle-to-vehicle (communication)
V2X	vehicle-to-everything (communication)
VHC	very high capacity (connectivity)
VMT	vehicle miles travelled

1. Introduction

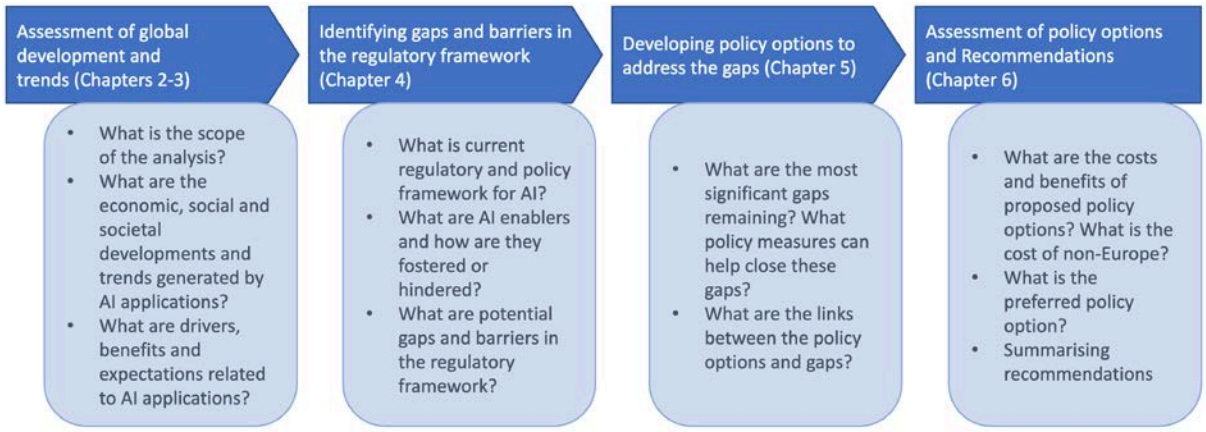
Development, deployment and uptake of artificial intelligence (AI) is one of the latest and most important stages of the ongoing digital revolution. The potential global impact of AI is tremendous, disrupting existing socio-economic structures, challenging familiar philosophical concepts and posing new requirements of institutions. The EU-wide response to the AI challenge is emerging, but lacks completeness. Initiatives of European Union (EU) countries on AI-adoption are promising, but the ecosystem needed to nurture such initiatives is lagging behind developments in the United States (US) and China. Each EU country tends to cater to their own domains of excellence through specific and focused approaches rather than trying to compete jointly at a global level with a full-scale approach. Typical areas of AI initiatives involve transportation, healthcare and industrial manufacturing.

In the transportation sector, artificial intelligence is most often associated with autonomous and semi-autonomous transportation. These new modes of transportation are supposed to help reduce traffic congestion, fuel emissions, air pollution and driving costs. They should also lower the number of road accidents, improve safety and address companies' needs of transportation under extreme conditions. Of all the modes of transport impacted by AI, self-driving vehicles are the ones experiencing major advancements.

However, restrictive regulations and non-standardised traffic rules are pushing European companies to develop their autonomous prototypes out of the continent. Local autonomous-driving permits lack uniformity that would make it easier for European industry to apply its innovations on a large scale. The lack of clarity in the legal framework over issues around liability in case of failures as well as co-ordination issues across the EU further complicate the issue. Europe has a role to play in furthering the uptake of artificial intelligence technologies in the transportation sector, and the following report is meant to analyse the cost of non-Europe (CoNE) in the sector.

This report studied the gains that common action at EU level could bring. Therefore, the aim of the report was to analyse the existing regulatory framework, identify potential gaps and barriers where taking an action at EU level could be beneficial, and conduct a cost of non-Europe analysis. The cost of non-Europe analysis estimated the (net) benefits of taking an action at EU level or in other words the (net) costs resulting from lack of such action. Figure 2 below presents an overview of our approach for the assessment of the Cost of Non-Europe on Robotics and AI in Transport.

Figure 2: Steps in identifying the CoNE for AI in transport



Source: Authors.

The study starts by defining the scope of the research. Chapter 2 defines artificial intelligence (AI) and the modes of transportation used in this study. It further discusses how we approach the analysis of AI in transport by categorising different elements of transport as AI enablers, AI applications and effects of AI. Chapter 2 outlines what is in the scope of the study.

Chapter 3 presents an analysis of the state-of-play on the transport market in the EU and where and how AI can feed into the sector. Following from this, Chapter 3 describes possible effects of AI in transport on economy, employment, society and environment.

Chapter 4 analyses the enablers for the development and deployment of AI in the transport sector. It looks at the state of key infrastructure as well as support for research, development and innovation (R&D&I). It also analyses the policy and legal framework at the EU level.

Chapter 5 then continues by summarising the gaps and barriers in the framework addressed in Chapter 4, indicating vectors for EU-level intervention. These vectors are then used to create possible policy options, the effects of which are quantitively measured by modelling economic impacts in Chapter 6. Chapter 6 concludes with assessment of impacts of suggested policy options and the cost of non-Europe for AI in transport.

To analyse the CoNE of AI in transport in a comprehensive manner, the economic impacts consider the situation before the deployment of AI, the deployment itself and its consequences. The situation before deployment equals to the current situation and is an important baseline, against which we can map future developments. It helps understand what the EU's starting position is and what critical factors will determine the AI deployment.

The report aims to quantify the critical factors for AI deployment as much as possible. The AI deployment refers to all possible application of AI in transport as a system based on predictions of AI evolution over the next decade. The consequences of the AI deployment describe impacts and effects, both positive and negative. Identified impacts and effects will be analysed in a qualitative manner and also quantified and CGE-modelled, where possible.

2. Scoping the Cost of Non-Europe analysis

Key points

Definitions of artificial intelligence are relatively broad, but applications that are of interest to this study exclude applications that are only based on algorithms. The study also covers forms of **road transportation**, including both vehicles as well as infrastructure and operations.

To measure the cost of non-Europe, the study has developed an analytical framework that identifies **first-order enablers** of new technologies. These enablers are divided into three major categories, namely **infrastructure** (road infrastructure, connectivity, and technology), **financial support** (public- and private-sector investment as well as state-aid and competition rules), and the **regulatory environment** (ethical framework for AI, liability and insurance as well as research, development, and innovation policies).

2.1. Types of applications and modes of transport covered

2.1.1. Defining artificial intelligence

This study follows the definition of artificial intelligence (AI) developed by the High-Level Expert Group on Artificial Intelligence (AI HLEG), set up by the European Commission. **Artificial intelligence** is understood to be 'software (and possibly also hardware) systems designed by humans that, given a complex goal, act in the physical or digital dimension by perceiving their environment through data acquisition, interpreting the collected structured or unstructured data, reasoning on the knowledge, or processing the information, derived from this data and deciding the best action(s) to take to achieve the given goal. AI systems can either use symbolic rules or learn a numeric model, and they can also adapt their behaviour by analysing how the environment is affected by their previous actions'.[1]

This definition of AI is relatively broad, and allows to incorporate applications based on machine learning and deep learning into the analysis. This definition, however, excludes 'soft' AI applications that are only based on algorithms. Some applications often receive the label AI only for marketing purposes. This is a challenge, however, only for the analysis and not for the theoretical framework.

2.1.2. Defining transport

This study focuses exclusively on **modes of transportation that take place by road**. The study covers all transport using roads and differentiates between personal transport (e.g. personal vehicles), mass/ public transportation (e.g. buses, taxis) and freight transport. While transport is commonly defined as a movement of people or goods from one location to another, this study also looks at the complex system that enables movement.[2] As such, transport includes both vehicles (i.e. actual machines used to move people or goods) as well as infrastructure and operations. The most obvious transport infrastructure is roads, but it also includes other types of fixed installations, such as parking and maintenance facilities, fuel stations, signage and road markings. This operational infrastructure is necessary for the movement of people and goods (e.g. loading and unloading, route planning, ticketing, driving). In addition to physical infrastructure, a political and legal framework smooths road transport. All elements of the transport system are interconnected and interdependent and, therefore, need to be considered when studying the deployment and consequences of AI in transport.

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1 AI HLEG (2019). A Definition of AI: Main Capabilities and Disciplines.

2 See Cambridge Dictionary.

2.2. Analytical framework for CoNE in AI and road transport

The analytical framework for the study departs from three aspects that shape the transport sector:

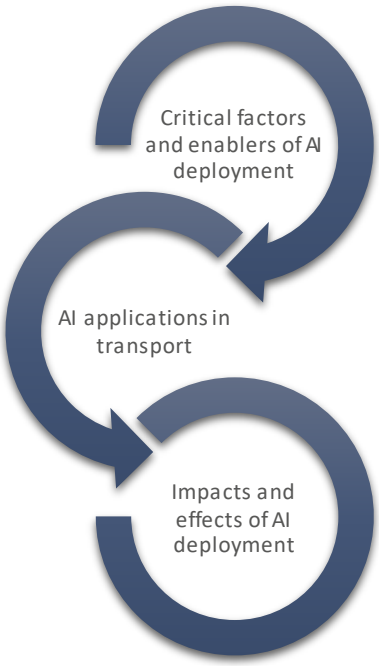
1. the megatrends that are driving the sector development,
2. the types of transportation that are under consideration, and
3. the framework under which those trends and transportation operate.

The diverse elements constituting these three aspects can be divided into three categories depending on the angle or direction of their application to the sector:

- enablers that allow AI to be deployed and thrive,
- applications within transport that are built using the AI technology, and
- effects of those AI applications on the economic, environmental, and social well-being of European citizens.

Enablers are those technical and social conditions that are prerequisites for the type of transport to operate. Without these enablers, these modes of transport would not function. At its most basic level, without physical roads and traffic lights, road transportation would not operate. But other conditions are equally important. For instance, if people did not believe that cars were a fundamentally safe mode of transport, they would be unwilling to sit in a vehicle (i.e. social acceptance). Importantly, for this condition, beliefs do not necessarily need to match reality. In the context of AI, the fact that self-driving vehicles should be safer does not stop debate about rare failures of automated systems, with more trust given to fallible drivers than to systems that people do not understand and trust.

Figure 3: Interplay between factors, AI applications and AI impacts



Applications are developed to change (and potentially improve) road transportation. Applications are automations of various vehicle functions (e.g. parking, autopilot), self-driving vehicles, platooning trucks, and other that will create the effects that we are looking to measure. Importantly, while developers may look at these applications as improvements, any application will have positive and negative effects, both intended and unintended.

Effects are the resulting outcomes and impacts of the new applications based on AI. We divided these effects into the four standard categories: economic, environmental, social, and effects on fundamental rights.

The following sections 2.3.1 – 2.3.4 will address each of these categories in more detail.

2.2.1. Megatrends in transport

AI applications in transport fuel and interact with several megatrends that are currently happening in the transport sector. The usage of the term 'megatrend' instead of 'trend' emphasises that these trends last longer and (will) have profound impacts beyond the transport sector but their development patterns and implications are more difficult to predict.[3] While many megatrends influence the developments in the transport sector, the study zooms in on those that are strongly relevant for AI and that are happening within the transport sector (as opposed, for example, to urbanisation, climate change or ageing society that are not sector-specific and not linked to AI).[4]

Most analysts identify three to five disruptive technological megatrends that are shaping the future of transport.[5] While the language differs slightly, all lists of megatrends can be boiled down to the following four items:[6]

- Digitisation,
- Automation,
- Sustainability, and
- Sharing economy.

Digitisation encompasses all types of integration of digital technologies into transportation. This means that it also covers autonomous driving (also known as connected and autonomous driving or CAD). However, considering that CAD is a very specific transport phenomenon that will profoundly change our attitudes and relationship to transport and transportation, we also distinguish **automation** as a separate megatrend.

Sustainability is frequently limited to electrification of vehicles only (e-mobility).[7] However, e-mobility is just one of the current trends of alternative powertrain. Other technologies – such as hydrogen – are also being developed, tested and deployed, signifying that environmental impact of transportation is going through a rapid rethink towards sustainability.

Sharing economy in transport stands for the changing attitudes towards car ownership and mobility in general. The persisting popularity of ride and car sharing signifies the emerging Mobility-as-a-Service (MaaS) as an alternative to car ownership.[8]

AI applications need to be described against the backdrop of these megatrends, keeping in mind that the relevance of AI differs across them. Transport applications of AI reinforce and largely define automation and digitisation. But sustainability and sharing economy have emerged mainly thanks

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3 Vladislav Maraš, Mirjana Bugarinović, Eleni Anoyrkati, Alba Avarello (2018). Megatrends – a Way to Identify the Future Transport Challenges. Working Paper of the H2020 research and innovation programme 'INtentify future Transport Research NeeDs (INTEND)', p. 35.

4 For the academic literature review on megatrends impacting transport see Ibid.

5 The Boston Consulting Group identifies six megatrends, but some of them (two-speed world and urbanisation) are of socio-economic nature and, therefore, represent more general megatrends. See BCG (2016). Transportation and Logistics in a Changing World: The Journey Back to Profitable Growth. Ptolemus Consulting Group looked at 12 key trends, however many of them (smartphonisation, electronic payments, smarter infrastructure) can be grouped under digitisation. See Ptolemus Consulting Group (2019). Augmented Mobility 2030 Global Study.

6 In addition to the above named studies, see PWC (2019). Five trends transforming the automotive industry; KPMG (2019). Mobility 2030: Transforming the mobility landscape; McKinsey (2019). The trends transforming mobility's future; Roland Berger (n.d.). Automotive disruption; IBM (n.d.). Automotive 2030: Racing toward a digital future.

7 For example, in PWC (2019). Five trends transforming the automotive industry; Roland Berger (n.d.). Automotive disruption.

8 KPMG (2019). Mobility 2030: Transforming the mobility landscape, pp. 7-10.

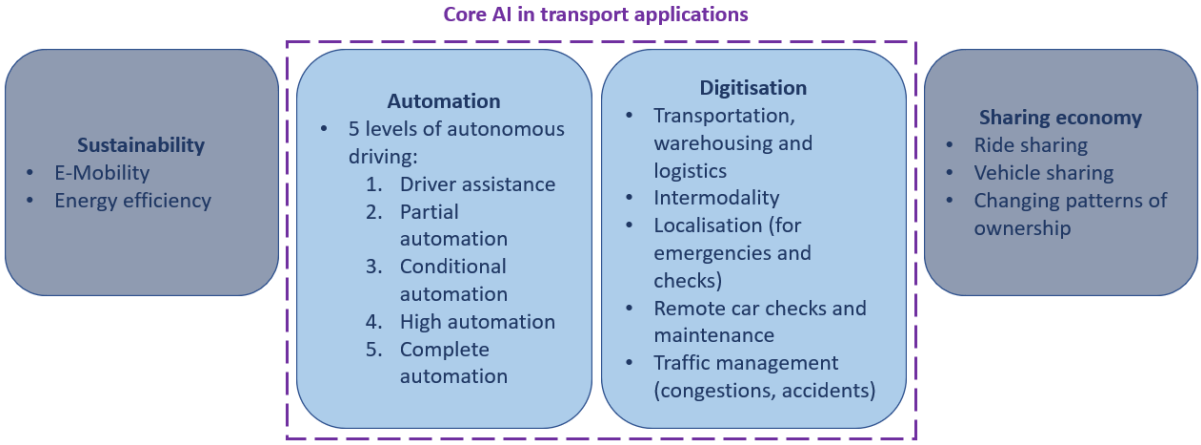
to other technologies, and while they still may be helped by AI (in general), AI's influence on these two trends is more of a support rather than precondition or enabler.

Therefore, this **CoNE analysis largely focuses on digitisation and automation**. While sustainability trends and the sharing economy have many facets, the analysis considers only those that are directly related to the use of AI in transport, namely:

- Sustainability
- Energy efficiency in vehicles
- E-Mobility
- Sharing economy
- Ride sharing
- Vehicle sharing, or more generally, changing patterns of vehicle ownership and use. As sharing becomes more convenient and wide-spread – and new modes of transportation develop – individual car ownership may decline, also because autonomous cars are likely to be more expensive, especially at the beginning.

Figure 4 below summarises the relevant transport megatrends and highlights the focus of the present CoNE analysis.

Figure 4: Megatrends in transport and focus of the CoNE analysis



2.2.2. Enablers

While not the main focus point of the study, the analysis still needs to understand the critical factors enabling successful AI development, deployment and use in transport. The enablers will fit into the analysis when considering the policy options, because EU-level support of various enablers will potentially impact on uptake and the various effects/ implications, which are the heart of the analysis. The study considers the following enabling factors: infrastructure, technology, investment, ethics, legal and policy framework and social acceptance.

Infrastructure

Well-developed, appropriate **road infrastructure** is necessary to benefit fully from AI applications in transport. To fulfil the promises of safe, efficient transportation without congestions, vehicles and road infrastructure need to operate as a well-integrated system. To deliver safe levels 3-5 of autonomous driving, the physical infrastructure has to be significantly enhanced and improved.[9]

[9] ERTRAC Working Group (2019). Connected Automated Driving Roadmap, pp. 6-8; Berkley Institute of Transportation Studies (2017). Intelligent Transportation Systems and Infrastructure, p. 4.

This includes (additional) development and installation of sensors to collect road and traffic information, compute it and share it with vehicles.

Connectivity is a critical element for higher levels of automation. Vehicles need to be able to position themselves against other vehicles (vehicle-to-vehicle or V2V communication) and to plan and navigate routes.[10] Connectivity needs to be sufficient to support multiple vehicles at once and instantaneously.

Smart grids and charging stations are indispensable to ensure sustainable and shared transport, but also to reap full benefits and efficiency gains of AI applications in transportation.[11]

Technology

The **AI technology** needs to be **mature** enough for the deployment – and the criteria to assess its maturity in the transport sector may be changing overtime. While major car manufacturers forecast 'true self-driving' or 'nearly self-driving' as early as 2021,[12] scholars caution against over-hasty AI deployment in safety-critical settings, which driving is considered to be.[13] Showing that AI-enabled systems is operational is not considered a high enough bar, and deploying a premature technology may result in costly system failures, as seen in some cases in the past.

Investment

Investment by private and public actors is essential to ensure the necessary transformation of infrastructure (i.e. roads and road infrastructure and connectivity infrastructure) to support AI deployment and use. Funding is also necessary to support research, development, and innovation (R&D&I) activities, including commercialisation of AI technology for transport.[14] It is well documented how levels of investment and venture capital have influenced the development of AI in general,[15] most notably the lack of investment caused 'AI winter' in 1980s.[16]

Ethical, legal and policy framework

An **ethical framework** for AI plays a pivotal role for both the acceptance and wider adoption of AI considering the nature and the extent of the potential implications of AI on the society.[17] An ethical framework would provide guidance and inspire trust where the legislation and policy are too slow to react to rapid and complex developments of AI.[18] The EU has taken the first step in this direction, having established the AI HLEG that developed Ethics Guidelines primarily addressed to the supply

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10 ERTRAC Working Group (2019). Connected Automated Driving Roadmap, pp. 10-11.

11 Mosquet, X., Pélata, P. (2019). Reinforcing the attractiveness and competitiveness of France in tomorrow's automotive industry and mobility.

12 Jon Walker (2020). The Self-Driving Car Timeline – Predictions from the Top 11 Global Automakers. EMERJ research.

13 Mary Cummings (2020). Rethinking the maturity of artificial intelligence in safety-critical settings. *AI Magazine*, in press.

14 WIFO, SPI. VTT and Ecorys (2017). Public Support Measures for Connected and Automated Driving. Report for DG GROW.

15 For the current level of investments see DHL and IBM (2018). Artificial intelligence in logistics, p. 12.

16 For a historical account see NRC (1999). Developments in Artificial Intelligence. Funding a Revolution: Government Support for Computing Research. National Academy Press.

17 The OECD concluded that 'trustworthy AI is key to reaping AI's benefits'. See OECD (2019). Artificial intelligence in society, p. 16.

18 On the problematic issues requiring an ethical response see, for instance, UNESCO and ITU (2019). Preliminary study on the ethics of artificial intelligence.

side.[19] EU-level action sends a powerful signal against fragmentation of the Single Market and providing more security and guidance for the producers and vendors.

Liability and insurance issues need to be sufficiently clear and fit for AI so that the use of such vehicles can actually start with low legal risks for those involved.[20]

State-aid and competition rules need to allow for support and promotion of AI-related research, infrastructure and data,[21] but at the same time remain effective against anti-competitive practices that AI applications may enable.[22]

R&D&I policies are of critical importance for EU competitiveness and advances in AI development and adoption. Due to Brexit, the EU has lost some of the leading AI research facilities, and to keep up the pace, the EU needs to foster and encourage AI research and development and promote innovation environment in the EU-27.[23]

Data regulation needs to allow companies collecting, sharing (both horizontally and vertically) and analysing large amounts of data necessary for semi- and fully automated vehicles to drive. Companies also need access to government data and data collected with public funding.[24]

Standardisation will drive and steer the market adoption of AI applications.[25] Standards/ certification can make or break development and deployment of specific AI systems. They are also a powerful tool for dissemination of best practices.

Social acceptance

Social acceptance is a critical step in adoption and commercialisation of AI. Without the public embracing the AI technology, many applications may remain theoretical or not reach their full capacity. The public perception and acceptance of AI is closely linked to (and is likely to be dependent on) the ethics of AI.[26]

Focus of the CoNE study

The **CoNE study focuses in particular on the legal and policy framework**. The study assumes that changes to the legal and policy framework influence each of the other enablers as none of them works in isolation. As such, the study will need to illustrate the various enablers and how they interact, but legal and policy will be the indicators of choice for this.

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19 AI HLEG (2019). Ethics Guidelines for Trustworthy Artificial Intelligence.

20 Renda A (2019). Artificial Intelligence: Ethics, governance and policy challenges. Report of a CEPS Task Force, pp. 88-89.

21 WIFO, SPI. VTT and Ecorys (2017). Public Support Measures for Connected and Automated Driving. Report for DG GROW, pp. 157ff.

22 Autorité de la concurrence and Bundeskartellamt (2019). Algorithms and competition – White paper.

23 Renda A (2019). Artificial Intelligence: Ethics, governance and policy challenges. Report of a CEPS Task Force, pp. 123-124.

24 Ibid., pp. 61, 99, 122-123.

25 Madiega T (2019). EU guidelines on ethics in artificial intelligence: Context and implementation. EPRS Briefing Paper, pp. 8-9.

26 On public perceptions of AI see Nordhoff S, de Winter J, Kyriakidis M, van Arem B, and Happee R (2018). Acceptance of Driverless Vehicles: Results from a Large Cross-National Questionnaire Study. *Journal of Advanced Transportation*; Pew Research Center (2018). Artificial Intelligence and the Future of Humans.

2.2.3. AI applications

There is myriad of AI applications in road transport that we currently know of – and many more are likely to be developed as AI is better developed and understood.[27] To narrow down the scope of this study, its focus will be on those applications that fall under the two main megatrends emphasised as most relevant in Section 2.2.1: automation and digitisation.

The main AI application under the automation megatrend is **self-driving vehicles** (e.g. trucks, means of public transportation, personal vehicles). A lot of other AI applications fall under the digitisation megatrend, of which the study takes into account the following:

- **Intelligent Transport Systems** (ITS) that can be supported and enhanced by AI to improve traffic analysis forecast and management, which will have further positive implications for road safety and accident/ incident prediction and traffic congestion;
- **AI for journey planning and optimisation**, which would also include AI-based ITS;
- Improvement of **vehicular control systems** that will ultimately optimise individual driving (and, therefore, traffic flow) and improve car and traffic safety;
- AI applications for remote transport infrastructure monitoring, maintenance and repair and remote vehicle monitoring, maintenance and repair;
- AI applications supporting **Mobility-as-a-Service** (MaaS) that make possible or optimise intermodal transportation and journey.

The **CoNE study focuses on those AI-based applications that are specific to the movement of goods and people**. As such, issues around warehousing and logistics-specific issues (such as package optimisation) will remain outside of the scope of this study. This does not mean that the analysis will not address them as a part of the wider framework, but the analysis will not look at their various effects.

2.2.4. Effects

As AI in transport unfolds along the megatrends, a variety of effects will be observed, which this study looks to analyse, both on a baseline and along different policy options. These effects will be measured both via a literature review and an economic model, based on a computable general equilibrium (CGE) model (see Annex III for detailed description). The CGE model will focus on the economic effects, while the literature study will analyse the environmental, social, and fundamental rights effects based on any qualitative and quantitative data that we might find.

As AI in transport unfolds along the megatrends, a variety of effects will be observed. While at the moment it is impossible to know what exactly will happen and how exactly it will happen, based on the state-of-the-art scholarship, at least the following implications can be expected.[28]

Economic implications

Economic implications of AI deployment in transport are likely to be mixed. On the one hand, positive economic effects of AI in the transport sector come out of the **increased efficiencies** that will be created along all modes of transport (including those within the scope of this study),

[27] An overview of various AI applications in transport is given in Abduljabbar R, Dia H, Liyanage S, and Bagloee S (2019). Applications of Artificial Intelligence in Transport: An Overview. *Sustainability*.

[28] Much of the literature to which artificial intelligence is relevant refers, rather, to the products and services that AI may support, but are not necessarily prerequisites. In the final analysis in Chapter 5 (i.e. CGE modelling), the impact of AI is isolated to determine its overall role.

increasing **economic competitiveness** of European industries, as well as **new businesses** that will be enabled with the use of AI.

One of the primary economic impacts of AI in the transportation sector comes from **reduced travel times** enabled by ITS, which provides benefits to both consumers and industry. This will lead to better traffic management and smooth traffic, lower traffic congestion levels and shorter waiting times at traffic lights. AS a result, also **fuel usage and costs** would be **reduced**, providing both an economic and (potential) environmental impact.

More efficient use of road infrastructure is likely to result in **lower maintenance costs**. The deployment of ITS will allow for better monitoring and remote maintenance and repair of infrastructure. In addition, some of the existing infrastructure (e.g. road marks) will become obsolete when fully autonomous cars are deployed. Together with the promised increase in **road safety**, this will **reduce public expenditure** on infrastructure, road policing and associated law enforcement as well as **public health costs**.

Second-order economic impacts can be expected for other sectors that are linked to transportation directly (e.g. software, logistics) or indirectly (i.e. become due to free travel time). For example, the increased adoption of AI-enabled cars should lead to **insurance costs optimisation** due to access to (more and better) data from CAVs. EU **hardware and software** companies working on Connected and Autonomous Vehicles (CAVs) should also experience economic gains.

However, the use of AI in transport will come at a cost that will partially off-set these benefits. The deployment and maintenance of the necessary infrastructure and connectivity are likely to constitute the most significant part of the future costs. Section 3.3.1 will explore in detail both economic costs and gains of AI in transport.

Social implications

Significant implications of AI applications are expected for the **employment** in the transport sector. While media frequently highlight the loss of jobs and AI replacing the human driver, industry and scholarly analysis present a more nuanced picture and considers further professions. For instance, the transport sector hopes that AI and robotics applications would **compensate for the worker shortage** that the industry has been experiencing for years.[29] AI application in transport will **increase demand for highly skilled labour** (e.g. software engineers), but **affect more low-skilled**, routine jobs (e.g. in haulage, private vehicle hire).[30] The study will discuss various effects on employment in Section 3.3.2.

Fully automated driving is predicted to be much **safer**, with fewer accidents and fewer injuries and property damage. It will also provide new opportunities to travel (for work or pleasure) for less mobile populations (e.g. disabled, elderly, children), people on lower incomes who cannot afford personal vehicle. Assuming that these technologies drive down the overall cost of transportation, by making it easier to access personalised transportation without requiring ownership, this could improve **social inclusion**. Fully automated drive could increase access to goods and services and provide other opportunities for excluded groups. Ultimately, improvements in the **quality of life** can be expected due to cumulative effects of AI applications in transport and will be strengthened

[29] IRU (2018). Tackling the driver shortage crisis.

[30] Acheampong R.A, Thomoupolos N, Marten K, Beyazıt E, Cugurullo F. and Dusparic I. (2018). Literature review on the social challenges of autonomous transport. STSM Report for COST Action CA16222 'Wider Impacts and Scenario Evaluation of Autonomous and Connected Transport (WISE-ACT), p. 4.

by the economic, environmental and fundamental rights' effects. Social effects will be outlined in more detail in Section 3.3.4.

Environmental implications

Environmental impacts of transport are many, and AI applications in transport are going to influence all of them (see Section 3.3.3 for details).[31] For instance, it is expected that self-driving cars and especially car/ ride sharing and improved public transport will significantly **reduce polluting emissions of carbon and other greenhouse gases**.[32] AI enabled management of traffic flows could reduce congestion and engine idling by ensuring constant flow of traffic at optimal speeds. Traffic forecasting would allow to choose the most time- and energy-efficient route. The **reduction of fuel consumption** will be enabled by greater efficiency of AVs, superior trip planning and driving functions. AI-enabled effective deployment and use of sustainable (electric) cars should enhance these positive effects on the environment.[33]

Some experts are also expecting longer term **waste reduction** on the assumption that fewer cars will be needed due to sharing economy, efficient public transportation and intermodality and therefore fewer are manufactured.

However, some scholars caution about potential **negative environmental impacts** that result from the so-called **rebound effects** that occur when an improved efficiency leads to higher consumption.[34] Driverless cars may be used more often and for longer trips due to the coverage of previously underserved users and because the trips will be more comfortable. This could (partially) offset the reduction of pollution and waste.

Fundamental rights implications

Technologies based on AI are disruptive both positively and negatively. The positive disruption through AI would lead to more equitable social outcomes and more efficient capital allocation. But these benefits also challenge cherished fundamental rights of EU citizens by bringing the risk of **discrimination**, **risks related to privacy, data protection,** and other fundamental rights.[35]

An effect of the increasing collection of data necessary for AI is in particular worrisome as it leads to a **shrinking privacy sphere** for all. This is reflected in the example of the creation of data patterns of drivers for insurance purposes, whereby drivers are '**nudged**' towards **better driving behaviour** with the incentive of reduced insurance premiums. Effectively, this also raises questions of **data ownership and control** as well as implications for **personal autonomy**.

Benefits of AI in transport relating to fundamental rights refer to aspects of **equality** and **inclusion**. Here, AI developments have the potential to enable higher mobility and inclusion in the socio-

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31 See CE Delft (2019). Handbook on the external costs of transport. Study for the DG MOVE.

32 Ryan M (2019). The Future of Transportation: Ethical, Legal, Social and Economic Impacts of Self-driving Vehicles in the Year 2025. *Science and Engineering Ethics*.; Scientific American (2014) Self-Driving Cars Could Cut Greenhouse Gas Pollution.

33 Mosquet, X., Pélata, P. (2019). Reinforcing the attractiveness and competitiveness of France in tomorrow's automotive industry and mobility, pp. 26ff.

34 Pakusch, C., Stevens, G., Boden, A. and Bossauer, P. (2018). Unintended Effects of Autonomous Driving: A Study on Mobility Preferences in the Future. *Sustainability* 10:7.

35 See Vetzo, M., Gerards, J., and Nehmelman, R. (2018). Algoritmes en grondrechten, Utrecht University/Boom Juridisch; Wagner B. et al. (2018). Algorithms and human rights. Study on the human rights dimensions of automated data processing techniques and possible regulatory implications, DGI(2017)12, prepared by the Committee of Experts on internet intermediaries (MSI-NET) for the Council of Europe.

economic life of people with reduced mobility, such as the disabled or elderly. Given that mobility restrictions for these groups of people are often based on physical limitations, such as limited sight, or ability to react quickly, autonomous vehicles may lead to the reinstating of their independence and (re)enabling their participation in economic and social life.[36]

2.3. The enablers and effects in the CoNE scope

The above discussion has addressed both first- and second-order enablers and effects of artificial intelligence in the transportation sector. Keeping all of the elements discussed above risks, however, having the analysis touch on too many interconnected components, especially for those components that fall well outside of the domain of the transportation sector. As such, our analysis looks to focus primarily on first-order enablers and effects, meaning those applications that will have a direct impact on transportation rather than an intermediary effect.

Smart grids are a good example of what we define as second-order effects. Smart grids are tied to the transportation sector in that electrification of vehicles is seen as an essential component of clean transportation. By extension, artificial intelligence helps to make smart grids more effective in numerous ways, such as through more effective energy storage management (production and distribution), improved cybersecurity within the grid, more efficient real-time pricing methods, and many other applications. However, smart grids are not a direct input into improved transportation. As such, they would remain outside of the scope of this exercise.

The table below lists first- and second-order enablers and effects, providing a guide as to what the study will and will not analyse. It should be noted that the econometric modelling (Chapter 5) will further narrow the scope focusing only on the first order economic effects.

Table 3: Enablers and effects of AI in transport

		First order (in scope)	Second order (out of scope)
Enablers		• Road infrastructure • Connectivity[37] • Technology • Public-sector investment • Private-sector investment • Ethical framework for AI • Liability and insurance • State-aid and competition rules • Research, development, and innovation policies	• Smart grids • Charging stations • Electric vehicles • Smart cities and the related infrastructure (such as sensors)
Effects	Economic	• Economic growth • Number of jobs for transport industry • Increased entrepreneurship • Increased efficiencies	• Manufacturing and production • Warehousing • Logistics-specific effects – increased efficiency of transportation in general will have an effect on logistics, but

[36] Allu, S. et al (n.d.). Accessible Personal Transportation for People with Disabilities Using Autonomous Vehicles. Purdue University working paper.

[37] Specifically ubiquitous 4G+ connectivity. For further discussion on why 5G need not be the focus and would, in fact, be a second-order enabler, see Form A, Born M, Freyberg A and Scheck F (n.d.). 5G: a key requirement for autonomous driving—really?

			• the study will not analyse components such as package delivery • Employment for the automotive industry, which would include issues such as fuelling
	Social	• Improved mobility, including social inclusion • Road safety • Quality of life	
	Environmental	• Reduced air and noise pollution[38] • Reduced waste • Reduced greenhouse gasses	• Reduced environmental effects of electrification in general
	Fundamental rights	• Data privacy and protection issues • Exclusion and discrimination	• Ethical decision-making • Data standardisation (and sharing)

[38] While increased efficiency can reduce pollution of individual trips, it should also be noted that this same increased efficiency can lead to greater numbers of trips, which can mitigate and environmental benefits.

3. Understanding the market for artificial intelligence and road transport

Key points

Artificial intelligence is a major enabler of autonomous vehicles, which will be by and far the most significant contributor to and driver of economic, economic, social, and fundamental rights effects of AI applications in the sector. It potentially transforms patterns of ownership, maintenance, and personal mobility.

AI in the transportation sector is expected to add 16 % equivalent of €11 trillion by 2030 to the global economic output. Moreover, AI is estimated to contribute to an annual average productivity growth of about 1.2 % over the same period. While experts believe that AI will lead to a net economic benefit, from an employment perspective, low skilled labour will bear the brunt of disruptions in the labour market. In Europe, optimistic case scenarios estimate that 3.2 million truck-drivers registered in 2017 are expected to decrease up to half a million by 2040.

AI is also expected to provide environmental benefits through better energy efficiency and driving of cars, the positive impact of the ITS able to optimise the flow of traffic, the reduced rate of accidents resulting from both improved road conditions and more capable than human autonomous vehicles, and possibly new usages and relationship to the car resulting from fully autonomous vehicle. On the other hand, there is both an uncertainty and a risk of a rebound effect, where the easier, more affordable way of traveling could partly negate the positive effects that AI could have on the environment.

From a social perspective, huge benefits are expected in safety of road traffic. Self-driving cars will be programmed to obey the laws and rules, they won't be distracted, speed or drive under influence of alcohol or drugs. They also provide new mobility options to some disadvantaged groups, such as the elderly and disabled. From a fundamental rights perspective, however, the data volume necessary to supported automated functions is enormous. Scientists calculate that cameras of AV would generate between 300 gigabytes to 5.4 terabytes per hour, and all sensors could record between 1.4 terabytes to around 19 terabytes per hour. The autonomous vehicle supported by AI potentially becomes another data privacy threat.

3.1. Market overview

3.1.1. Description of the road transport industry by segment

This section describes the different segments of road transportation. The descriptive analysis is largely based on the Transport glossary of European Commission and Eurostat and, therefore, terms and definitions correspond to legal ones.[39] Within this framework, we differentiate between the transport of passengers (personal or public) and that of goods (freight transport).

Personal transport

Passenger vehicles exclusively designed to seat no more than nine persons (including the driver) are the most used means of transport on European roads. The most common categories of such vehicles include private (also indicated as passenger) cars and light commercial motor vehicles (e.g. taxi vans, with a gross vehicle weight of no more than 3.5 tonnes).[40] Privately owned vehicles operating for personal use remain the dominant passenger transportation mode accounting for

[39] European Union, United Nations, UTF and OECD (2019). Glossary for transport statistics, 5th edition.

[40] ACEA (n.d.). Vehicle in use statistics.

71 % of overall European passenger traffic.[41] By 2017, in EU-28, there were some 268 million passenger vehicles with a motorisation rate of 602 vehicles per 1 000 inhabitants.[42]

Table 4: Vehicles in use in the EU-28, 2017

VEHICLES IN USE		
Motor vehicles (EU)	308.3 million units	*2017*
Passenger cars (EU)	268.0 million units	*2017*
Motorisation rate (EU)	602 vehicles per 1,000 inhabitants	*2017*
Average age of cars (EU)	11.1 years	*2017*

Source: European Automobile Manufacturers Association.

Electric and hybrid electric passenger vehicles

Electric passenger vehicles refer to the aforementioned tonnage for their propulsion electricity stored in an on-board battery, chargeable by plugging car charger into an electric grid. In this report, all vehicles with a built-in electric motor will be referred as EVs (electric vehicles).

Hybrid electric vehicles (HEVs), also refer to the aforementioned tonnage with the distinction of combining a conventional internal combustion engine with an electric propulsion system. HEVs do not need a recharging infrastructure as the electricity is generated internally from both braking and the internal combustion engine.

In the recent years, there has been a constant increase in the number of electric and hybrid electric passenger vehicles registered across Europe. In 2017, around 2 million (0.8 %) registered passenger cars were classified as electric or hybrid electric.[43] The most rapid growth in this sector came from hybrid electric-petrol cars with almost seven times more prototypes registered in 2017 (1.5 million) compared to the number recorded in 2013 (0.2 million).[44]

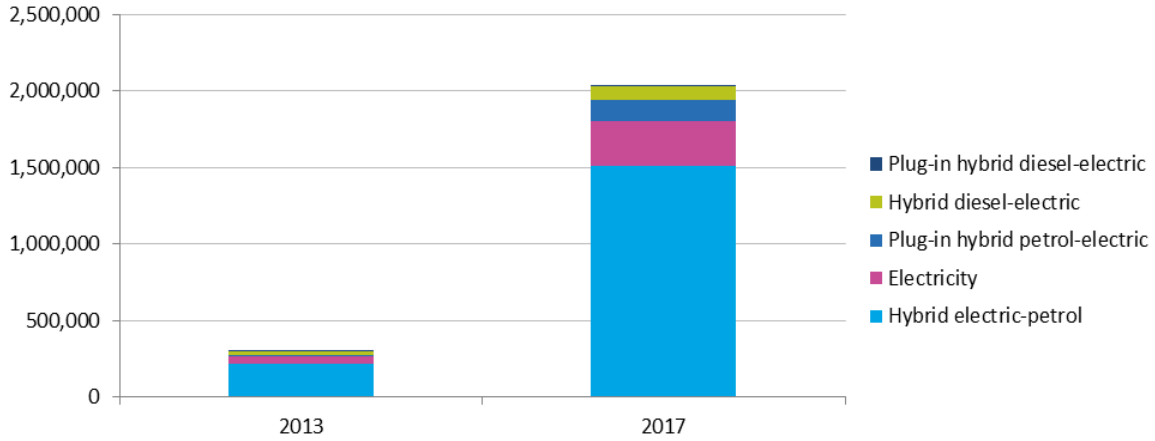
41 European Court of Auditors (2018). Towards a successful transport sector in the EU: challenges to be addressed, p. 18.

42 ACEA (n.d.). Vehicle in use statistics.

43 Eurostat (2019). Number of electric cars is on the rise.

44 Ibid.

Figure 5: Number of electric and hybrid electric cars registered in the EU-28, 2013-2017

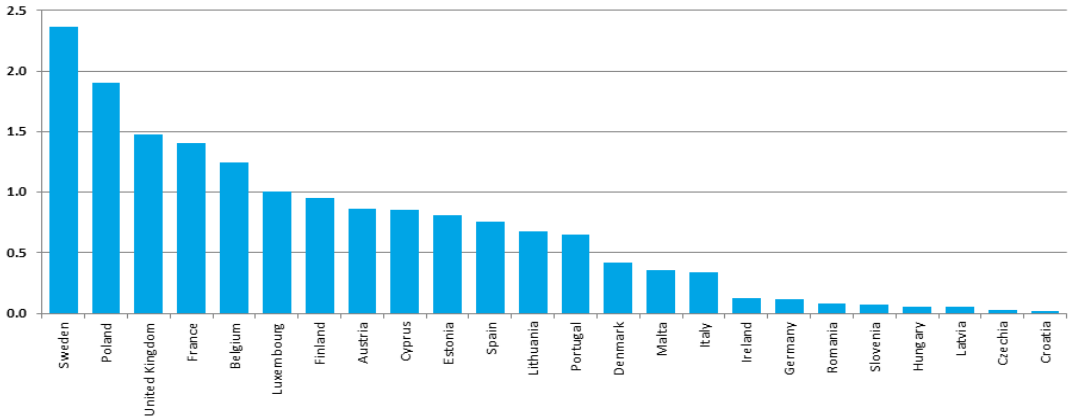


2013: For the United Kingdom, data are for 2012
2017: For Italy, data are for 2016; for Romania, data are for 2015

Source: Eurostat.

Among the EU Member States, Sweden leads in terms of adoption of EVs and HEVs followed by four other countries with more than 1 % of their registered cars being either electric or hybrid electric: Poland (1.9 %), United Kingdom (1.5 %), France (1.4 %) and Belgium (1.2 %).[45]

Figure 6: Share of registered EVs and HEVs in the EU (in %), 2017



Italy: 2016 data
Romania: 2015 data

Source: Eurostat.

Freight transport

Road freight transport refers to the total movement of goods using vehicles on national and/or international road network. Commercial vehicles responsible for road freight transport are exclusively designed to carry goods and are categorised as following:[46]

[45] Eurostat (2019). Number of electric cars is on the rise.

[46] European Union, United Nations, UTF and OECD (2019). Glossary for transport statistics, 5th edition, p.41.

1 Light goods road vehicles (e.g. transit vans, pickup trucks) with a gross vehicle weight of not more than 3.5 tonnes.
2 Medium and heavy goods road vehicles (e.g. trucks) with a gross vehicle weight above 3.5 tonnes.

Light goods road vehicles are key players in the logistics chain, responsible for the 'last mile' delivery of goods in urban areas and mainly used by SMEs as business tools. Heavy goods road vehicles are vital for cross-border trade among European countries and beyond. The share of road use for inland freight transport has increased from 75.1 % in 2011 to 76.4 % in 2016. Road freight transport is one of the most important sectors of the European economy responsible for 44 % of goods transported, generating close to 2 % GDP.[47] Since 2017 many European countries have seen a rise in adoption of electric vans and trucks. New registered electric vans and trucks are shown in section 3.1.4.

Public transport

Public transport presents an alternative to the use of private cars and includes busses, coaches and minibuses designed to seat more than nine persons. Public transport systems operate on fixed routes and schedules and are being used by around 32 % of Europeans at least once a week.[48] While transit buses dominate public transport within a single metropolitan region, coaches and minibuses are massively used for longer distances such are intercity or cross-country services.

Coaches, buses and trolley-buses account for 9.4 % of inland European passenger transport.[49] This represents more than 525.5 billion passenger-kilometres per year. In the EU, urban and sub-urban buses make 55.7 % of all public transport journeys (or 32.1 billion passenger journeys per year).[50]

Though public transport is often understood as transport systems fully belonging to the state, the private sector has an increasing participation in Europe in these services. The involvement of private sector in European public transportation has brought digital innovation and new services offering lower cost for the user and reliable travel times. Since 2018, the public transport has also seen a rise in the adoption of electric buses. The numbers for new registered buses across European member states are shown in section 3.1.4.

3.1.2. Size of sector segments

Road transport is vital for the European economy and single market. It accounts for the bulk of passenger and freight journeys by volume in Europe. The sector employs about 5.1 million people across the EU and generates about 2 % of its GDP.[51] Personal transport is the dominant passenger mode of transportation as Europeans travel mainly by road. Trucks and vans are the most used means of transport to deliver goods and services carrying 76.7 % of freight transported over land.[52]

The European automotive sector is among the world's biggest manufacturers of motor vehicles producing 19.2 million cars, vans, trucks and buses per year, and the largest private investor in R&D in Europe, accounting for €54 billion invested in 2018.[53] The automotive sector employs over 13.8

47 European Commission (2012). Road transport: A change of gear, p. 2.
48 Flash Eurobarometer 382b (2014). Europeans' satisfaction with urban transport, p. 4.
49 Eurostat (2020). Passenger transport statistics, p. 1.
50 ACEA (2019). Economic and Market Report: EU Automotive Industry - Full-year 2018.
51 European Commission (2012). Road transport: A change of gear, p. 2.
52 ACEA (n.d.). Facts about the automobile industry.
53 ACEA (2018), €54 billion spent on R&D by EU auto sector per year, latest data show.

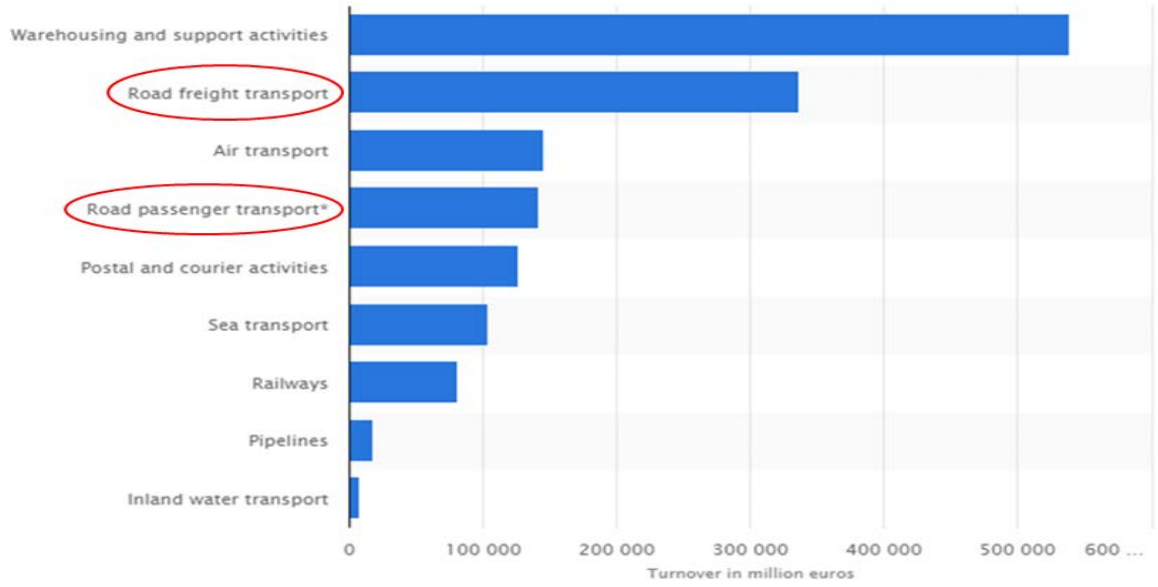
million people across the EU.[54] The sector is an important contributor to the EU economy, accounting for €84.4 billion of trade surplus and an annual turnover that equals 7 % of EU GDP.[55]

3.1.3. Transport contribution to the EU Economy

European household expenditures in the transport sector are significant. In 2017, private households spent €1 089 billion on transport-related items that is equivalent of 13 % of their total consumption. The majority (€542 billion) was spent on transport equipment (e.g. to buy fuel for the car). Around 30 % of the total (€313 billion) was used to purchase vehicles whereas €234 billion was spent on transport services (e.g. bus, train, plane tickets).[56]

The **total turnover of the transport sector** in Europe was €1.5 trillion in 2016. Road freight transport was ranked second among other activities, generating €336.9 billion of turnover over the same period. Road passenger transport turnover amounted to €141 billion.[57]

Figure 7: Total turnover of the transport sector in the EU-28 in 2016, by mode of transport (in millions of euros)



Source: Statista, 2019.

Road freight sector is the **largest employer within the EU transport industry**.[58] In 2016, the road freight sector employed 3.2 million people, ahead of warehousing and support activities. Germany had the greatest transport workforce among the EU countries.

54 European Commission (n.d.). Automotive industry.

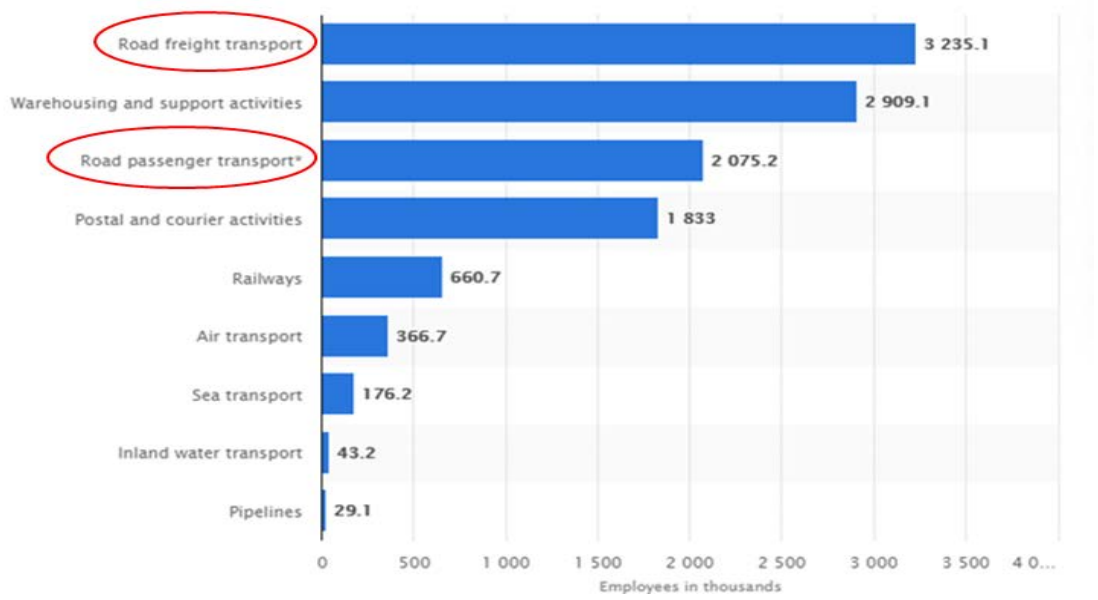
55 ACEA (n.d.). Facts about the automobile industry.

56 European Commission (2019). Transport in the European Union: Current trends and issues.

57 Statista (2020). Total turnover in the transport sector in the European Union (EU-28) in 2016, by mode of transport.

58 Statistica (2020). Number of employees in the transport industry in the EU-28 2016, by sector.

Figure 8: Number of employees in the transport industry in the EU-28 (in thousands) in 2016, by sector



Source: Statista.

In 2017, the transport and storage services sector accounted for 11.7 million employees, or 5.3 % of the total workforce in Europe. Around 52 % of them worked in land transport (road, rail and pipelines).[59]

The transport and storage services sector accounted for 5 % of total **gross value added** (GVA) in the EU-28 in 2017, equivalent to €675 billion of GVA in current prices.[60] The automobile industry **exports** 6.1 million vehicles each year worth €138.4 billion. This corresponds to €84.4 billion of **trade surplus** for the EU.[61]

Since 2010, **passenger transport volumes** (measured in passengers per km) have grown by 9 %. Passenger cars have seen an increase of 6 % in their usage, whereas the use of buses and coaches decreased by 4 %. Passenger transport demand in Europe (per km) reached an all-time high in 2017 amounting to 6 913.3 billion persons/km (17.3 % higher than in 2000). Passenger cars accounted for 70.9 % of this total.[62]

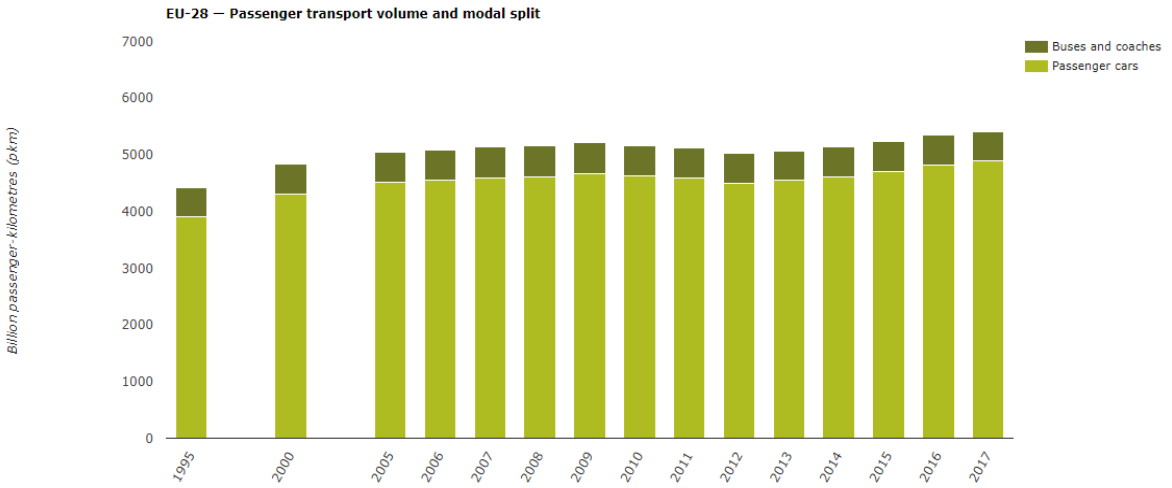
59 European Comission (2019). EU transport in figures. Statistical pocketbook 2019.

60 Ibid., p. 19.

61 ACEA (2019). The EU automobile industry: engine of innovation, employment, trade and growth. Video.

62 EEA (n.d.). Passenger and freight transport demand in Europe.

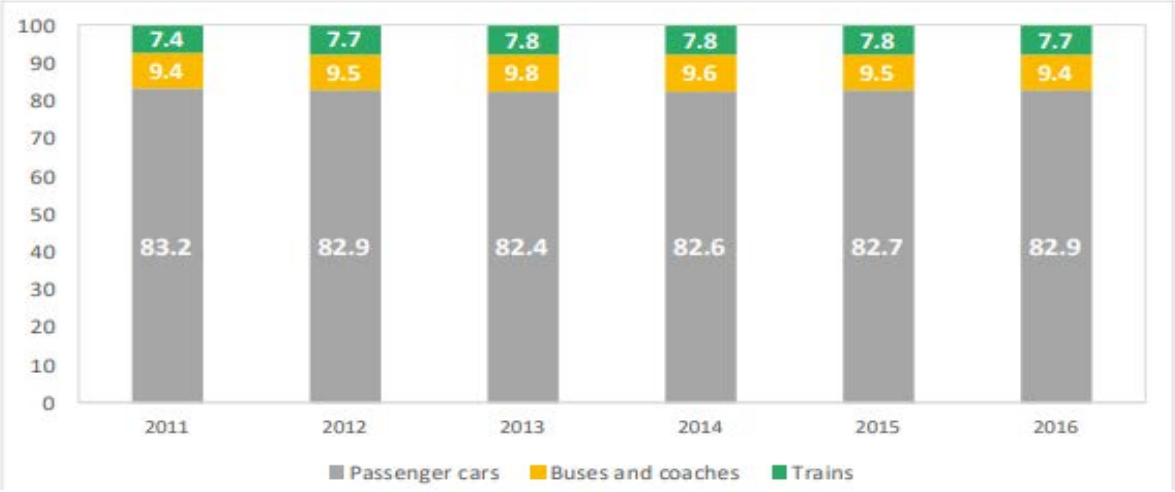
Figure 9: EU-28 passenger transport volume and modal split



Source: European Environmental Agency.

Road transport is dominated by personal transport (82.9 %), followed by buses and coaches (9.4 %).[63]

Figure 10: Share of passengers per km (in %) travelling by cars, buses and trains in the EU-28



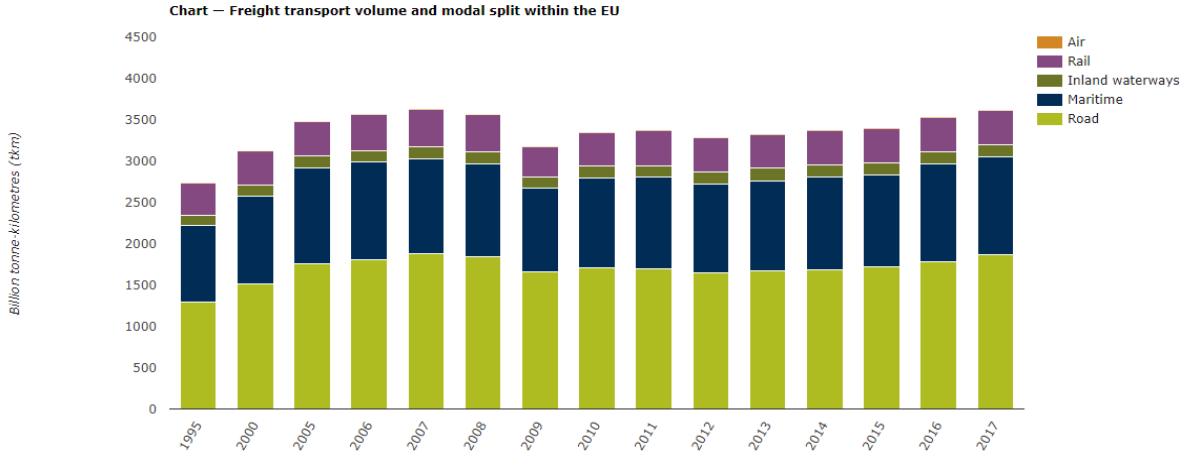
Source: European Court of Auditors (2018). Towards a successful transport sector in the EU: challenges to be addressed, p. 18.

Total **road freight volumes** in 2017 were around one-quarter higher than in 2000 as 49 % of EU freight transport activity was carried out by road in 2017. The total goods transport activities in the EU-28 amounted for 3 731 billion km. The figure below includes intra-EU air and sea transport but

[63] European Court of Auditors (2018). Towards a successful transport sector in the EU: challenges to be addressed, p. 18.

not transport activities between the EU and the rest of the world. Road transport accounted for 50.1 % of this total.[64]

Figure 11: Freight transport volume and modal split within the EU-28



Source: European Environmental Agency.

In the EU-28, the **share of road use for inland freight transport** has increased from 75.1 % in 2011 to 76.4 % in 2016.[65]

Figure 12: Share of freight ton/km (in %) transported by road, inland waterways and rail in the EU-28

Source: European Court of Auditors (2018). Towards a successful transport sector in the EU: challenges to be addressed, p. 19.

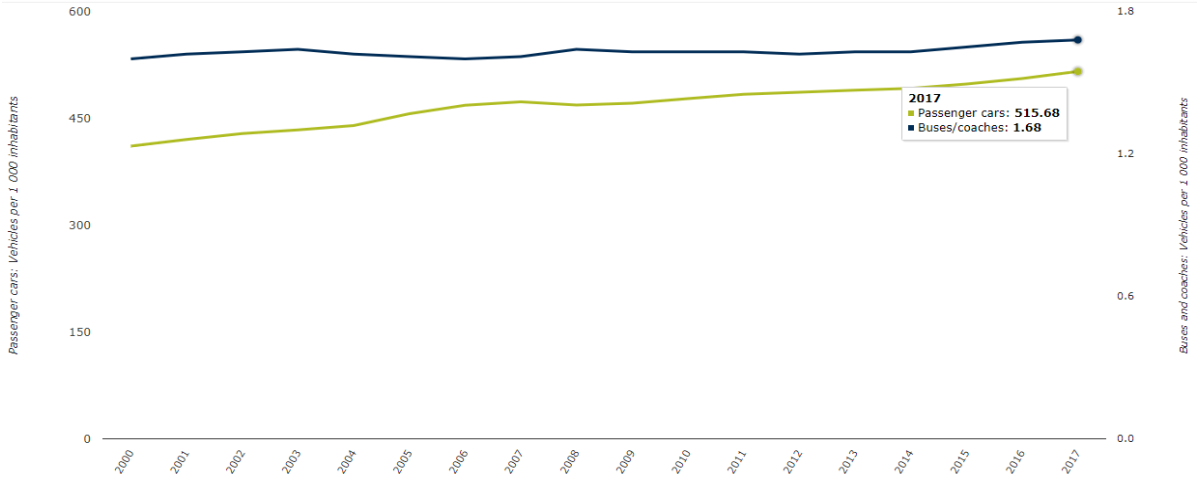
Vehicle ownership in the EU continues to grow. The number of passenger cars per 1 000 inhabitants has increased by almost 28 % from 410 per 1 000 inhabitants in 2000 to 515.68 per 1 000 inhabitants

64 EEA (n.d.). Passenger and freight transport demand in Europe.

65 European Court of Auditors (2018). Towards a successful transport sector in the EU: challenges to be addressed, p. 19.

in 2017. Over the same period, this change was more moderate for buses and coaches: from 1.6 buses and coaches per 1 000 inhabitants in 2000 to only 1.68 in 2017.[66]

Figure 13: Vehicle ownership in the EU-28 (per 1 000 inhabitants)

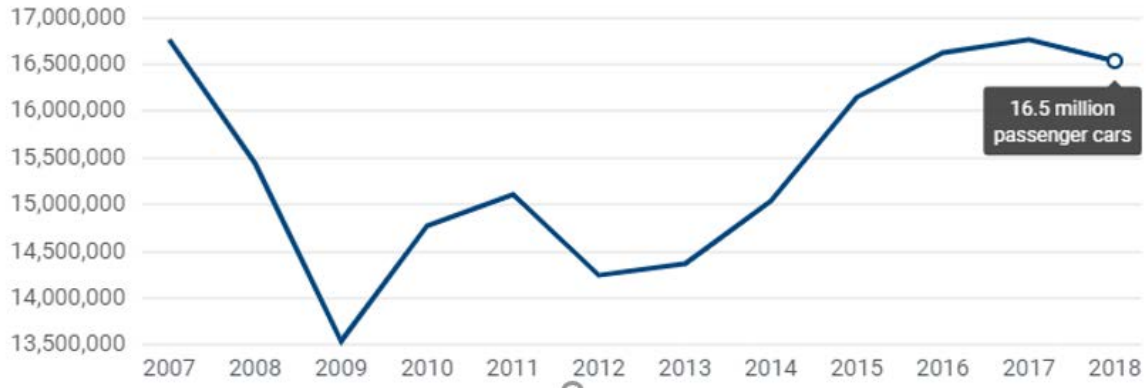


Source: European Environmental Agency.

3.1.4. Sales and production

19.2 million motor vehicles were **manufactured** in the EU in 2018 of which 16.5 million were **passenger cars**.[67] Production of passenger cars in the EU slowed down in 2018, as domestic demand weakened and car export volumes declined (-1.6 %).[68]

Figure 14: Passenger car production in the EU-28



Source: European Automobile Manufacturing Association.

Over 2.6 million **commercial vehicles** were produced in the EU in 2018 with an increase of 400 000 compared to 2016.[69]

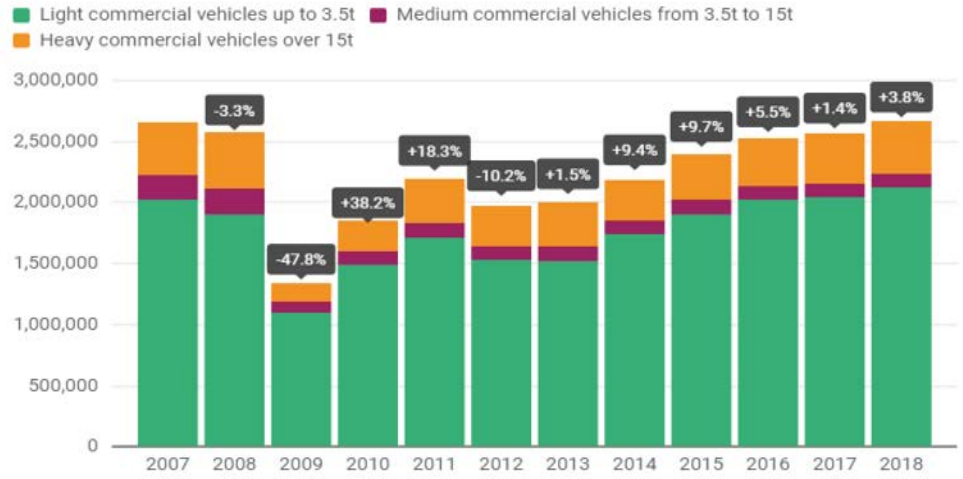
66 EEA (2019). Vehicle ownership and truck intensity.

67 ACEA (n.d.). Passenger cars EU.

68 ACEA (2019). Economic and Market Report: EU Automotive Industry - Full-year 2018, p. 15.

69 ACEA (n.d.). Commercial vehicles EU.

Figure 1: Commercial vehicle production in the EU-28



Source: European Automobile Manufacturing Association.

15.1 million **new passenger cars were registered** in the EU in 2018. Registrations in the EU-28 were dominated by the larger Member States (Germany, France, the UK) that accounted for more than 50 % of the total. Germany is the largest market, with a 23 % share of the total European market.[70]

In 2019, the adoption of electric cars saw a rapid growth across European countries. Germany (26 030) had the biggest number of **EV registrations** by Q1 2020 followed by France (25 960), and the Netherlands (8 699). Czech Republic and Italy significantly adopted EVs in 2019 with a year to year change of respectively 497.9 % and 355.2 %.

Table 5: New passenger EV registrations in EU-27 and UK

Country	Q1 2020	Q1 2019	% Change
Germany	26 030	15 944	63.3
France	25 960	10 569	145.6
Netherlands	8 699	8 626	0.8
Sweden	5 638	4 091	37.8
Italy	5 399	1 186	355.2
Spain	3 948	2 752	43.5
Czech Republic	855	143	497.9
Total EU27	94 722	55 968	69.2
EU14	88 790	52 988	67.6
UK	18 256	5 997	204.4
EFTA	20 285	21 887	-7.3

Source: IDATE Digiworld, data extracted from National Automobile Manufacturers' Associations.

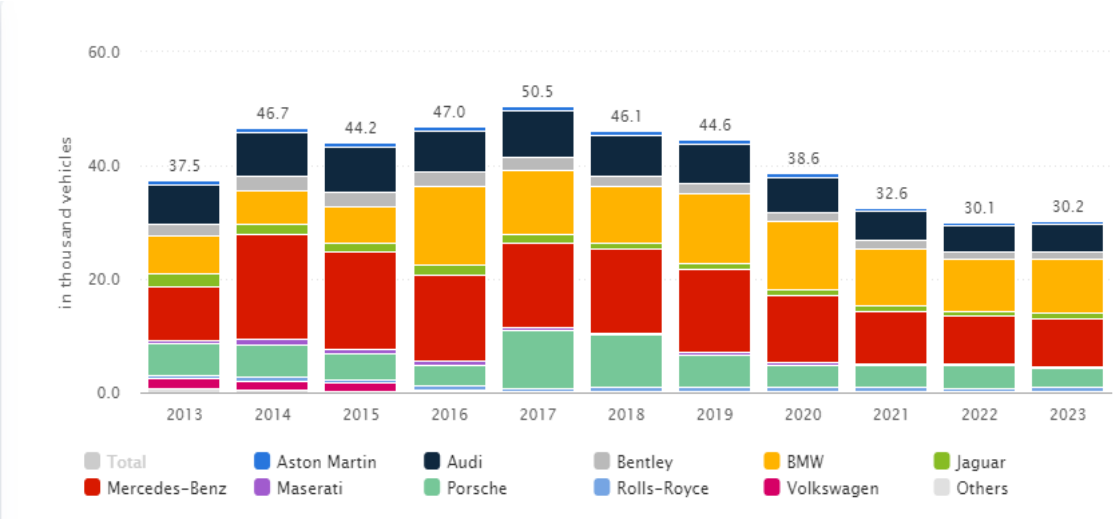
[70] ICCT (2019). European vehicle market statistics. Pocketbook 2019/20, p. 11.

In the recent years, the **luxury car market** across Europe has been steady with relatively small change in highs and lows. Such segment generally follows the economic trends and is also influenced by the distribution of wealth within the EU. As shown in Figure 16, luxury cars sales in Europe saw an increase between 2015 and 2017 when the euro area experienced the highest economic growth in the last 5 years (on average more than 2 %).[71]

Overall, German automakers (i.e. Mercedes Benz, Audi) dominate the sales in Europe while British and American ones continue to drive sales in this segment.

A downturn of luxury car sales is expected to follow in the post-COVID-19 period as a result of the expected recession in 2020.

Figure 2: Luxury car sales by make in EU-27 and UK, (in thousand vehicles)



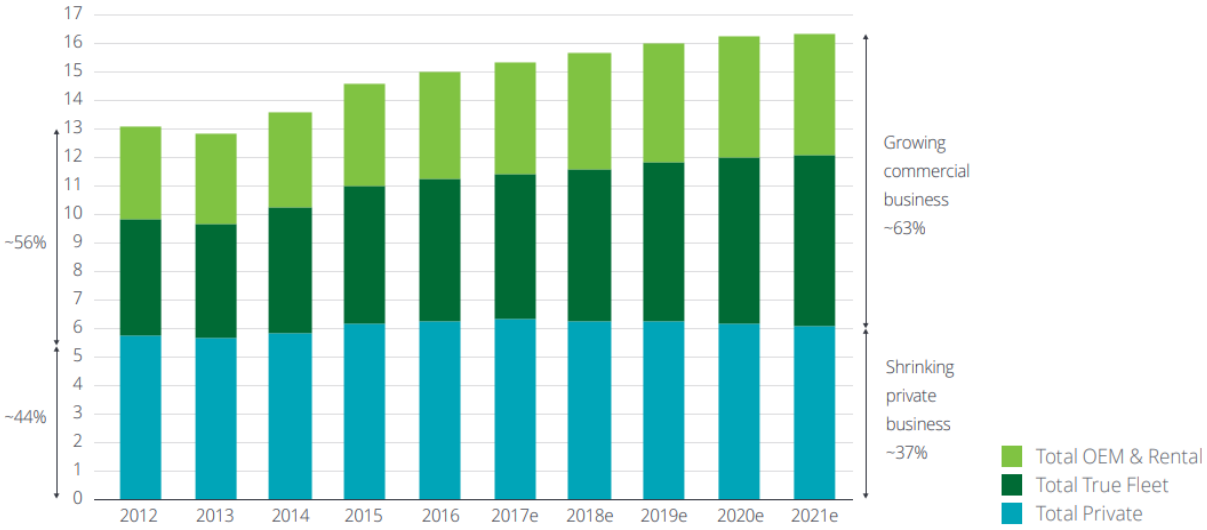
Source: Statista, 2020.
Note: In scope are passenger luxury cars, ultra-luxury cars; out of scope are premium compact and executive cars, luxury SUVs/ crossover cars.

In the recent years, the corporate channel in Europe has overtaken the private channel in terms of vehicles registrations. **Corporate fleets registrations** rose from 7.2 million (less than 50 % of total car registrations) in 2010 to 8.7 million (58 % of total registrations) in 2016. In 2016, Germany led true fleet registrations (924 305 new registered corporate cars) followed by France (751 561) and Italy (430 489).

Pre-COVID-19 forecasts expected a slight increase in European corporate fleet. Such growth remains uncertain following the post-COVID-19 recession.

[71] World Bank (2019). GDP growth (annual %) - Euro area.

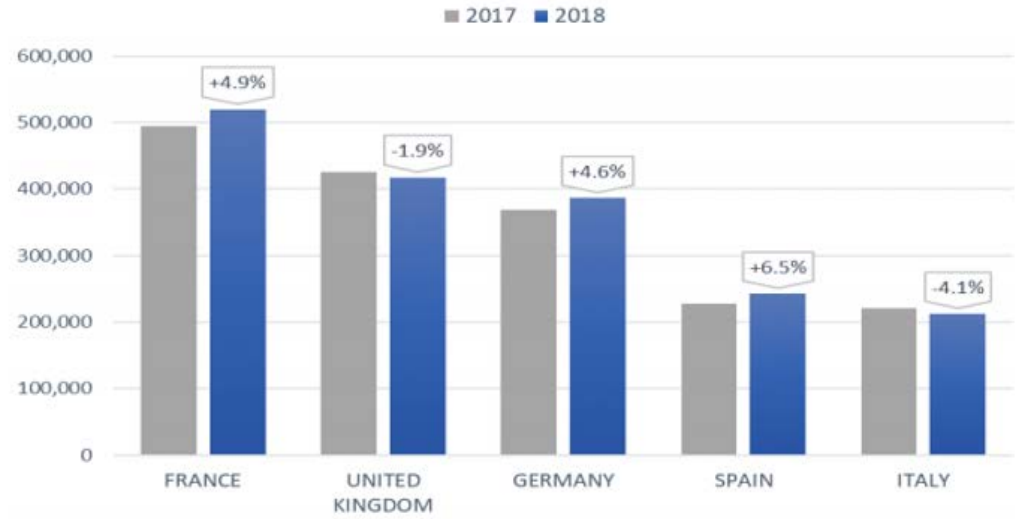
Figure 3: Corporate car registrations in Western Europe (in millions), 2012-2021



Source: Deloitte analysis, Dataforce (2016), LMC (2016).
Notes: OEM refers to OEM self-registrations (to employees). Rental refers to rental cars (short, medium, and long-term rental). True fleet refers to corporate fleets with or without full-service leasing

In 2017, there were some 29 million **vans** on the EU's roads. Overall, in 2018, EU demand for commercial vehicles continued to grow and went up by 3.2 % compared to 2017. Approximately 2.5 million commercial vehicles/vans and buses were registered in 2018 across the EU, which is the highest volume on record since 2007.[72] In Q4 2019, commercial vehicle registrations in Europe increased by 5.7 %.

Figure 4: New commercial vehicles registrations in the five big EU markets



Source: European Automobile Manufacturing Association.

In 2019, the **demand for new electric vans** across Europe grew by 22.9 %, representing 1.2 % of total EU light commercial vehicle sales. The biggest markets for electric vans were France (8 087)

[72] ACEA (2019). Economic and Market Report: EU Automotive Industry - Full-year 2018, p. 18.

and Germany (6 704) that made up almost 60 % of prototypes registered across the EU.[73] The number of new hybrid electric vans registered in 2019 grew by 159.8 % compared to the previous year, accounting for 4 577 new prototypes. The triple-digit growth, however, was mainly the result of an emerging market.

Table 6: New electric and hybrid electric vans registrations in the EU-28

	ELECTRICALLY-CHARGEABLE			HYBRID ELECTRIC		
	2019	2018	%change	2019	2018	%change
Austria	504	459	9.8	0	0	
Belgium	400	263	52.1	45	18	150.0
Cyprus	4	–		0	–	
Czech Republic	33	22	50.0	3	0	
Denmark	267	222	20.3	451	397	13.60
Estonia	3	1	200.0	0	0	
Finland	60	55	9.1	16	16	0.0
France	8,087	8,153	-0.8	1,861	760	144.9
Germany	6,704	6,006	11.6	312	124	151.6
Greece	11	13	-15.4	2	0	
Hungary	75	123	-39.0	7	0	
Ireland	332	84	295.2	1	0	
Italy	1,046	644	62.4	1,296	437	196.6
Latvia	2	0		0	0	
Luxembourg	85	44	93	2	0	
Netherlands	1,280	978	30.9	4	0	
Poland	130	42	209.52	2	1	100.00
Portugal	213	253	-15.8	4	9	-55.6
Romania	54	23	134.8	8	0	
Slovakia	23	18	27.8	0	0	
Slovenia	41	–			–	
Spain	1,937	1,825	6.1	553	0	
Sweden	1,389	755	84.0	10	0	
United Kingdom	3,427	1,259	172.2		–	
EUROPEAN UNION	26,107	21,242	22.9	4,577	1,762	159.8
Norway	2,016	1,774	13.6	0	0	
Switzerland	581	298	95.0	50	3	1,566.7
EFTA	2,597	2,072	25.3	50	3	1,566.7
EU+EFTA	28,704	23,314	23.1	4,627	1,765	162.2

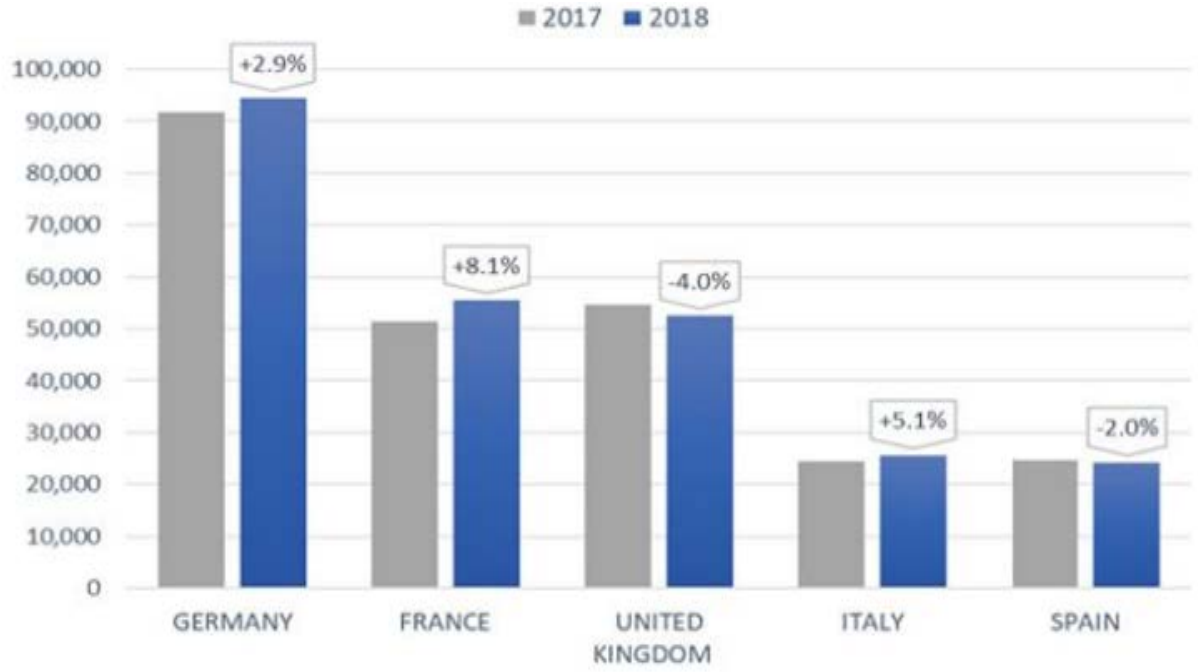
Source: European Automobile Manufacturing Association, 2020.

In 2017, more than 6 million trucks were in circulation throughout the EU. In 2018, **newly registered heavy-trucks** (excluding buses and coaches) across the EU grew by 3.5 % compared to 2017

[73] ACEA (2020). Fuel types of new vans: diesel 92.8%, electric 1.2%, alternative fuels 1.3% market share in 2019. Press release.

accounting for over 200 thousand units.[74] Furthermore, 269 700 heavy-trucks were exported worldwide in 2018, valued €5.5 billion and responsible for a trade surplus of €5.2 billion. In Q4 2019, EU demand for new trucks decreased by 9.4 % resulting in the decline in heavy-truck registrations.[75]

Figure 5: New medium and heavy commercial vehicle registrations in the five big EU markets



Source: European Automobile Manufacturing Association.

In 2019, the demand for transport saw a rapid growth (+109.2 %) across the EU. Such high growth is mainly the result of a low base of comparison. New registrations of **electric trucks** went from 357 trucks in 2018 to 747 in 2019, accounting for 0.2 % market share.[76] Germany leads by far the adoption of new electric trucks (608) followed by the Netherlands (76) and France (24). Together they accounted for 95 % of all EU truck registrations in 2019.[77] By contrast no electric trucks were registered at all in 12 EU countries over the same period.

Hybrid electric trucks saw a decline in sales in 2019, accounting for down 10.8 % compared to 2018.

74 ACEA (n.d.). Trucks.

75 ACEA (2018). Economic and Market Report - EU Automotive Industry Full-year 2018.

76 ACEA (2020). Fuel types of new trucks: diesel 97.9%, electric 0.2%, hybrid 0.1% market share in 2019. Press release.

77 Ibid.

Table 7: New electric and hybrid electric trucks registrations in the EU-28

	ELECTRICALLY-CHARGEABLE			HYBRID ELECTRIC		
	2019	2018	%change	2019	2018	%change
Austria		–			–	
Belgium	0	0		6	0	
Cyprus	0	–		1	–	
Czech Republic	6	–		0	–	
Denmark	3	3	0.0	0	0	
Estonia	0	0		0	0	
Finland	0	0		5	5	0.0
France	24	9	166.7	64	49	30.6
Germany	608	279	117.9	10	4	150.0
Greece	0	0		0	0	
Hungary	0	0		0	0	
Ireland	0	0		0	0	
Italy	10	3	233.3	74	138	-46.4
Latvia	0	0		0	0	
Luxembourg		–			–	
Netherlands	76	25	204.0	4	6	-33.3
Poland	0	0		2	1	100.00
Portugal	0	0		9	12	-25.0
Romania	0	0		0	0	
Slovakia	0	0		0	0	
Slovenia		–			–	
Spain	8	4	100.0	91	85	7.1
Sweden	2	2	0.0	6	5	20.0
United Kingdom	10	32	-68.8	0	0	
EUROPEAN UNION	747	357	109.2	272	305	-10.8
Norway	2	10	-80.0	0	0	
Switzerland	13	8	62.5	1	0	
EFTA	15	18	-16.7	1	0	
EU+EFTA	762	375	103.2	273	305	-10.5

Source: European Automobile Manufacturing Association, 2020.

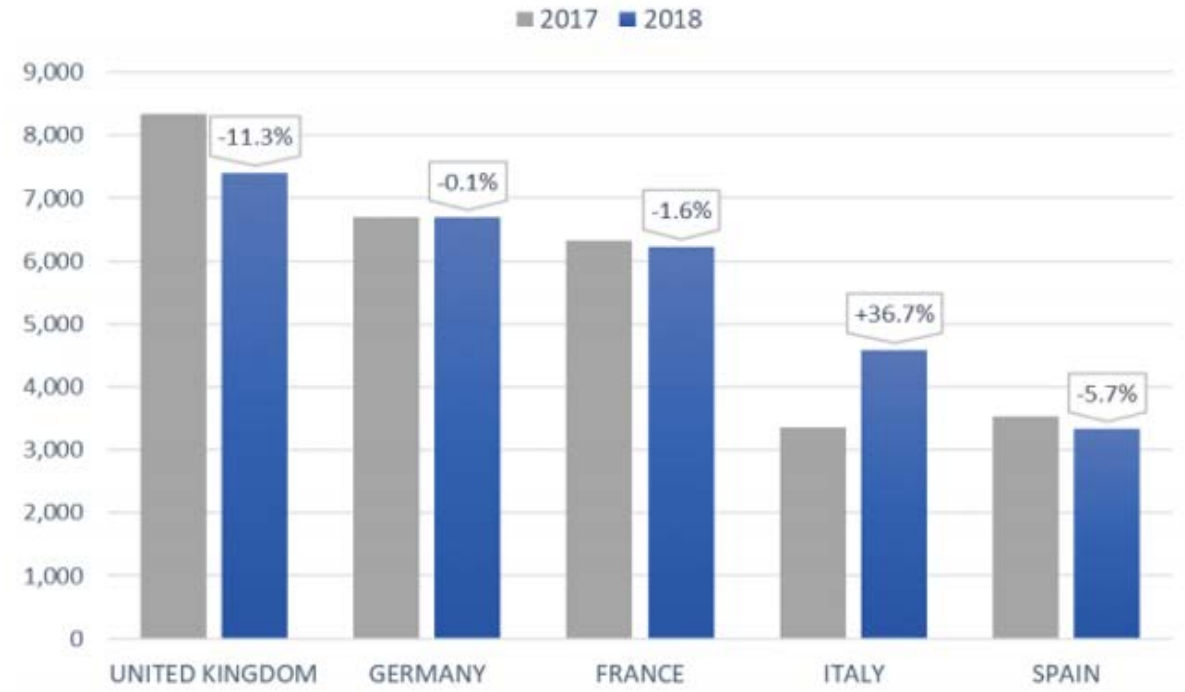
In 2017, there were 892 861 buses in circulation on Europe's roads.[78] In 2018, registrations were up by 1.3 % compared to 2017, with 41 599 **buses and coaches** registered across the EU.[79] In 2019, new bus and coach registrations increased by 1.8 %.[80]

78 ACEA (2017). Fact sheet: Buses.

79 European Comission (2019). EU transport in figures. Statistical pocketbook 2019.

80 ACEA (2018). Economic and Market Report - EU Automotive Industry Full-year 2018.

Figure 6: New medium and heavy bus and coach registrations in the five big EU markets



Source: European Automobile Manufacturing Association.

The adoption of **electric buses** is increasing every year in Europe. In 2019, registrations of new electric buses increased by 170.5 % accounting for 1 607 units and almost 4.0 % of total EU bus sales. There exists, however, a significant difference among EU Member States in terms of electric bus adoption. In 2019, the Netherlands was the biggest market registering 381 new electric buses, followed by France (285) and Germany (187).[81] These three countries accounted for more than half of all electric busses sold last year. On the other hand, eight EU countries did not register any new prototype.

In 2019, **hybrid buses** adoption followed a rising trend with 1 918 new units sold across the EU, equivalent of 59.7 % more than in 2018. Almost all hybrid bus registrations were concentrated in just six countries: Germany (454), Spain (427), Belgium (371), Italy (255), France (210) and the Netherlands (125).[82] By contrast, 13 EU countries registered no units at all.

[81] ACEA (2020). Fuel types of new buses: diesel 85%, hybrid 4.8%, electric 4%, alternative fuels 6.2% share in 2019. Press release.

[82] Ibid.

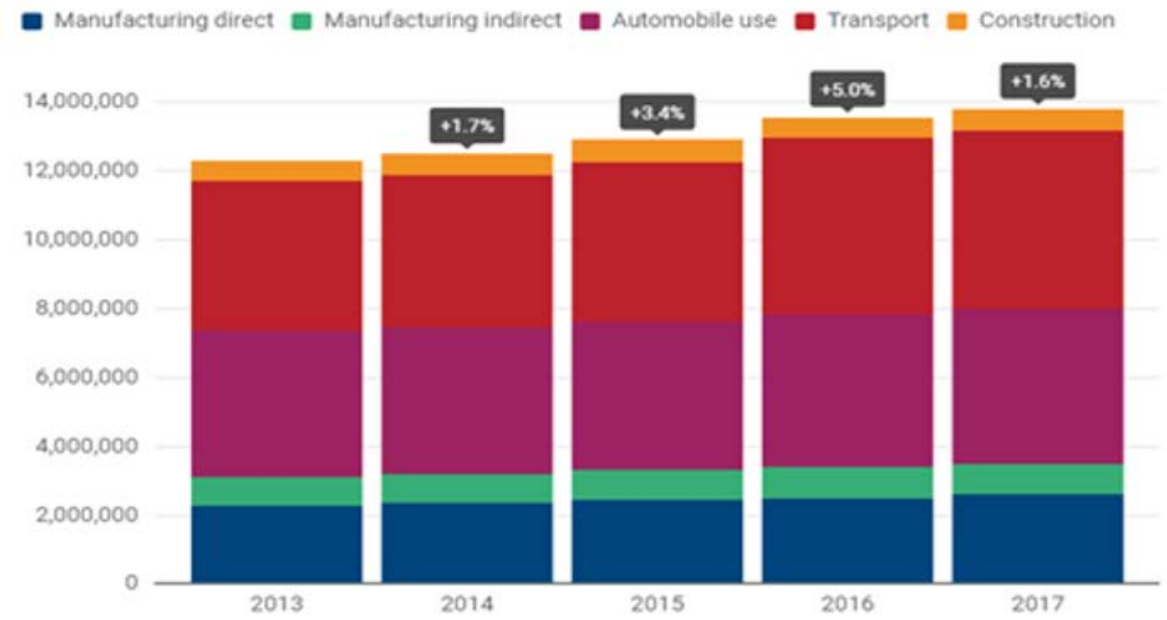
Table 8: New electric and hybrid electric buses and coaches' registrations in the EU-28

	ELECTRICALLY-CHARGEABLE			HYBRID ELECTRIC		
	2019	2018	%change	2019	2018	%change
Austria	60	18	233.3	0	0	
Belgium	37	14	164.3	371	221	67.9
Cyprus	0	–		0	–	
Czech Republic	4	–		0	–	
Denmark	100	2	4,900.0	0	0	
Estonia	0	0		0	0	
Finland	40	1	3,900.0	0	0	
France	285	95	200.0	210	266	-21.1
Germany	187	43	334.9	454	227	100.0
Greece	0	1	-100.0	0	0	
Hungary	0	1	-100.0	0	0	
Ireland	0	0		0	0	
Italy	65	53	22.6	255	19	1,242.1
Latvia	2	4	-50.0	0	0	
Luxembourg	–			–		
Netherlands	381	103	269.9	125	0	
Poland	54	63	-14.29	51	200	-74.50
Portugal	17	10	70.0	10	0	
Romania	50	11	354.5	0	0	
Slovakia	0	18	-100.0	0	0	
Slovenia	–				–	
Spain	103	30	243.3	427	260	64.2
Sweden	98	36	172.2	15	8	87.5
United Kingdom	124	91	36.3		0	
EUROPEAN UNION	1,607	594	170.5	1,918	1,201	59.7
Norway	157	12	1,208.3	0	0	
Switzerland	10	18	-44.4	103	38	171.1
EFTA	167	30	456.7	103	38	171.1
EU+EFTA	1,774	624	184.3	2,021	1,239	63.1

Source: European Automobile Manufacturing Association, 2020.

The **automotive sector provides direct and indirect jobs** to 13.8 million Europeans, representing 6.1 % of total EU employment.

Figure 7: Employment in the EU automotive sector



Source: European Automobile Manufacturing Association.

2.6 million of these workers were employed in the **manufacturing of motor vehicles** in 2017. Overall, manufacturing accounts for 3.5 million jobs, directly and indirectly.[83]

Table 9: Employment in manufacturing

EMPLOYMENT		
Manufacture of motor vehicles (EU)	2.6 million people = 8.5% of EU employment in manufacturing	*2017*
Total (EU manufacturing, services and construction)	13.8 million people = 6.1% of total EU employment	*2017*

Source: European Automobile Manufacturing Association.

3.1.5. Research and Development

European automotive sector R&D

The automotive sector is the **biggest EU's investor in R&D**, responsible for 28 % of total spending. Moreover, EU automotive investment in R&D has increased by 6.7 % to reach €57.4 billion annually in 2017.[84] Automotive original equipment manufacturers (OEMs) were leading the list of companies with the highest expenditure on R&D in the last five years, with Volkswagen (over €13 billion annually) coming first and well ahead of other sectors like pharmaceuticals and biotechnology. In the global ranking, over the last three years, Volkswagen has been ranked 3rd and 4th and Daimler

[83] ACEA (n.d.). Key Figures.

[84] ACEA (n.d.). Research and Innovation.

has been 10th in terms of R&D expenditure.[85] The share of companies from the EU in global R&D in the automotive sector was up from 36 % to 44 %.[86]

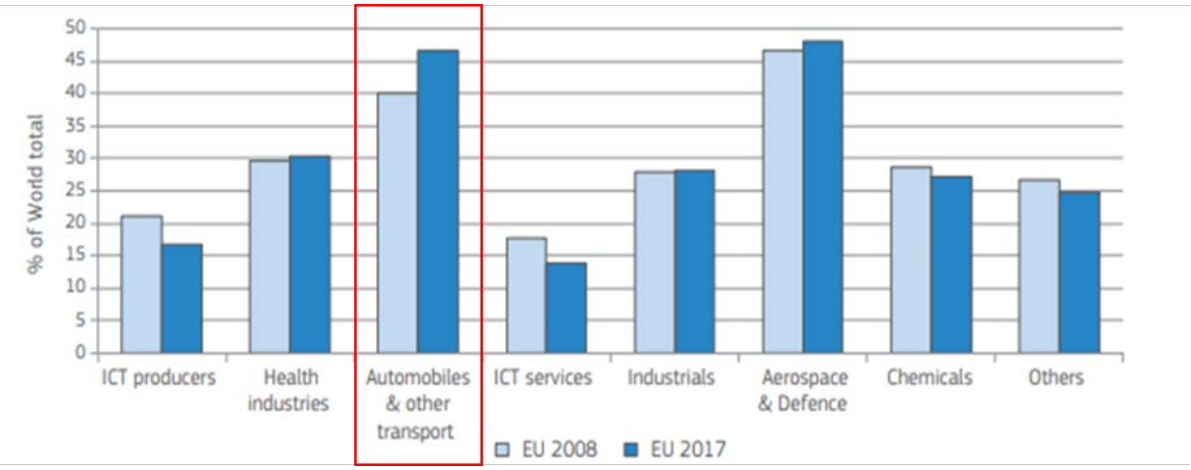
Table 10: Leading R&D investors by countries

EU rank	Company	Country	Industry	R&D 2016/17 (€million)
1	VOLKSWAGEN	Germany	Automobiles & Parts	13672,0
2	DAIMLER	Germany	Automobiles & Parts	7536,0
3	ROBERT BOSCH	Germany	Automobiles & Parts	5587,0
4	ASTRAZENECA	UK	Pharmaceuticals & Biotechnology	5358,1
5	BMW	Germany	Automobiles & Parts	5164,0
6	SANOFI	France	Pharmaceuticals & Biotechnology	5156,0
7	SIEMENS	Germany	Electronic & Electrical Equipment	5056,0
8	NOKIA	Finland	Technology Hardware & Equipment	4904,0
9	BAYER	Germany	Pharmaceuticals & Biotechnology	4774,0
10	FIAT CHRYSLER AUTOMOBILES	Netherlands	Automobiles & Parts	4219,0

Source: European Commission (2017). The 2017 EU Industrial R&D Investment Scoreboard.

EU companies increased their contribution to global R&D expenditure in automotive by more than 6 percentage points between 2008 and 2017, reinforcing their specialisation.[87]

Figure 8: EU's share of global R&D investment, by sector



Source: European Commission: EU Industrial R&D Investment Scoreboard, 2018.
Note: Automobiles and other transports stands for: Auto Parts; Automobiles; Commercial Vehicles and Trucks; Tyres.

[85] European Commission (2017). The 2017 EU Industrial R&D Investment Scoreboard; European Comission (2018). EU R&D - The 2018 EU Industrial R&D; European Comission (2019). EU R&D - The 2019 EU Industrial R&D.

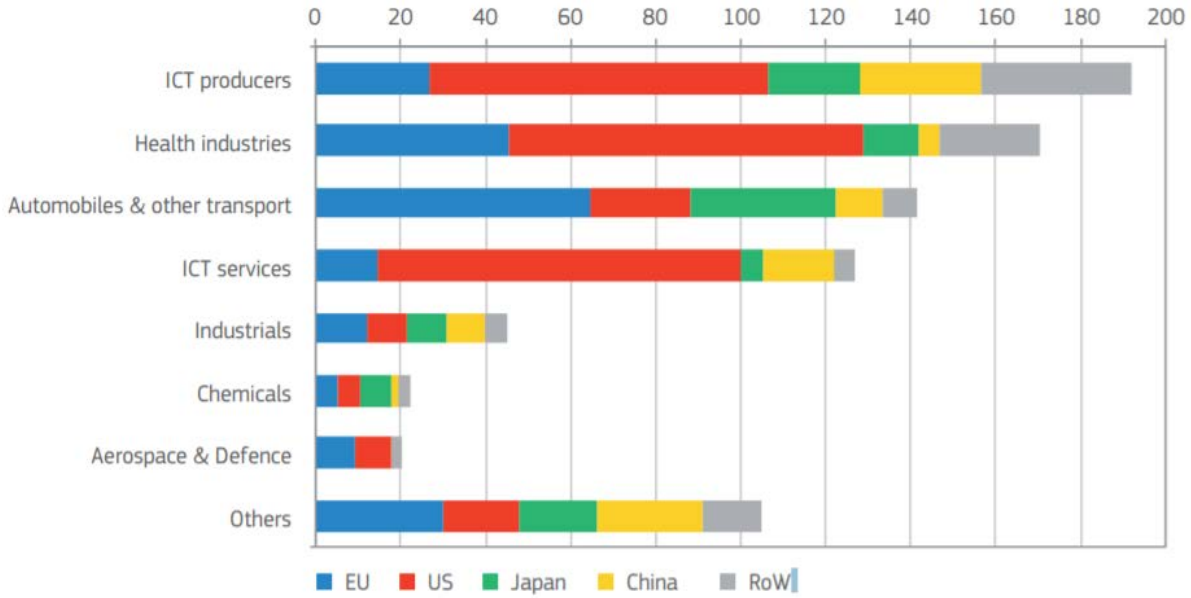
[86] KPMG (2018). R&D in the automotive sector.

[87] European Comission (2018). EU R&D - The 2018 EU Industrial R&D.

The distribution of global R&D investment by industry and region

In 2018-2019, European companies invested more than €60 billion annually in R&D on automobiles and other transport, ranking the automobile industry ahead of other technology-driven industries.[88] EU companies account for 47 % of automobiles and other transport contribution to the total R&D Scoreboard of top 2 500 company investors globally.[89]

Figure 9: R&D investment by the 2 500 companies by industry and main country, in billions of euros



Source: European Commission (2019). The 2019 EU Industrial R&D Investment Scoreboard, p. 33.

3.2. How artificial intelligence feeds the industry

Self-driving vehicles (also known as driverless, robotic, fully autonomous or automated vehicles) are probably one of the most prominent and most reported applications of AI in transport. Self-driving cars are expected to have a major impact on the operation of the transportation system (e.g. traffic congestion, safety), to profoundly change the travel behaviour and travel patterns and to alter the relationship between people and cars.[90] They are the pinnacle of automation of the driving function that started with driver assistance and partial automation, which are widely used at the moment. Predictions about the availability of fully autonomous cars differ.[91] Optimistic experts and policy-makers expecting their commercial adoption by 2025-2030.[92] More cautious experts point to many technical and regulatory issues – that will significantly impact the cost of automated vehicles

88 Ibid.; European Commission (2019). The 2019 EU Industrial R&D Investment Scoreboard.

89 Ibid.

90 Stanley B, Gyimesi K (2016). A New Relationship—People and Cars; IBM Institute for Business Value.

91 For details see SAE International (2016). Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. Standard J3016_201806.

92 Roland Berger (2014). Autonomous driving; EU Commissioner for Transport Violeta Bulc as reported by Koetaier J (2019). Self-driving Cars In 10 Years: EU Expects 'Fully Automated' Cars by 2030. *Forbes*; McKinsey (n.d.). Autonomous driving.

– that need to be solved first, and based on the experience with previous vehicle technology deployment, predict decades till driverless cars become commercially viable.[93]

AI is also being used for (advanced) connected cars with some autonomous features like assisted parking or autonomous driving into specific conditions like highways. Those are situations less complex that can be handled by narrow AI. For example, highways are one-way streets with limited number of intersections, only from the right way. White lanes on the road create the equivalent of virtual lanes (except in the case of snow), which facilitates decision making. There are already solutions on the market with for instance around Tesla cars (with Auto Pilot).

Nonetheless, driverless technology has been either in use or tested in several areas. The most advanced applications of driverless vehicles can be found in farming and mining, although these off-road applications are beyond the scope of this study.[94] Other applications are either in testing or pilot stages. Automated shuttles and campus roundabouts are being actively piloted, and their wide use is expected in the near future. Such vehicles are usually deployed at low speed (up to 20 kmh) and short routes (about 1 km) with few stops.[95] Driverless buses have been tested around for almost five years, also under limited conditions.[96] Robo-taxis are being tested in the US and China and could be also deployed in Europe by the end of 2020 – beginning 2021.[97] Platooning of trucks tests have been successfully completed in Europe.[98]

Artificial Neural Networks (ANN), bee colony optimisation (BCO) algorithms, ant colony optimisation techniques and other algorithms have been used to improve **traffic analysis, forecast and management**[99] and support and enhance **Intelligent Transport Systems (ITS)**.[100] ITS use different technologies and communication systems to alleviate congestion and improve driving experience, but AI (and specifically machine learning) can provide a step change for them by allowing instantaneous analysis and decision-making. The current focus of ITS research and development into traffic control and prediction is on short- and long-term traffic flow prediction in urban networks, vehicles speed and route prediction, traffic volume prediction, route planning to avoid traffic jams, reduction of the time stopped at intersections, traffic signals control and traffic congestion reduction.[101] ITS also looks into **road safety and accident/ incident prediction** by

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93 Litman T (2020). Autonomous Vehicle Implementation Predictions: Implications for Transport Planning. Victoria Transport Policy Institute, p. 23-29; Davies A and Marshall A (2019). Are We There Yet? A Reality Check on Self-Driving Cars. *Wired*.

94 Peters J (2019). The future of autonomous vehicles runs off roads and on to farms, construction sites and mines. TechCrunch.

95 Haque A and Brakewood C (2020). A synthesis and comparison of American automated shuttle pilot projects, *Case Studies on Transport Policy* 8: 3, pp. 928-937.

96 The Telegraph (2016). World's first driverless bus service begins carrying passengers in French city of Lyon; The Guardian (2018). Germany launches world's first autonomous tram in Potsdam.

97 The Verge (2019). Waymo's robot taxi service is improving, but riders still have complaints; CNBC(2019). Mercedes robo-taxi service gets underway in California; Udemans C (2019). AutoX, NEVS to deploy robotaxis in Europe next year. *TechNode*.

98 The Verge (2016). Self-driving truck convoy completes its first major journey across Europe. Further multi-brand real-life platooning testing is carried out in the Horizon 2020 project ENSEMBLE.

99 Abduljabbar R, Dia H, Liyanage S, and Bagloee S (2019). Applications of Artificial Intelligence in Transport: An Overview. *Sustainability* 11.

100 Machin M, Sanguesa J, Garrido P and Martinez F (2018). On the use of artificial intelligence techniques in intelligent transportation systems. 2018 IEEE Wireless Communications and Networking Conference Workshops (WCNCW), Barcelona, pp. 332-337.

101 Ibid.

designing intelligent systems for visual monitoring, vehicular accidents modelling and analysing accident frequency and reasons.

Large parts of ITS research and development focus on the improvement of **vehicular control systems**. For instance, anti-lock braking systems (ABS), minimising emissions and human-knowledge integration in autonomous vehicles are all parts of ITS. To prevent accidents, researcher work on driver fatigue detection, dangerous driving identification and automatic incident detection.[102] Due to better localisation, faster response is possible in emergency situations.

Linked to the described above AI application to traffic management and prediction, AI is becoming instrumental for logistics. The very same ITS can be used for **journey planning and optimisation** due analysing the fleet management data, traffic and road safety data.

The combination of data from IoT sensors in the car, maintenance logs and from external sources (e.g. data from the road cameras on the changes in the driving pattern of a specific car) will be analysed by AI to predict failures and maintenance requirements.[103] AI would thus enable **remote car checks** (i.e. without bringing the car to a garage), **vehicle self-diagnostics** (probably even as the car is moving) and **remote maintenance** (e.g. where software update can fix the problem).

AI applications will also allow for a more efficient **transport infrastructure maintenance and repair**. By combining the data from IoT road sensors and cameras with the data from cars, public authorities can quickly detect and repair road damage – with significant cost savings.[104] AI can be used to automatically detect damage by comparing and analysing the current state with the historical records at a very high level of accuracy.[105]

AI applications should enable a higher integration of different transport modes (**intermodality** or multimodality) and reduce inefficiencies in transportation for goods and people.[106] Intermodality will enhance the shared mobility experience making it more user-centric and needs-based. Big data, IoT and AI are the necessary elements for the large-scale data collection and processing that ensure a complete integration of different transport modes. For example, for personal travel, they can provide all information and services necessary for trip planning (e.g. timetables, real-time data on travel time, road tolls/charging, fare prices, personal, information service demand data etc.).[107]

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[102] Machin M, Sanguesa J, Garrido P and Martinez F (2018). On the use of artificial intelligence techniques in intelligent transportation systems. 2018 IEEE Wireless Communications and Networking Conference Workshops (WCNCW), Barcelona, pp. 332-337.

[103] McKInsey (2015). Ten ways autonomous driving could redefine the automotive world; the maintenance company Predii issued a white paper on the topic: Repair intelligence: An Innovative Application of Artificial Intelligence in Automotive Maintenance.

[104] A local council made significant savings in a recent pilot: BBC (2020). Blackpool pothole-fixing artificial intelligence 'saves £1m'.

[105] De Telegraaf (2018). Slimme camera moet brug redden; Ynformed (2020). Using Artificial Intelligence for road safety: a smarter way of maintenance; Morales F, Reyes A, Caceres N, Romero L, and Benitez F (2018). Automatic Prediction of Maintenance Intervention Types in Roads using Machine Learning and Historical Records. *SAGE Journal of Transportation Research Board* 2672: 44, pp. 43-54.

[106] McKinsey Center for Future Mobility (2019). Race 2050 - A vision for the European automotive industry, p. 24.

[107] EBRD (2018). Disruptive technology and innovation in transport. Policy paper on sustainable infrastructure, p. 23.

3.3. Effects of AI on transport

3.3.1. Economic effects

This section provides supportive evidence with respect to economic costs and benefits of AI adoption in the transport industry. The analytical framework of economic effects is focused on the primary economic impacts of AI in global and regional GDP, job creation and entrepreneurship.

AI has the potential to **enhance productivity growth and fuel GDP** as well as incentivise entrepreneurship to bring innovative solutions. It could incrementally add 14 % equivalent of €13 trillion by 2030 to the global economic output (approximately €1.5 trillion to Northern Europe's GDP).[108] Moreover, AI is estimated to contribute to an annual average productivity growth of about 1.2 % over the same period.[109]

AI impact in the **job creation remains arguable**, as automating physical and cognitive tasks could lead to massive job loss for low-skilled workers in the transportation industry. While low-skilled workers risk being replaced by technology and machines, the demand for high-skilled workers (data analysis, engineering, cybersecurity and vehicle monitoring) working alongside machines or developing AI mobility solutions is expected to increase. Yet, there are also indications that the work of mechanical and manufacturing engineers may change requiring new skills and education from them.[110] By and large, the negative impact in employment rates will prevail and could reduce the gross impact of AI by around 10 percentage points by 2030.[111] Substantial transitional costs and negative externalities may accompany the transition to an AI-enabled economy, representing both around half of the 10 percentage points.

GDP

AI-based solutions are expected to improve many aspects of the transportation and logistics sector resulting in a positive impact in the economy. In this context, it is estimated that transport and logistics sector will see a gain approximately 10 % in GDP by 2030.[112] Such benefit is coming directly or indirectly from the improvements AI is bringing to companies' internal processes and to the sector's functioning as a whole.

Arguably the most important element of investment in AI derives from the need of the European automotive industry to remain competitive in the global marketplace. The automotive industry finds itself **deploying AI in all parts of its value chain**, including R&D support, supply chain management, manufacturing, sales, customer experience, and mobility services. Of all of these use cases, the majority is seen in mobility services, with 22 % of automotive firms deploying AI at scale

[108] The Northern Europe region comprises of the following countries: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Sweden, United Kingdom, Switzerland, Norway. The estimate comes from PwC (2017). Sizing the price: What's the real value of AI for your business and how can you capitalise?

[109] Bughin et al. (2018). NOTES FROM THE AI FRONTIER: MODELING THE IMPACT OF AI ON THE WORLD ECONOMY. *Mckinsey Global Institute.*

[110] English T (2020). Will AI and Generative Design Steal our Engineering Jobs? Interesting Engineering.

[111] Bughin et al. (2018). NOTES FROM THE AI FRONTIER: MODELING THE IMPACT OF AI ON THE WORLD ECONOMY. *Mckinsey Global Institute.*

[112] PWC (2018). The macroeconomic impact of artificial intelligence.

in 2019.[113] While the majority of firms have not yet successfully integrated AI across their supply and value chains, it could potentially become a critical competitiveness issue for European industry.

While the panorama of such improvements is dynamic and not yet completed at this point in time, we expect the following implications to be key contributors to the economic gains of AI adoption.

Optimisation of transportation grid

AI solutions are targeting the optimisation of transportation grid for more efficient scheduling, routing and parking management. Consequently, accurate predictions with respect to future traffic flow will **reduce fuel cost** for urban and freight transport as well as **incidents on the road network.** Currently, congestion in the EU is often located in and around urban areas and costs approximately €100 billion annually, or nearly 1 % of the EU's GDP.[114]

AI holds the potential to **reduce traveling times** for the benefit of both consumers and industry. This comes out of efficiencies rendered by traffic management using ITS, which predicts future demand on road infrastructure at various times of the day, helping to reduce congestion, distributing traffic more evenly (with fewer accidents to interrupt traffic flow) and even optimising traffic lights.[115] For instance, compared to a traditional pre-time signal plan, AI backed ITS holds the promise of reducing waiting time at traffic lights by up to 47 %.[116] On that account, a recent estimate in the United Kingdom claimed that **reducing travel times** for workers would result in approximately €23 billion of savings to country's GDP.[117] In the same line, the Netherlands is expecting to reduce overall traveling time by 9 % thanks to ITS adoption that is estimated to save up to €272 million per year.[118]

Public expenditure

From a public sector perspective, AI will directly affect **road maintenance costs.** Traffic lights, street signs and road marking would be unnecessary in the long run because fully autonomous vehicles would be programmed to know and follow the traffic laws. This would lead to savings in **road maintenance costs**.[119] The transition towards a smart road infrastructure could save EU-27 countries and UK a portion of the annual €38 billion of **operational and maintenance costs** of their road networks, corresponding to 0.3 % of the European GDP.[120] That said, this transition will also bring **new installations and maintenance costs** (e.g. sensors and cameras, etc.).

Other sectors of the economy are also expected to reap the benefits from a secured and optimised transportation grid. Hence, overall public expenditures and in particular the healthcare system are

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113 Capgemini. (2019). Accelerating automotive's AI transformation: How driving AI enterprise-wide can turbo-charge organizational value.

114 European Comission (n.d.). Clean transport, Urban transport.

115 Peter, M. (2018). Reducing the Traffic Headache: Three Technology Solutions Cities Should Consider. Blog post.

116 Ibid.

117 Després, J. et al. (2018). An analysis of possible socio-economic effects of a Cooperative, Connected and Automated Mobility (CCAM) in Europe effects of automated driving on the economy, employment and skills. European Commission. In addition to these benefits, the authors of this report also identified the following issues as providing economic savings: increased demand for reduced travel and freight costs, telecommunication data traffic increases, growth in revenues from sectors like digital media.

118 European Bank for Reconstruction and Development (2019). Disruptive technology and innovation in transport. Policy paper.

119 Marshall, A. and Davies, A. (2018). Lots of lobbies and zero zombies: How self-driving cars will reshape cities. *Wired*.

120 Schroten, A. et. al. (2019). Overview of transport infrastructure expenditures and costs. Study for DG MOVE.

likely to benefit **from fewer accidents**, in which public property is damaged and/or persons are injured. This will further **reduce costs of health care** linked to injuries (short- and long-term), costs due to absence from work and other long-term costs associated with traffic accidents**.** The average cost of crashes as percentage of GDP in Europe is around 2 % with Austria and Croatia leading with 3 % of their GDP.[121] Hence, the **reduction of motor-vehicle fatality rates** thanks to automated vehicles is expected to save a portion of Member states health care budget.

In the US, it is estimated that automated vehicles, could save 1-2 % of the overall US healthcare budget.[122] **Infrastructural damages in road networks** are expected to see the same trend as very often accidents are the main cause of public property damage.

Moreover, due to the fewer (and eventually significantly fewer) accidents and traffic violations, there will be no need for traffic police. On the one hand, this would mean **savings on law enforcement costs** for municipal budgets and increase of welfare. On the other hand, municipal budgets would **lose an important source of income**, namely traffic fines as well as parking fees.[123]

Congestion

The increase use of MaaS is **discouraging car ownership** and may increase mass transportation but it is yet arguable if this results in reduced traffic congestion. Personal mileage from ride sharing services in Europe has experienced an explosive growth, mounting from a few trips in 2012 to about 2.6 billion trips in 2017.[124] Vehicle miles travelled (VMT) from ride sharing companies grew with a compound annual growth rate of 150 % from 2013 (30 million) to 2016 (500 million).[125] Hence, as ride sharing companies continue to offer favourable tariffs and more services to travellers, their increased usage may increase urban traffic and incentivise the shift towards car-oriented mobility.

Personal mileage in Europe **is expected to rise by 23 % by 2030** equivalent to 5.88 trillion km as result of electrification and sharing.[126] AVs are estimated to account for 40 % of that value by 2030, as their adoption will open access to the mobility of new travellers that currently do not rely on cars.[127] In the US, the use of AVs is expected to increase by double digits the traveling of people aged from 16-24 and over 65, which is estimated to result in additional 1.6 trillion kilometres annually by 2050.[128] **AVs' empty trips** to reach new travellers or round trips to avoid parking costs would thus create additional traffic in urban areas. That said, the capability of AVs to interact with ITS and directly drive to free parking lots could reduce to some extent the empty round trips.

Energy costs

Scholars and experts express mixed opinions about the potential of AI and especially autonomous vehicles for **energy saving and related costs**. Some studies show that, for various deployment

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121 Wijnen, W, Vanden Berghen W. (2017) Analysis of road crash costs in EU countries

122 Clements, L. and Kockelman, K. (2017). Economics effects of Automated Vehicles. *Transportation Research Record*.

123 For instance, Amsterdam collects yearly more than €150 million in parking fees (about one quarter of all city revenues from municipal taxes). For more than one quarter of all Dutch municipalities, revenue from parking fees represents over 10 % of all revenues from municipal taxes. See CBS (2014). Parking fee revenues estimated at 660 million euros in 2014.

124 PwC (n.d.). Mobility insights: Tackling the growing issue of congestion in urban areas.

125 Ibid.

126 PwC (2018). Five trends transforming the Automotive Industry.

127 Ibid.

128 KPMG (2015). The clockspeed dilemma.

scenarios, there will be energy savings from using autonomous cars (both electric and hybrid).[129] The AI-enabled factors that would allow to save energy are platooning, eco-driving and lighter vehicles of more optimal size (as many unnecessary parts can be disposed with).[130] However, many studies predict **rebound or backfire effects**. Energy economy of AI-enabled vehicles and time cost savings – coupled with a more pleasurable travel experience – are likely to trigger behavioural responses that will **increase the net energy use**. This is **due to vehicles driving at higher speeds, travelling and commuting over longer distances, more frequent travelling, and new passenger trips due to inclusion of previously unserved or underserved people** (e.g. disabled, elderly, young people).[131]

Second-order impacts of AI-enabled cars

Sectors closely linked to the transportation industry will certainly see changes from AI-enabled cars adoption. Hence, as **insurance companies** gain access to more information on an individual driver and vehicle, insurance policies can be personalised and consequently improved towards more **cost-effective products**. However, in the long run, revenues of the insurance industry are expected to decrease, especially with the introduction of fully autonomous vehicles.[132]

At the same time, the adoption of autonomous vehicles could have a positive impact on industries providing entertainment (i.e. streaming movie or music platforms) and telecommunication services.[133] That is because **savings from reduced travel times**, at least for workers, will not necessarily all lead to increased productivity, but also to **increased use of social media and mobile communication.**

Software and hardware market for CAV

CAV technologies are gaining significant industry focus from automotive OEMs targeting the advancement of on-vehicle technologies. Such technologies include software (e.g. computer vision and safety critical systems) and hardware development such as radar, and GPS trackers to name a few.

The global market for CAV technologies is evolving at a fast pace and is estimated to worth £63 billion by 2035, as industry players see such solutions a necessity to sophisticate means of transport and indeed an opportunity to grab market share.[134] Between 2020 and 2030, Europe expects revenues of approximately **€41.5 billion from autonomous hardware** components and

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129 See, for instance, calculations for the US: U.S. Energy Information Administration (2018). Autonomous Vehicles: Uncertainties and Energy Implications, pp. 12-16.

130 U.S. Energy Information Administration (2017). Study of the Potential Energy Consumption Impacts of Connected and Automated Vehicles.

131 Ibid.; Taiebat M, Stolper S, and Xu M (2019). Forecasting the Impact of Connected and Automated Vehicles on Energy Use: A Microeconomic Study of Induced Travel and Energy Rebound. *Applied Energy Journal*, pp. 28-30.

132 Rohr, C. and Dunkerley, F. (2018). Exploring the Social and Economic Impacts of a Common EU Approach to Liability Rules for Connected and Autonomous Vehicles, p. 167. RAND Europe.

133 Després, J. et al. (2018). An analysis of possible socio-economic effects of a Cooperative, Connected and Automated Mobility (CCAM) in Europe effects of automated driving on the economy, employment and skills. European Commission. In addition to these benefits, the authors of this report also identified the following issues as providing economic savings: increased demand for reduced travel and freight costs, telecommunication data traffic increases, growth in revenues from sectors like digital media.

134 Transport Systems Catapult (2017). Market forecast for connected and autonomous vehicles in UK.

€15 billion from new software.[135] The UK, one of the most advanced European countries in the production of software and hardware solutions, is expecting a contribution from CAV technologies of further £1.8 billion to its gross output over the same period.[136] The UK also expects that the CAV industry could add up to 25 000 jobs, with 70 percent of that job growth expected to be in the software industry.[137]

Despite the significant surge in interest in this sector, CAV technologies costs and consumer attitude are yet unclear as the solutions are under constant development.

Logistics - Shipping, package and supply deliveries

AI adoption in the logistics sector targets the automation of the supply chain to enhance its efficiency and thus cut a significant part of its expenses. While automating warehouses is the most common use case today, pioneering companies are planning freight deliveries without drivers by 2021.[138] Self-driving trucks are expected to eliminate costs by 40 % and drive longer distances without stops, accelerating thus trade exchanges.[139] Moreover, the economic gains of self-driving trucks in the trucking industry are estimated to range from $100 to 500 billion per year by 2025.[140] However, the **overall GDP impact of AI in logistics is still unclear**, and academic literature presents a divergence of views when comparing **job destruction versus enhanced efficiency and cost reduction** for the sector.

3.3.2. Effects on employment

AI is expected to lead to large **shifts in the demand for skills** in the transportation and logistics sector. Consequently, around 375 million jobs globally are expected to be affected by the adoption of AI, where 69 % of jobs loss accounts for **low skilled labour**.[141] Compared to other transportation modes, road transport is the most labour-intensive sector accounting for 138 million employees globally, with a large majority being low skilled workers.[142]

Job cuts are likely to affect all sectors employing drivers, from warehousing and supports to wholesale driving and postal activities. For instance, the introduction of support systems (i.e. assistant driving, lane and distance control, etc.) is expected to take away manual driving responsibilities from heavy goods vehicle drivers whereas algorithms will carry out more and more traffic management tasks, likely leading to further cuts in operators' positions.[143]

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135 Alonso Raposo M, Grosso M, Després J, Fernández Macías E, Galassi C, Krasenbrink A, Krause J, Levati L, Mourtzouchou A, Saveyn B, Thiel C and Ciuffo B (2018). An analysis of possible socio-economic effects of a Cooperative, Connected and Automated Mobility (CCAM) in Europe effects of automated driving on the economy, employment and skills. JRC111477, p. 36.

136 Ibid.

137 Catapult Transport Systems. (2017). Market forecast for connected and autonomous vehicles.

138 FleetOwner (2019). TuSimple plans freight deliveries without drivers in 2021.

139 McKinsey & Company (2018). Distraction or disruption? Autonomous trucks gain ground in US logistics.

140 Manyika, J. et al. (2013). Disruptive technologies: Advances that will transform life, business, and the global economy. McKinsey Global Institute.

141 Ibid.

142 World Maritime University (2019). Transport 2040: Automation, Technology, Employment - The Future of Work.

143 Ibid.

ITF (2017) estimates that the current 3.2 million truck-driving jobs in Europe may decrease to 2.3 or even up to 0.5 million by 2040 according to different scenarios.[144] Such scenarios also take into account a significant number of truck drivers that will retire in the coming years.

In contrast, **white-collar jobs** will be positively impacted, supporting a bias towards the shift. Manufacturing and driving CAVs will increasingly require more AI software engineering skills as well as supervision and selective intervention.[145] Moreover, the increased dependency of road transportation on ICT-based equipment's and products will require new ICT skills.[146] However, predicting what kind of new occupations will be created in the future remains a challenge. By and large, future developments towards autonomous cars (trucking included) and delivery are expected to speed the job loss for low skilled workers but increase the demand for AI talents.

Job loss for low-skilled workers

Future changes towards autonomous vehicles and delivery will cause **job loss** for many drivers and other low skilled jobs in the transportation industry. By 2030, low-skilled workforce in passenger transport required to transport the current number of passengers is expected to be halved. The estimate corresponds to developed regions including Europe that is more likely to adopt such technologies faster, and at a larger scale.[147]

Conversely, the automation of manual tasks is expected to reduce heavy goods vehicle drivers by approximately 9 % globally, over the same period.[148] The increased global movement of goods is one of the main factors to slow the decline in labour demand in this case, especially in developing regions.

AI-based applications are enhancing the shared mobility trend challenging traditional taxis and speeding job loss. This is because AI allows shared mobility applications to identify customers and match rides in a fraction of the time and with lower fares. For instance, since the advent of ride sharing in the US in early 2013, taxi ridership in LA has declined by an estimated 77 %, and worst scenarios saw taxi companies losing 12 out of 15 of their drivers.[149]

In the meantime, job cuts are already happening in the logistic sector as giant e-commerce companies are substituting workers using robotic process automation to automate warehouses and fasten customers' delivery. Repetitive tasks like supply chain forecasting and planning, order entry, remanufacturing and refurbishing activities are all candidates for more automation. Machine learning techniques are already being used in warehouses to automate simple tasks (i.e. packaging/unpacking) as well as demand and inventory planning using predictive analytics to

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144 Després, J. et al. (2018). An analysis of possible socio-economic effects of a Cooperative, Connected and Automated Mobility (CCAM) in Europe effects of automated driving on the economy, employment and skills. European Commission.

145 Spulber, A. and Wallace, R. (n.d.). Impact of Automated Vehicle Technologies on Driver Skills. Center for Automotive Research.

146 Thierer, A. and Hagemann, R. (2014). Removing Roadblocks to Intelligent Vehicles and Driverless Cars. *Wake Forest Journal of Law & Policy*, Vol. 5, pp. 339-391.

147 Schröder-Hinrichs, J. et al. (2019). Transport 2040: Automation, Technology, Employment - The Future of Work. *World Maritime University*. Interestingly, developing regions, i.e Latin America, are expected to see a smaller decline of approximately 26 %, as they would need more time to adopt new technologies and infrastructures.

148 Ibid.

149 Hiltzik, M. (2020). Column: Uber and Lyft increase traffic and pollution. Why do cities let it happen?. Los Angeles Times. Taxi ridership in LA, article numbers refer to LA Department of Transportation; Lopez. S. (2020). Column: Cabbies hit by LAXit pickup squeeze are planning their own exit. Los Angeles Times.

account for potential disruptions. More automated centres will need fewer humans to carry or move things, and more using, managing or overseeing robotics.[150] In 2019, Amazon had more than 200 000 robotic vehicles to move goods through its delivery fulfilment centres in the US.[151] Over the same period, the company introduced packing robots to some of its US facilities with the target of cutting costs and packing four to five times faster than the average rate of human packers. The adoption of packing robots is expected to substitute around 1 300 jobs in 55 US-based facilities.[152]

Compensating for driver shortage

Industry organisations hope that fully autonomous vehicles would alleviate the ongoing '**driver shortage crisis**'.[153] The joint OECD and ITF research shows that, depending on the speed of AI deployment, **AI applications may compensate for the lacking drivers completely or partially** – but **may also lead to unemployment** if AI is deployed too quickly and labour markets react too slowly.[154]

New jobs and evolution of jobs

In the long-term, however, the main effect of AI application in transport is expected to be an **evolution of the driving job**.[155] It is likely that the jobs will become more 'geographically stable' (i.e. less long-distance driving). The job will also become more multi-dimensional and require more skills: with driving being only a small part of the job, more time will be devoted to back-office tasks with possible tasks in management and control areas. These changes may make the new driving job more attractive for a larger and more diverse pool of candidates, making the workforce more gender- and age-equal.

As AI plays a major role not in CAV and intelligent mobility services, there is an increasing demand for AI talents. Tech giants and other active actors in the transportation sector (i.e. mobility start-ups, equipment manufacturers) are looking for and hiring **new talents** to develop these technologies in-house or acquire innovative mobility start-ups. As noted above, in the UK alone, the production of CAV technologies is estimated to create 25 000 net additional jobs by 2035 with major requests in software development (70 %). Moreover, many applications in logistics are currently **creating new positions faster than employers can fill them**.[156] By and large, this wave of automation in both road transportation and supply chain management is likely to create new jobs in engineering and software development that will optimise the interaction between the technology and humans.

Entrepreneurship

The developments in terms of connectivity and AI software has opened a wide range of mobility applications like car sharing, free-floating vehicle fleets, carpooling and ride-hailing. Such developments are incentivising entrepreneurship in the mobility sector where numerous AI start-ups are receiving support not only from transportation sector but also from tech giants.

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150 Guillot, G. (2018). Are supply chain jobs at risk of automation?. SupplychainDive.

151 O'Brien M (2019). As robots slowly take over Amazon's warehouses, are they causing more harm than good? *Independent*.

152 Dastin, J. (2019). Exclusive: Amazon rolls out machines that pack orders and replace jobs. Reuters.

153 IRU (2018). Tackling the driver shortage crisis.

154 Ibid.

155 OECD and ITF (2017). Managing the Transition to Driverless Road Freight Transport, pp. 40-42.

156 Association for Advancing Automation (n.d.). Work in the Automation Age.

In 2018, the US mobility start-ups were at the forefront with $13.5 billion funding followed by the Europeans with $2.6 billion and Israelis with $310 million.[157] In Europe, mobility start-ups are also a catalyst for economic growth through employment, as on average the unicorn ones have a team of 21 employees.[158] Moreover, mobility-as-a-service (Maas) solutions are creating cost-efficient mobility options to consumers and households, reducing thus vehicle acquisition and maintenance expenditures.

3.3.3. Environmental effects

Beyond the economic impact, AI in transportation is also associated with positive impacts on the environment. Those impacts derive from the better **energy efficiency** and driving of cars, the positive impact of the ITS able to optimise the flow of traffic, the reduced rate of accidents resulting from both improved road conditions and more capable than human autonomous vehicles, and possibly new usages and relationship to the car resulting from fully autonomous vehicle. On the other hand, there is both an **uncertainty and a risk of a rebound effect**, where the easier, more affordable way of traveling could partly negate the positive effects that AI could have on the environment.

Reduced air and noise pollution, greenhouse gasses emissions and fuel consumption

While different impacts can be distinguished on the environment, they usually derive from similar improvements / benefits associated to the use of AI and also depend on parameters such as the energy mix (share of fuel vs electricity cars) or whether the energy used is highly carbonised or not. As a result, reduction in fuel consumption and greenhouse gasses emission are usually correlated and if the consumption of fuel is reduced, **air pollution and noise pollution** are likely to be reduced too. In this reasoning, the correlation is valid only in terms of greenhouse gas emission per trip.

However, an increased number of trips per person (i.e. rebound effect) could very well compensate the increased efficiency if people use this increased efficiency to travel more. Furthermore, air pollution not only result from the incomplete combustion of fuel but also result from non-fuel exhaust pollution such as particle released from the abrasion of tire and brakes and is thus not directly correlated to fuel consumption but rather to the fluidity of the driving. This kind of pollution is sizeable as one estimate that exhaust and non-exhaust sources almost equally contribute to traffic related PM10 emission.[159]

Impact from the use ITS and big data to optimise traffic flows

A Cost and Benefits Analysis on the impact of the deployment of ITS in the EU and UK estimated that **fuel consumption savings** account for 11 % of the benefits from ITS, behind reduced accident rate (22 % of the benefits) and reduced travel time (66 % of the benefits) in the EU.[160] This obviously has economic impact but also results in reduced greenhouse gasses emission as well as possibly in the reduction of non-exhaust fuel emission of PM10. Indeed, it is possible that reduced traffic results in

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157 de Concini, A. (2018). Financing innovation in clean and sustainable mobility: Study on access to finance for the innovative road transport sector. Innovation Finance Advisory and European Investment Bank Advisory Services for European Commission.

158 Via-ID (2018). Who are the European startups of Mobility?

159 Grigoratos, T. and Martini, G. (2014). Non-exhaust traffic related emissions. Brake and tyre wear PM. European Commission.

160 Asselin-Miller, N. et al. (2016). Study on the Deployment of C-ITS in Europe: Final Report. Ricardo Energy & Environment for European Commission.

less braking and more optimal driving speed. On the other hand, reduced traffic might as well result in some more aggressive driving behaviour, which is possible in short- to mid-term perspective, till fully autonomous cars hit the road, and would counterbalance the positive effect. Indeed, higher speed result in higher energy consumption. As an example, a speed increase from 70 to 80 miles per hour increase average energy use by 13.9 % by mile.[161]

Similarly, in the logistic sector, **increased operational efficiency resulting from** the use of **big data** could lead to $500 billion savings worldwide in time and fuel. In terms of CO2 emissions, savings of 280 mega tonnes could be achieved worldwide thanks to a wider use of big data.[162] In 2016 in the EU and UK, only 19 % of companies in the mobility and logistics sectors used big data, which highlights the potential for even more positive environmental impacts.

AI enabled management of traffic flows could thus reduce congestion and engine idling by ensuring constant flow of traffic at optimal speeds. Traffic forecasting would allow choosing the most time- and energy-efficient route. This would **reduce** both the emissions and **fuel consumption** as well as **air pollution and noise pollution** (the latter one also due to less braking and honking). An effective sharing economy is likely to lead to fewer vehicles in use and a more efficient use of vehicles in general (e.g. shifting from low occupancy vehicles to public and shared use).[163] In a simulation made in the city of Rome, Italy, it was shown that a 100 % penetration of autonomous vehicle would result in reduced noise pollution due to more intelligent routing that would notably have more impact in the centre of the city, while some outer highway could result in increased noise pollution because the more important capacity gain.[164] On average, however the impact would be positive for noise pollution.

Impact from Connected and Autonomous Vehicles

Another positive impact result from the development of autonomous vehicle which impact fuel consumption in two different ways:

- The capability to **reduce space** when driving **between cars/ trucks** could reduce fuel consumption thanks to improved aerodynamics. For trucks, it has been estimated that fuel consumption could be reduced by 10 % to 15 % highlighting the interest of truck platooning on the highway.[165]
- Additional fuel savings may also come from autonomous vehicles smart parking decisions helping **avoid 'cruising for parking'**. This saving would result from the capability to drive autonomously directly to a free parking lot resulting from intelligent road infrastructure and an ITS signalling free places.[166] It is indeed considered that 8 % of total traffic result from cars looking for parking.

Autonomous vehicles would have a more indirect impact on noise pollution than ITS. Indeed, autonomous vehicle will more likely be electrical than using fossil fuel. One reason for this result

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161 Thomas, J. et al. (2013). Predicting Light Duty Vehicle Fuel Economy as a Function of Highway Speed. *SAE International*, Vol. 6(2), pp. 859–875.

162 Transforming transport (2017). Mobility Meets Big Data.

163 Liyanage S, Dia H, Abduljabbar R and Asadi Bagloee S (2019). Flexible Mobility On-Demand: An Environmental Scan. *Sustainability* 11:5; Nunes A and Hernandez K (2019). Autonomous Vehicles and Public Health: High Cost or High Opportunity Cost? *Transportation Research Part A: Policy and Practice* 138, pp. 28 –36

164 Patella, S., Aletta, F. and Mannini, L. (2019). Assessing the impact of Autonomous Vehicles on urban noise pollution. De Gruyter.

165 Bullis, K. (2011). How Vehicle Automation will Cut Fuel Consumption. MIT's Technology Review.

166 Ibid.

from the reduced space that electric motor takes within the car, which then free space for additional equipment required for autonomous vehicle. Since electrical vehicles generate less noise than combustion engine, this would positively impact noise emissions. Another way to consider the impact of CAV on noise pollution is to consider that CAV, like ITS result in safer and more fluid driving, which in turn would reduce noise pollution (less braking and honking).

Reduced waste production

Due to higher road safety and avoidance of accidents by connected cars, cars would need less safety mechanisms (e.g. steel reinforcements) and therefore weigh less. This, in turn, means that they could use less engine performance, all of which would further reduce emissions, air pollution and fuel consumption.[167] Also because electrical vehicle have simpler mechanic, this could result in more efficient use of natural resources and vehicles that would last longer than they currently do. Potentially, vehicles may be built from more sustainable materials reducing waste production in the long run. It shall be noted that, while these speculations are correct in their reasoning, the decision to reduce safety mechanisms might very well be questioned and never be in fact adopted.

Battery of electric vehicles could generate less waste thanks to the use of AI to more efficiently manage the charging cycle of the battery, extend its life, and therefore result in less battery being produced and a reduced need for the recycling of batteries. This technique is currently used in latest smartphone operating systems. AI is also used to better predict the capacity of the battery and detect when they need to be changed/recycled.[168]

A **long-term waste reduction** is conceivable as well due to potentially fewer cars on the roads and less necessity to buy new ones. Most experts agree that, in the future, private car ownership by individuals is going to decline and sharing of cars or rides will become a dominant model of travelling.[169] This is due to fewer road accidents and more efficient vehicle exploitation and maintenance as well as due to the rise of MaaS as an efficient and convenient mode of transportation and prohibitively high cost of newly developed vehicles of high or full automation levels.[170] This assertion though is questionable, as a complete lifecycle assessment should be performed to include all the additional sensors and equipment required for an autonomous vehicle to work.

Negative or uncertain impact

AI applications are key to produce a positive impact on the environment. Due to MaaS, sharing economy and reduced cost of having taxis or busses autonomously driven, the **vehicle installed base could decrease** by 25 % in Europe to 200 million vehicles by 2030 (versus 280 million today).[171] This trend however is not expected to be the same in other regions of the world such as in China, where on the contrary, the park is forecasted to grow by 2030. This finding highlights the fact that positive evolution might be partly offset by paradoxical evolutions.

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[167] Pakusch C, Stevens G., Boden, A. and Bossauer, P. (2018). Unintended Effects of Autonomous Driving: A Study on Mobility Preferences in the Future. *Sustainability* 10:7.

[168] Zhang, Y. et al. (2020) Identifying degradation patterns of lithium ion batteries from impedance spectroscopy using machine learning. Nature Communications.

[169] Coren M (2017). There's a new subscription business model arriving for cars. *Quartz*; Weiss C, Gaenzle S and Römer M (n.d.). How automakers can survive the self-driving era.

[170] Litman T (2020). Autonomous Vehicle Implementation Predictions: Implications for Transport Planning. Victoria Transport Policy Institute, p. 4-5.

[171] PwC (2017). Five trends transforming the Automotive Industry.

One such paradox is that **many potential energy-reduction benefits** may be **realised through partial automation**, while the major energy/ emission downside **risks appear more likely at full automation**.[172] Depending on the scenario of usage, energy usage and greenhouse gasses emissions could either nearly be divided or multiplied by two.

Some scholars also caution about potential **negative environmental impacts** that result from the so-called **rebound effects**.[173] If AI applications would lead to a more cost- and energy-efficient vehicle or ride, people may want to buy additional cars or hitch more, longer or unnecessary rides. It is also likely that a new class of unoccupied rides will emerge as self-driving cars would need to manoeuvre themselves from assignment to assignment. These and other rebound effects will (partially) negate the initial positive environmental effects. Another kind of rebound effect could be illustrated with the creation of new opportunities for peoples previously not served to benefit from transportation services, such as elderly or physically impaired people. In Europe, despite a decrease of the installed base of vehicle, personal mileage could rise by 23 % by 2030 to 5.88 trillion kilometres.[174]

Last but not least, the underlying hypothesis behind the positive effects of ITS or CAV on the environment is that people are willing to use those capabilities if they are provided. This assumption is neglecting the willingness of people to drive, experience the sensation of driving or simply the willingness to possess its own car rather than share it or rent it.

3.3.4. Social effects

This section provides supportive evidence with respect to social costs and benefits of AI adoption in the transportation industry. The analytical framework of economic effects is elaborated in the following sub-sections and is focused on the primary social impacts of AI.

Equal opportunity

More specifically, as the costs of e.g. self-driven cars using AI-systems is expected to be substantial during their early introduction, when compared to non-automated vehicles, they will likely only be affordable for middle- and high-income consumers. This stands to further increase the divide between low-income and high-income consumer's access to the benefits of the technology in question. In turn, this may also create country-level divides and market centralisation, as wealthier countries (e.g. the Nordics, Germany, the Netherlands) will provide a larger consumer-base than other EU Member States (e.g. Italy, Spain, Southern and Eastern Europe), making it more lucrative for automotive producers to focus on the markets pertaining to the former country-group.

Road safety

Huge benefits are expected in **safety** of road traffic.[175] Self-driving cars will be programmed to obey the laws and rules, they won't be distracted, speed or drive under influence of alcohol or drugs. ITS will also foster road safety by reducing congestions and distributing traffic more evenly, by

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172 Wadud, Z., MacKenzie, D. and Leiby, P. (2016). Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles. *Elsevier*, Vol. 18(1), pp. 1-18.

173 Pakusch, C. et al. (2018). Unintended Effects of Autonomous Driving: A Study on Mobility Preferences in the Future. *Sustainability*, Vol. 10(7).

174 PwC (2017). Five trends transforming the Automotive Industry.

175 Acheampong R.A, Thomoupolos N, Marten K, Beyazıt E, Cugurullo F. and Dusparic I. (2018). Literature review on the social challenges of autonomous transport, p. 4; Ryan M (2019). The Future of Transportation: Ethical, Legal, Social and Economic Impacts of Self-driving Vehicles in the Year 2025. *Science and Engineering Ethics*.

monitoring the condition of the infrastructure and remotely repairing it or scheduling on time road works. AI applications in transport should thus reduce the number of accidents on the road as well as the number of fatal accidents and accidents with injuries. Higher levels of automation should also bring health benefits for drivers by eliminating driver stress, reducing risk taking behaviour and distractions.

However, scholars warn that in **short- to mid-term**, when both human drivers and self-driving cars will co-exist on the roads, the **number of accidents would not change or may actually increase**. The reasons for this being people not being used or not trusting to self-driving cars or even taking higher risks when interacting with self-driving vehicles.[176] Also, system failures or sudden break downs may result in high casualties.[177]

Quality of life

The overall **quality of life** is expected to improve due to cumulative effects of AI applications in transport as well as its positive implications on economy and employment, environment and fundamental rights. The European Environment Agency (EEA) notes that especially in the cities transport has 'a marked effect on quality of life', and the reduction in pollution (air, noise, greenhouse gases emissions) associated with traffic considerably improves it.[178] This effects needs to be considered against the potential of a rebound effect that would lead to more and longer travel and, thus, reduce or cancel out positive implications.

AI applications can improve the quality of transportation services both in urban and in rural areas and provide an overall better travel experience.[179] The accessibility of various locations could be significantly improved for less mobile population groups, such as the elderly and disabled, thus enhancing social inclusion. AI use in traffic management may have implication for city planning: availability of autonomous car sharing and public transport would allow to free-up road and parking spaces for recreational purposes and green areas. At the same time, improved connectivity and accessibility could induce further suburbanisation, increase car use and energy consumption and emissions.[180]

3.3.5. Effects on fundamental rights

Data protection and privacy

AI applications in transport will considerably challenge people's privacy and protection of personal data. The **data volume** necessary to supported automated functions is **enormous**. In 2016 already, it was estimated that contemporary cars collected around 100 000 data points, and this number is growing as vehicles climb up on the ladder of automation.[181] Scientists calculate that cameras of AV alone would generate between 300 gigabytes to 5.4 terabytes per hour,[182] and all sensors could record between 1.4 terabytes to around 19 terabytes per hour, depending on the level of

176 Ibid.

177 Acheampong R.A, Thomoupolos N, Marten K, Beyazıt E, Cugurullo F. and Dusparic I. (2018). Literature review on the social challenges of autonomous transport, p. 4.

178 EEA (2016). Front-running cities changing transport, improving quality of life.

179 Roland Berger (2018). Reconnecting the rural: Autonomous driving as a solution for non-urban mobility.

180 Acheampong R.A, Thomoupolos N, Marten K, Beyazıt E, Cugurullo F. and Dusparic I. (2018). Literature review on the social challenges of autonomous transport, p. 4.

181 West D M (2016), Moving Forward: Self-Driving Vehicles in China, Europe, Japan, Korea, and the United States. Brookings Center for Technology Innovation, p. 1.

182 Miller R (2020). Rolling Zettabytes: Quantifying the Data Impact of Connected Cars. Data Center Frontier.

automation and technology used.[183] Much of these data will be personal, related both to the vehicle passengers and to people encountered en route. Some of the data will be processed locally by the vehicle, but about 30 % needs to be transmitted to refine models and train algorithms as well as to store for audit trail in case of accidents.[184] Securing the data storage, processing and transmission does not only function as an end in itself, but it is also relevant for the **physical security** of vehicles, as examples of 'friendly hackers' exposing software vulnerabilities, taking over cars even while they were driving, have shown.[185]

As to privacy aspects, data is being collected from a large array of sources, whereby it remains unclear why particular information is being collected, whether this information is accessible. Privacy concerns are multifold, in that various vehicle communications and MaaS applications expose movement patterns and location, which might be accessed by third parties, and there are further concerns about the possibility of this data being used to further enrich consumer profiles, to target individuals better through advertisement. Anonymisation techniques have been deemed insufficient to this end, considering that 'human traces are unique'.[186]

Many scholars fear that AI applications in transport will turn **cars** into new **surveillance tools**.[187] The gradual automation of vehicles means a higher degree of integration of a large variety of services, all of which depend on data. Through geospatial positioning system, navigation tools, sensors and other data collection mechanisms, it is possible to collect highly contextual data about passengers' movements, routines, habits and preferences. The trove of personal, locational and financial data generated by AVs could be leveraged and monetised for personalised advertising, content provision, product and services development. Even anonymised, such data can be repackaged and sold to third parties. Privacy may become an expensive feature of future vehicles available for additional pay.[188] A positive effect of AI-enabled surveillance should be pointed out: in the case of an accident, help can be provided faster and responsibility determined with clarity.

Human dignity and personal autonomy

Applications of AI in transport is likely to transform both the industry and customers' place in it. The wealth of data collected, stored and processed by AV and other AI applications could transform the companies from car makers into platforms that provide hardware, software and services and are also intermediaries for other service providers. The car itself will turn into a bundle of services, while **passengers** will **become a commodity** in the sense that their attention, freed from driving, can be now sold to advertisers and entertainers.[189]

Based on the data, AI applications can also **influence people's behaviour** and make choices/ decisions for the people. **Personal autonomy**, which can be considered a crucial aspect of human

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183 Dmitriev S (2017). Autonomous cars will generate more than 300 TB of data per year. Tuxera.

184 Miller R (2020). Rolling Zettabytes: Quantifying the Data Impact of Connected Cars. Data Center Frontier,

185 World Economic Forum and Accenture (2016), Digital Transformation of Industries: Automotive Industry. White Paper, p. 7.

186 Taeihagh A and Hazel Si Min Lim (2018), Governing Autonomous Vehicles: Emerging Responses for Safety, Liability, Privacy, Cybersecurity, and Industry Risks, *Transport Reviews*, p. 11.

187 Lafrance A. (2016). How Self-Driving Cars Will Threaten Privacy. *The Atlantic*; Alvarez León L.F. (2019). Eyes on the Road: Surveillance Logics in the Autonomous Vehicle Economy. *Surveillance & Society* 17: 1/2, pp. 198-204.

188 Andesopn M (2019). The Self-Driving Car Is a Surveillance Tool. IEEE Spectrum.

189 This is a part of a larger trends in relation to personal data analysed in detail in Zuboff, S (2019). The age of surveillance capitalism: he Fight for a Human Future at the New Frontier of Power. PublicAffairs.

dignity or privacy, **shrinks** to the decision of whether to use AV or not, which at some point may not even be a real choice any more.[190]

For some people, AV and other AI applications in transport may actually **enhance personal autonomy**. People with impaired driving abilities (e.g. disabled, elderly, children, but also parents with children) will enjoy **increased mobility** being able to decide about the trips and travel alone, independently from, for instance, other members of the family. However, precisely these vulnerable people will be at **greater risk to be subjected to AI control**. To receive an appropriate service, they would need to expose their vulnerable status. Such people will encounter a serious dilemma between using AVs and not travelling at all.[191]

Equality and inclusion

Applications of AI in transport, and AVs in particular, have a potential to significantly improve equality and inclusion in the society by providing mobility for great numbers of people.[192] Elderly, disabled, people with Down syndrome, children and many other will benefit of independent means of transportation provided by AVs. This will **improve employment chances** for some categories of people resulting in productivity gains. A study for the US found that driverless cars could enable new employment for approximately 2 million individuals with disabilities, while also saving annually $19 billion from missed medical appointments.[193] Improved transportation also provides **access to education, healthcare, cultural and leisure activities** as well as alternative possibilities to stay **connected with friends and family, to travel and to contribute to the community**. Ultimately, this will have a positive impact on the **quality of life**.

However, already now questions are raised whether AVs are designed having in mind these vulnerable people and account for their special needs, including the higher data protection requirements.[194] AI developers need to be aware of different special needs of individuals with different disabilities and include them to be part of the **universal design**.[195] For instance, vehicle controls need to trained to understand hearing- and speech-impaired people and children. AVs need to be able to signal visually impaired people when they arrive to pick up and have special user interfaces. When using MaaS applications, people will likely to create profiles where they provide detailed information about their disabilities and important/ frequent routes (e.g. doctor's office, work). Special information may need to be provided about children. While this information is necessary to fetch these people an appropriate ride, it is highly sensitive and expose vulnerabilities, which many would prefer to remain private. If these special needs and data protection requirements are not built-in in AI applications by default, the new technology may end up **discriminating** and **increasing** the existing **digital divide and exclusion**.

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190 For the discussion see Kofferman N.R. (2010). (The right to) personal autonomy in the case law of the European Court of Human Rights. Research report at Leiden University; Floridi L. (2016). On Human Dignity as a Foundation for the Right to Privacy. *Philosophy & Technology* 29, pp. 307–312 (2016); Weinrib J. (2019). Dignity and Autonomy. Max Planck Encyclopedia of Comparative Constitutional Law.

191 Glancy D.J (2012). Privacy in Autonomous Vehicles. *Santa Clara Law Review* 52:4, pp. 1186-1187.

192 Halsey A. (2017). Driverless cars promise far greater mobility for the elderly and people with disabilities. *The Washington Post*.

193 Claypool H., Bin-Nun A. and Gerlach J. (2017). Self-Driving Cars: The Impact on People with Disabilities. The Ruderman White Paper.

194 Halsey A. (2017). Driverless cars promise far greater mobility for the elderly and people with disabilities. *The Washington Post*.

195 Földesi E. (2017). Disabled people spoke about their benefits and requirements on autonomous cars. *Medium*.

4. Enabling artificial intelligence in road transport

Key points

The enabling environment for extracting full value from artificial intelligence applications in road transport requires three key enablers: **infrastructure** (road infrastructure, connectivity, and technology), **financial support** (public- and private-sector investment as well as state-aid and competition rules), and a well-functioning **regulatory environment** (ethical framework for AI, liability and insurance as well as research, development, and innovation policies).

There are four potential gaps and barriers to the uptake of AI technologies in road transport, specifically issues around liability, empowering users, cybersecurity, and data protection.

With **liability** two main alternatives are (i) fault-based liability and (ii) strict liability regimes. Fault liability and civil liability are not harmonised at the EU level. With respect to strict liability, harmonisation is limited to damages caused by defective products under the PLD. In addition, the MID allows the compensation for the damages caused by motor vehicles (including AV). However, it does not harmonise the liability rules across EU Member States.

In addition, most transparency requirements related to the characteristics and functionality of products and digital content and services apply only in the B2C context. Additional transparency for the consumer could help reduce information asymmetries and increase **user empowerment** and increase uptake.

Both **cybersecurity and data protection** relate, in particular, to the social effects of AI in road transport, which have potential spill over economic effects. Poor data practices, for example, threaten European citizens' fundamental rights to data protection. At the same time, if poor data and cybersecurity practices create negative perceptions of the industry, it will have a long-term detrimental effect on the uptake of the technology.

4.1. Key enablers in detail

4.1.1. Infrastructure

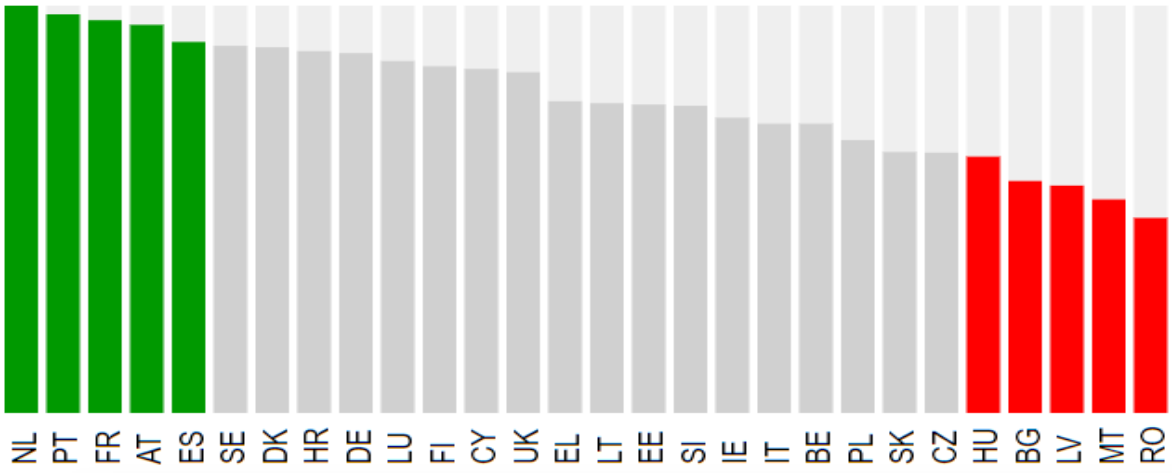
Roads

Quality of the road infrastructure is crucial to optimal implementation of AI applications for transport. Especially when it comes to connected autonomous driving (CAD) at level 3 or higher, the physical infrastructure has to meet significantly enhanced and improved quality standards.[196] Figure 24 below presents an overview of the quality of roads in EU Member States. In general, the European road infrastructure is of decent quality, and above average when compared on a global level.[197] However, differences exist within the EU: while road infrastructures in the Netherlands and Portugal are among the best in the world, the quality of roads in some Eastern European countries, such as Romania, Latvia and Bulgaria will need further investment.

[196] ERTRAC Working Group (2019). Connected Automated Driving Roadmap, pp. 6-8; Berkley Institute of Transportation Studies (2017). Intelligent Transportation Systems and Infrastructure, p. 4.

[197] World Economic Forum (2018), Executive Opinion Survey.

Figure 10: Quality of roads in the EU



Source: European Commission reproduction of data from the WEF Global Competitiveness Report 2018.[198]

Connectivity

Enhancing fixed and mobile very-high capacity (VHC) connectivity is on the EU's agenda for the coming decade. Among other priorities, a future-proof 5G connectivity infrastructure is necessary to facilitate connected and automated mobility. In particular, 5G connections could cover not only safety functions but also significantly improve driverless functionality, help in traffic forecasting and enable the service provider to monitor data from the vehicle. To achieve these benefits, the network must provide multi-Gbps throughput so that each vehicle has access to an average of 100 Mbps throughput as well as at maximum 1 millisecond latency.[199] Importantly, the system needs to create slices to isolate and secure traffic while sharing network resources.

Uninterrupted 5G coverage is needed along 'all major terrestrial transport paths, including the trans-European transport networks' for effortless movement of autonomous vehicles of at level 4-5 automation from country to country.[200] These cross-border corridors are of specific interest, because they are technically and economically challenging areas. Border zones generally have less population and traffic, which provide lower economies of scale. A lack of interoperability and different levels of connectivity could also cause issues between countries.[201]

As the figure below shows, some European countries, such as Belgium, Switzerland, Germany, Spain, Luxembourg, Netherlands and Norway, seem to have more advanced infrastructure than other countries and could probably be ready for level-4 deployment on the 5G corridors. However, other countries, like Italy, Slovakia and Lithuania, seem to have older infrastructure and may need a new fibre deployment to achieve level-4 compatibility.

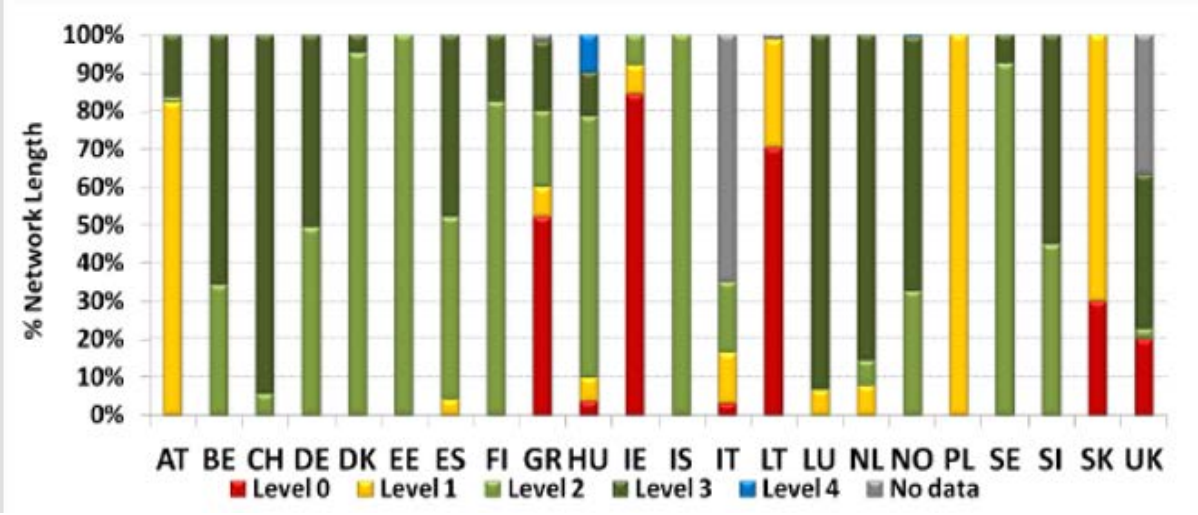
198 The WEF report looks at the quality of the overall road network; however, there can be large differences between primary and secondary road infrastructure. Hungarian motorways supported by revenues from tolls, for example, are high quality (as noted in Figure 24 of this report).

199 Latency is the time between initiating an action and receiving a response. When visiting a web site, for example, it is the amount of time between clicking on a link and data from that web site starting to load in a browser.

200 Ecorys, CBO, IDATE, VVA and WIK Consult (2020). Supporting the implementation of CEF2 Digital.

201 European Committee of the Regions (2018). State of play of connected and automated driving and future challenges and opportunities for Europe's Cities and Regions.

Figure 11: CAD readiness of road infrastructure in selected European countries



Source: TEN-T 2017 Performance Report / CEDR.
Note: Data for Belgium refers to Flanders only.

Vehicle-to-everything communication (V2X)

For full automation (level 5), a CAD requires various communication methods, which are captured by the term vehicle-to-everything communication (V2X). V2X allows a vehicle to improve its perception of the environment and to take appropriate decisions when driving and routing. It also feeds Intelligent Transportation System (ITS) with more data, improving how a CAD reacts to non-traffic related objects, such as pedestrians.

V2X thus encompass cumulatively the following forms of communication:

- Vehicle to Vehicle (V2V): e.g. to alert the car behind yours that your car is braking,
- Vehicle to Infrastructure (V2I): e.g. to communicate pieces of information to be transmitted to an ITS or to be broadcasted to other vehicles, another typical use case could be the transmission of traffic light status so that cars/drivers can adapt their driving,
- Vehicle to Pedestrian (V2P): e.g. to inform a car that a pedestrian, possibly beyond visibility is approaching the road or vice versa.

As such V2X is an enabler of AI in transportation as it improves the effectiveness of deep learning mechanism used to improve safety and reliability of autonomous vehicles. It is also helps ITS to more reliably foresee the evolution of the road traffic and provide more effective routing. While existing cellular technologies could fulfil this objective, but latency remains a concern.

From a technological point of view, V2X should work outside of a conventional cellular network while delivering the required performance (availability, latency) to provide increased road safety and convenience. Because of those requirements, V2X is seen as the biggest potential use case for edge computing reaching €25.6 billion by 2024 and the biggest benefits with €10.2 billion of expected revenues by 2024.[202]

[202] Ramahandry T (2019). Edge computing: Battle between cloud providers, industrials and telcos, *IDATE DigiWorld*.

4G+

Latest cellular technologies have two capabilities relevant for AI:

- Capability to transmit and receive more data per user and on a consolidated basis,
- Increased reactivity / reduced latency.

Modern vehicles and especially CAVs generate more data through an increasing number of sensors, which combined together, can feed AI-based driving system. This could generate hundreds of terabytes of data each month.[203] While not all data generated would need to be uploaded, a significant amount of data will still be transmitted and existing cellular networks could not cope. At this stage, much of this data could be transmitted with other network technology, such as with WiFi when at home. Also, the amount of data to be transmitted could vary compared to the locally generated data depending on the ability of the AI-based system to be completely autonomous.

The second capability of latest networks useful for an AI-based system is its much improved latency and better handling of Quality of Service.[204] While V2X combined with Multi Access Edge Computing is key to reducing the overall latency for most time-sensitive application (with latency in the realm of a few milliseconds), 4G+ and 5G could further reduce latency , which is important for the whole ITS. In this situation, Quality of Service is critical, and the ability of 5G to dedicate and prioritise potentially shared network resource to different applications (with network slicing) will be critically important.

However, if AI-based decisions can be taken locally thanks to improved and more energy efficient chips implemented in the vehicles, it might reduce the requirement on cellular networks. Also, the effective deployment and coverage of the network will be critical to support those capabilities. The capabilities vastly depend on how the network has been deployed, in terms of densification, and the use of the right frequency bands depending on each area.

4.1.2. Funding and competitiveness measures at the EU level

In Chapter 2, technology, R&D&I and investment have been mentioned as separate enablers of AI in transport. This section discusses them jointly as the development and deployment of technology does depend on the level of targeted R&D&I support. At the same time, R&D&I and funding are necessary to deploy and/or upgrade infrastructure for AI in transport. From a technological point of view, CAD is still in development and test phase, with some recent severe and fatal accidents and some delays over the ambitious targets. The most important technological challenges to realise fully automated driving lie with training algorithms towards ensuring safe and efficient vehicle operation in every driving situation.[205]

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[203] Barua S (n.d.). Flood of Data Will Get Generated in Autonomous Cars. AutoTech Review.

[204] Quality of Service (QoS) is the ability of a network to manage traffic so that it can prioritise those elements that are the most important. Some more advanced home networks, as an example, prioritise streaming multimedia over other less critical traffic to ensure smooth audio and video.

[205] An overview of specific research gaps for connected automated road transport is presented in: European Commission. (2017). Connected and Automated Transport: Studies and reports; see also Alonso Raposo, M. (Ed.), Ciuffo, B. (Ed.), Ardente, F., Aurambout, J-P., Baldini, G., Braun, R., Christidis, P., Christodoulou, A., Duboz, A., Felici, S., Ferragut, J., Georgakaki, A., Gkoumas , K., Grosso, M., Iglesias, M., Julea, A., Krause, J., Martens, B., Mathieux, F., Menzel, G., Mondello, S., Navajas Cawood, E., Pekár, F., Raileanu, I-C., Scholz, H., Tamba, M., Tsakalidis, A., van Balen, M., Vandecasteele, I., The future of road transport - Implications of automated, connected, low-carbon and shared mobility, EUR 29748 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-03409-4, doi:10.2760/9247, JRC116644.

The EU has continuously funded collaborative research in the area of automated driving. The funding started more than ten years ago with the 6th Framework Programme followed by the 7th Framework Programme – predecessors of Horizon 2020.[206] More recently, the funding has become more systemic, addressing a range of issues linked to AI in transport. According to the EU Strategy for mobility of the future, the EU approach is multi-pronged and targets both the research and development in the field of AV, the deployment of necessary infrastructure (in the broadest sense) and the development of intelligent transport systems as well as skills and expertise. [207]

The deployment of connectivity infrastructure and services is an essential precondition for the effective application of AI in transport. Both 5G deployment and satellite services can deliver the necessary connectivity. The 5G Action Plan for Europe aims to promote early 5G deployment in major urban areas and along major transport path and foresees two main actions in this regard:[208]

- to ensure that every Member State identifies at least one major city to be '5G-enabled' by the end of 2020 and that all urban areas and major terrestrial transport paths have uninterrupted 5G coverage by 2025; and
- to set roll-out and quality objectives for the monitoring of the progress of key fibre and cell deployment (to support the above action).

The Commission commits to work with the Member States and stakeholders to develop a network of pan-European 5G corridors for experimentation and large-scale deployment of advanced connectivity supporting connected cars. Various EU funds target the further roll-out of connectivity for CAD.[209] European Structural and Investment Funds (ESIF) have been of utmost importance, with a budget of €6.1 billion earmarked for investment in digital networks that facilitate 5G deployment.

Table 11: ESIF funding for 5G per EU Member State (in millions of euros)

Country	Millions of euros	Country	Millions of euros
Austria	34	Italy	890
Belgium	-	Latvia	44
Bulgaria	-	Lithuania	44
Croatia	204	Luxembourg	-
Cyprus	19	Malta	-
Czechia	521	Netherlands	-
Denmark	-	Poland	1 020
Estonia	43	Portugal	-
Finland	0.5	Romania	1 020
France	587	Slovakia	98
Germany	138	Slovenia	50
Greece	254	Spain	420

206 ERTRAC (2019). Connected Automated Driving Roadmap, p. 19.

207 European Commission (2018). On the road to automated mobility: An EU strategy for mobility of the future. COM(2018) 283 of 17.05.2018.

208 European Commission (2016). 5G for Europe: an Action Plan. COM(2016) 588 of 14.09.2016, esp. pp. 3-4 and 7.

209 European Committee of the Regions (2018). State of play of connected and automated driving and future challenges and opportunities for Europe's Cities and Regions.

Hungary	394	Sweden	71
Ireland	75	UK	177

Source: European 5G Observatory.

To co-fund relevant R&D projects over 2014-2020, the Commission allocated a total budget of €300 million through the EU's research and innovation programme Horizon 2020 for experimentation with 5G cross-border corridors. Horizon 2020 funding covers a variety of issues linked to AV, from safety to trials and testing to user awareness and acceptance. When dealing with the R&D side, three projects should be mentioned that are co-funded with €49.3 million via Horizon 2020 that are trialling 5G cross-border corridors over more than 1 000 km of European highways.[210] In 2020, these 5G corridor trials have been complemented by three projects on 5G-based mobility and transport solutions funded with €41 million via Horizon 2020.

All these projects are also a part of the 5G Public Private Partnership (5G-PPP) – a coalition of stakeholders from the electronic communications sectors and its supply chain dedicated to R&D&I in 5G to secure European technological leadership.[211] The 5G-PPP leverages private R&D&I investments by using European Horizon 2020 funds. It is currently running 11 mobility-related 5G projects and has leveraged more than €1 billion of private investments for them.[212] To engage a broader range of stakeholders in the development of 5G-based transport and mobility, the 5G-PPP has drafted a strategic document that aims primarily at stimulating further investments in pan-European 5G corridors.[213] The 5G-PPP considers the joint proactive action by industry and governments an indispensable first step towards AV and intelligent transport.

For 2021-2027, the funding will continue via the new Connecting Europe Facility (CEF), Digital Europe programme (DEP) and Horizon Europe – the successor of Horizon 2020. The revised financial envelope for transport under the CEF will be €21.4 billion.[214] Based on various estimates, the investment necessary to reach pan-European uninterrupted 5G coverage amounts to €5 to €18 billion. To bridge the investment gap and leverage private investments, the European Commission estimates that EU public support of €1 to €1.5 billion would be necessary.[215] The CEF proposal already contains an indicative list of corridor sections that can be supported with public funding to ensure that major roads are covered by 2025.[216] The priority is given to major roads, including trans-European transport networks, in order to enable uninterrupted provision of synergy digital services and maximise positive spill-overs to the adjacent areas. These cover two types of sections:

[210] The projects are 5G-CARMEN, 5GCROCO and 5G-Mobix. For more information see Cross-border corridors for Connected and Automated Mobility (CAM) and Connected and automated mobility: three 5G Corridor trial projects to be launched at ICT 2018 event.

[211] See the official website: https://5g-ppp.eu/ .

[212] For the short description of the projects see European Commission (2020). EU boosts investment in 5G hardware innovation and trialling 5G-based connected and automated mobility.

[213] 5G-PPP (2019). 5G Strategic Deployment Agenda for Connected and Automated Mobility in Europe. Initial proposal.

[214] European Council. Conclusions of the Special meeting of the European Council (17, 18, 19, 20 and 21 July 2020). EUCO 10/20, pp. 19-20.

[215] 5G-PPP (2019). 5G Strategic Deployment Agenda for Connected and Automated Mobility in Europe. Initial proposal, p. 10.

[216] See Part V of the Annex to the Proposal for a Regulation of the European Parliament and of the Council establishing the Connecting Europe Facility and repealing Regulations (EU) No 1316/2013 and (EU) No 283/2014, COM(2018) 438 of 06.06.2018.

- cross-border sections with additional 5G corridors for experimentation in connected and automated mobility (CAM) and
- more extensive sections for large-scale deployment of CAM and the full range of other 5G services.

It was estimated that 26 000 km of highways in the EU could be considered cross-border corridors that could benefit from CEF2 investment (see figure below).[217] Investments in the backhaul, 5G networks and V2N infrastructure are estimated at a minimum of €38 000 per km and €1 billion in total, and a maximum of around €210 000 per km and €5.46 billion in total. This investment will most likely consist of a combination of national and EU public funding, and private funding from road operators, telecom operators, car manufacturers and application providers.

Figure 26: Cross-border corridors for connected and automated mobility

Source: Ecorys, CBO, IDATE, VVA and WIK Consult (2020), Supporting the implementation of CEF2 Digital.

The DEP will support the deployment of innovative new technologies and solutions (including AI) in the field of mobility and transport. The CEF proposal clarifies that, under the DEP, services will be developed that run over the connectivity infrastructure of the CEF.[218] The DEP aims to build and

[217] Ecorys, CBO, IDATE, VVA and WIK Consult (2020), Supporting the implementation of CEF2 Digital.

[218] See Section 1.4.4 of the Proposal for a Regulation of the European Parliament and of the Council establishing the Connecting Europe Facility and repealing Regulations (EU) No 1316/2013 and (EU) No 283/2014, COM(2018) 438 of 06.06.2018

strengthen core AI capacities in the EU, for instance, by creating reference sites for experimentation and testing of AI applications in transport and mobility. The initial financial envelope for AI under the DEP was €2.4 billion.[219]

Europe's new largest research programme - Horizon Europe – will support R&D projects on AI in transport through the cluster 'Climate, Energy and Mobility' (pillar II) that covers the topics of 'communities and cities', 'industrial competitiveness in transport' and 'smart mobility'.[220] Initially, €15 billion were foreseen for this cluster for 2021-2027 (approximately 16 % of the total budget of Horizon Europe).[221]

In the context of research on connected and automated transport, the EU has developed a joint strategic planning and aims to coordinate national and multinational research and funding programmes. The STRIA Roadmap on Connected and Automated Transport of 2019 is a product of cooperation between industry, academia and authorities that has identified short, medium- and long-term research initiatives and provides insights into the relationship between activities (e.g. urgency, overlaps and gaps) and recommendations how to speed up the deployment.[222]

Space infrastructure is critical for providing geo-positioning information and uninterrupted connectivity, including as a part of 5G networks, for transport.[223] Also the revised proposal for the EU space programmes continues to provide significant funding to such important space programmes like global satellite navigation system Galileo (€8 billion) and European Geostationary Navigation Overlay Service (EGNOS).[224] Galileo is being developed for navigation services for AV as it is the main European asset for the provision of high precision maps and secured positioning.[225]

Whether the planned public funding is sufficient to boost EU's international competitiveness is a moot question because estimates on the investment by private and public actors that is needed to take the final steps are not available.[226] Also, as described in Section 3.1.5, the EU automotive industry is the largest private investor in R&D in the EU and ranks high globally. In an international comparison, a separate number of the public investments related specifically to AI in transport are hard to come by. However, the research on investments in R&D&I in AI in general has firmly placed

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219 Proposal for a Regulation of the European Parliament and of the Council establishing the Digital Europe programme for the period 2021-2027, COM(2018) 434 of 06.06.2018. This was based on the initial total budget for the DEP of about €9.2 billion. This budget was reduced to €6.8 billion at the Special Council to accommodate the COVID-19 recovery package. Herewith, the share of AI expenditure is likely to be reduced, too. European Council. Conclusions of the Special meeting of the European Council (17, 18, 19, 20 and 21 July 2020). EUCO 10/20, p. 20.

220 Proposal for a Regulation of the European Parliament and of the Council establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination, COM(2018) 435 of 06.06.2018.

221 Also in this case, following the reduction of the overall budget of Horizon Europe from €94 billion to €75.9 billion, this financial envelope may be slashed. European Council. Conclusions of the Special meeting of the European Council (17, 18, 19, 20 and 21 July 2020). EUCO 10/20, p. 18.

222 European Commission (2019). STRIA Roadmap on Connected and Automated Transport: Road, Rail and Waterborne.

223 European Commission (2016). Space Strategy for Europe, COM(2016) 704 of 26.10.2016.

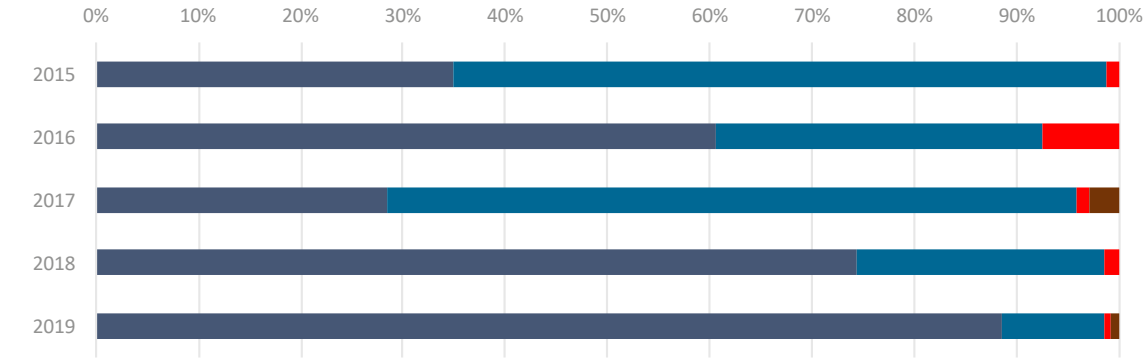
224 European Council. Conclusions of the Special meeting of the European Council (17, 18, 19, 20 and 21 July 2020). EUCO 10/20, p. 18. For a concise description of the Galileo and EGNOS application see EGSA (2017). EGNOS and Galileo for ITS and road transport: High flexibility, low investment.

225 See GCS-Europe (2019). Galileo: a critical component for autonomous driving. A prototype was built and tested within the ESCAPE project: GSA (2019). First Galileo-enables autonomous vehicle successfully demonstrated. Further applications and services are being developed by the PRoPART project, see Inside GNAA (2020). Brussels View: Driverless Merging Ahead.

226 We note that new funding decisions have or will be taken in the context of COVID-19 crisis.

the EU third, behind the United States and Asian countries (China, Korea, Japan).[227] One of the main reasons for that is the lack of venture capital funding available for European start-ups. According to OECD, private equity investments in AV have been steadily growing since 2015 and represent a larger share of all AI investments (30 % in mid-2018).[228] The lion share of this venture capital, in absolute numbers, goes to US-based start-ups (80 % in 2017-2018), followed by China-based start-ups (15 %[229]), Israel-based (3 %[230]) and, finally, the EU-based (2 % or $89 million[231]). OECD attributes the increase in venture capital funding to the growth of the average amount per investment: in the US, it increased from $20 million in 2016 up to $200 million in 2018.

Figure 12: Venture capital funding in AV in 2015-2019 (share of global amount per region, in billions of US dollars)



	2019	2018	2017	2016	2015
USA	3,08	4,46	1	0,55	0,28
Asia	0,35	1,45	2,37	0,29	0,51
Europe	0,021	0,089	0,045	0,069	0,01
Other	0,03	0	0,1	0	0

Source: CB Insights at Reuters.
Note: 2019 numbers were available only to 1st July.

Both the Commission and research (specifically on connected and automated driving) emphasised another problem of European investments: fragmentation and lack of coordination.[232] A third

[227] See a comprehensive research on many metrics related to AI development and deployment in Castro, D., McLaughlin, M. and Chivot, E. (2019). Who Is Winning the AI Race: China, the EU or the United States? Research paper by Center for Data Innovation.

[228] OECD (2018), Private Equity Investment in Artificial Intelligence. OECD Going Digital Policy Note, OECD, Paris.

[229] McKinsey reports that, over the last five years, Chinese startups received $7 billion in venture capital. See McKinsey (2019). How China will help fuel the revolution in autonomous vehicles.

[230] Although Israel is leading by far on a per capita investment basis. See KPMG (2020). 2020 Autonomous Vehicles Readiness Index, pp. 53 and 55.

[231] Reid H, Ostad E (2019). European startups navigate long, winding road to self-driving future. Reuters.

[232] See European Commission (2018). Member States and Commission to work together to boost artificial intelligence 'made in Europe'. Press release; WIFO, SPI, VTT and Ecorys (2017). Public Support Measures for Connected and Automated Driving. Study for DG GROW, p. 49.

problem is the over-reliance on public funding in the area of connected and automated driving.[233] The new funding instruments seem to address both problems. They offer a more streamlined framework for R&D&I in AI with the CEF, DEP and Horizon Europe as main instruments having different focal points and complementing each other. The specific objective of the CEF and the DEP is to use public funding as a leverage to unlock the private one, by focusing on the least attractive areas for private investment (e.g. persistent market failures). In this way, the EU aims to raise around €20 billion per year in public and private investments in AI.[234]

Whether these remarkable efforts to address venture capital shortage will be enough to sustain the intense competition from the US and China remains to be seen. Some experts even remark the competitive gain of the lack of funding: being on tight budgets, AV start-ups are pushed to find innovative technical solutions.[235]

Meanwhile, scholars point out that EU's weaknesses should be addressed beyond funding. The EU struggles to retain talent, especially at the executive level, has problems translating research into business applications and adopting AI.[236] Much of the planned funding under the DEP and Horizon Europe targets the research-to-market gap. Development and deployment of AI in transport are further fostered by a few industrial initiatives. Within the network of Digital Innovation Hubs (DIH), 30 that are focused on AI were selected for coaching to develop collaborative business models.[237]

In 2016, the Commission initiated the creation of Cooperative Intelligent Transport Systems (C-ITS).[238] C-ITS refer to the cooperative element of automated driving enabled by connectivity. Specifically, C-ITS are responsible for communication and interaction between different road users and between road users and infrastructure. The platform C-ROADS was launched to harmonise the C-ITS deployment and ensure interoperability across Europe.[239]

The cooperation and coordination between the telecommunications and automotive industries is important for the success of connected and automated driving. To promote digitisation of the transport sector, create synergy in infrastructure planning and ensure interoperability, the European Automotive-Telecom Alliance (EATA) was launched in 2016.[240] Six main industry associations and companies from all EU Member States participate in the EATA to discuss regulatory issues and cross-border coordination and cooperation as well as tests and pilots.

Promoting competitiveness includes promoting digital skills of the work force. There seem to be no special EU-level programmes targeting the transport sector. However, there are umbrella programmes that aim to close the digital skills gap in Europe in general, most notably the Digital

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233 WIFO, SPI, VTT and Ecorys (2017). Public Support Measures for Connected and Automated Driving. Study for DG GROW, p. 51.

234 European Commission (2018). Member States and Commission to work together to boost artificial intelligence 'made in Europe'. Press release.

235 Reid H, Ostad E (2019). European startups navigate long, winding road to self-driving future. Reuters.

236 Castro, D., McLaughlin, M. and Chivot, E. (2019). Who Is Winning the AI Race: China, the EU or the United States? Research paper by Center for Data Innovation.

237 For more information see European Commission (2019). 30 Digital Innovation Hubs focused on Artificial Intelligence selected for a training programme.

238 European Commission (2016). A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility. COM(2016) 766 of 30.11.2016.

239 Official website: https://www.c-roads.eu/platform/about/about.html .

240 Official website: https://eata.be/about-us/ .

Skills and Jobs Coalition.[241] In July 2020, the European Commission launched the European Skills Agenda for sustainable competitiveness, social fairness and resilience that sets out ambitious targets in digital skills acquisition by 2025.[242] The Commission estimated that about €48 billion annually of public and private investments would be necessary to close the skills gap, and it plans to use EU funds from the European Social Fund Plus, Erasmus, InvestEU, DEP and the Recovery and Resilience Facility finance upskilling and reskilling initiatives and trigger private investments.

4.1.3. EU legal and regulatory framework for AI in transport

EU regulatory framework for autonomous vehicles

Introduction of autonomous vehicles to the Single Market

Specific legal instruments applying to AV

The **General Vehicles Safety Regulation (GVSR)** increases the safety requirements for motor vehicles dedicated and designed for transportation of passengers, goods and for their trailers.[243] It contains specific definitions and provisions within the field of AV. This regulation is the first EU legal instrument defining what are 'automated vehicles'[244] and 'fully automated vehicles'.[245] It contains a set of specific systems that will become mandatory for automated vehicles and fully automated vehicles such as systems that must be able to replace the driver and carry out his tasks or that provide real-time information to the vehicle about its environment (except for the driver availability monitoring systems which do not apply to fully automated vehicles).[246] The regulation also empowers the Commission to adopt delegated acts to specify the technical requirements of these systems.

In addition to the specific provisions related to AV, the GVSR deals with four issues that have potential implications for AV:

- First, it defines new advanced safety systems such as intelligent speed assistance, advanced driver distraction warning, advanced emergency braking system and emergency lane-keeping system;[247]
- Second, it imposes on manufacturers the obligations to ensure that all vehicles, systems, technical units and components comply with technical regulatory requirements concerning, *inter alia*, protection against unauthorised use and

[241] For more information see the Digital Skills and Jobs Coalition.

[242] Main materials are available in European Commission (2020). Commission presents European Skills Agenda for sustainable competitiveness, social fairness and resilience. Press release.

[243] Regulation 2019/2144 of the European Parliament and of the Council of 27 November 2019 on type-approval requirements for motor vehicles and their trailers, and systems, components and separate technical units intended for such vehicles, as regards their general safety and the protection of vehicle occupants and vulnerable road users, OJ L 325 of 16.12.2019. This Regulation shall apply from 18 July 2022 and replace Regulations 78/2009, 79/2009 and 661/2009. Motor vehicles designed and constructed for transportation of passengers are vehicles of Classes M1, M2 and M3. Motor vehicles designed and constructed for transportation of goods are vehicles of classes N1, N2 and N3. Classes O1, O2 and O3 relate to trailers for motor vehicles.

[244] Article 3(21) GVSR: 'a motor vehicle designed and constructed to move autonomously for certain periods of time without continuous driver supervision but in respect of which driver intervention is still expected or required'.

[245] Article 3(22) GVSR: 'a motor vehicle that has been designed and constructed to move autonomously without any driver supervision'.

[246] Article 11 GVSR.

[247] Article 3 GVSR.

cyberattacks and remote access to in-vehicle data or software modification that endanger vehicle passengers and other road users;[248]

- Third, it also requires event data recorder, intelligent speed assistance and advanced driver distraction warning for all motor vehicles; braking and lane-keeping systems for cars and light commercial vehicles as well as special systems to detect and avoid vulnerable road users for buses and trucks;[249] and provides high-level technical requirements for those safety systems, including with regard to the processing of personal data.[250]

The **Approval and Market Surveillance of Vehicles Regulation (AMSVR)** lays down an administrative type-approval procedure for manufacturers willing to market a vehicle, system, component or separate technical unit in the entire EU territory.[251] The manufacturer has to demonstrate that each candidate vehicle type, system, component or separate technical unit comply with technical regulatory requirements contained in Annex II AMSVR. They refer to many UNECE technical regulations on standardisation of car components (e.g. directional equipment, lamps, heating systems). EU type-approval certificates are issued by national approval authorities and allow a manufacturer to market vehicles EU-wide without any additional requirements. EU type-approvals are issued after verification of the compliance with the relevant requirements. Compliance checks are carried out by technical services designated by approval authorities. During the certification process, manufacturers must establish an information folder and can be required to grant access to any software or algorithm but also, if needed, to provide information or documentation necessary to understand this software or algorithms.[252] Thus, approval authorities and technical services can request information that is necessary to understand software and algorithms underlying the functioning of AV.

National authorities can also refuse to issue EU type-approval certificates for vehicles or components that present high safety risks despite compliance with the relevant requirements.[253] It can happen, for instance, when specific technical requirements do not (yet) exist for components necessary for AV. Moreover, to allow innovation while ensuring safety, the regulation includes a procedure for manufacturers to obtain, under specific cumulative conditions, a type-approval if they use new technologies or new concepts that prevent from complying with the relevant requirements.[254] These type-approvals can only be issued if the manufacturer (i) justifies why new technologies or concepts prevent compliance with the relevant requirements; (ii) ensures a level of safety equivalent

248 Article 4.5. GVSR.

249 Articles 6 and 7 GVSR.

250 Article 6 GVSR. Additionally, Recital 10 of the Regulation specifies that advanced emergency braking systems, intelligent speed assistance, emergency lane-keeping systems, driver drowsiness and attention warning, advanced driver distraction warning and reversing detection systems should function without using any biometric information of drivers and passengers.

251 Regulation 2018/858 of the European Parliament and of the Council of 30 May 2018 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, OJ L 151 of 14.06.2018. This Regulation shall apply from 1st September 2020 and repeal Directive 2007/46 of the European Parliament and of the Council of 5 September 2007 establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles (Framework Directive).

252 Article 25.4. AMSVR.

253 Article 26.5. AMSVR.

254 Article 39 AMSVR. In 2019 Commission issued a set of guidelines relating to the decision of granting type approval under this procedure. See European Commission (2019), Guidelines on the exemption procedure for the EU approval of automated vehicles.

to that provided by the relevant requirements, and (iii) provides test results to ensure a similar safety level. After the adoption of implementing acts, the European Commission will decide whether or not to grant an exemption. In the meantime, national authorities can grant provisional exemptions limited to their territories.

Finally, the AMSVR ensures that manufacturers grant an unlimited, standardised and non-discriminatory access to vehicles' on-board diagnostics (ODB) and repair and maintenance information[255] (including security features of the vehicle).[256]

The **eCall Regulation** requires that cars are equipped with a system enabling to automatically or manually send data and establish an audio communication with 112 in case of emergency.[257] The regulation also includes the following safeguards for data protection and privacy of car users: a limited set of data is processed and transferred only in cases of emergency; the eCall system cannot be traced, constantly tracked or (mis)used for permanent surveillance; the data, including location data, in the system memory are continuously erased; the system cannot exchange data with added value services, and vehicle's users are informed about the data usage by the system.[258]

Horizontal rules

In addition to the sector-specific rules related to AV, the **General Product Safety Directive (GPSD)**[259] ensures that only safe consumer products (i.e. that *do not present any risk or only the minimum risks* under normal conditions of use taking into account, *inter alia,* its characteristics and effects of the product on other products[260]) are placed on the market by manufacturers.[261] The GPSD imposes an obligation on producers to provide consumers with information about their products to enable consumers to assess the risks inherent to these products during their reasonably foreseeable lifecycle. Finally, it enables the Member States to check the safety of the products and, if necessary, to take proportionate actions (e.g. mandating the use of a specific warning, ban the marketing of a product, ordering the recall of a product). In the absence of a specific requirement concerning driver drowsiness monitoring systems, the safety of such products should comply with the rules of the GPSD.[262]

The **Radio Equipment Directive (RED)**[263] establishes a regulatory framework for the placing on the market and free movement of radio equipment that operates on radioelectric frequencies under 3 000 GHz.[264] As radio equipment can be used in AV, for instance, as one of the vehicle components communicating with the road infrastructure or other vehicles, compliance with the RED rules must

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255 Articles 3(48) and 3(49) of AMSVR for definition.

256 Articles 61, 62 and 63 AMSVR. Annex X of the Regulation details the content and the technical requirements of this obligation.

257 Regulation 2015/758 of the European Parliament and of the Council of 29 April 2015 concerning type-approval requirements for the deployment of the eCall in-vehicle system based on the 112 service, OJ L 123 of 19.05.2015. The Regulation applies to every new type of cars and light commercial vehicles built after 31 March 2018.

258 Article 6 eCall Regulation.

259 Directive 2001/95 of the European Parliament and of the Council of 3 December 2001 on general product safety, OJ L 11 of 15.01.2002.

260 Article 2 GPSD for the definition.

261 Article 3 GPSD.

262 Motor Vehicles General Safety Regulation integrate rules on such products but will only apply from 18 July 2022.

263 Directive 2014/53 of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment, OJ L 153 of 22.05.2014.

264 Articles 2.1.1) and 2.1.4) RED.

be ensured.[265] The RED imposes the following relevant obligations on manufacturers: (i) radio equipment must meet essential requirements in terms of safety and electromagnetic compatibility;[266] (ii) manufacturers must provide consumers with easily understandable safety information and use instructions that include a description of the software incorporated in the product.[267] The directive also empowers the European Commission to adopt delegated acts identifying equipment where manufacturers must provide information on the compliance of the combination of these products and software with essential requirements of the RED.[268]

The **Regulation on ENISA and on ICT cybersecurity certification (Cybersecurity Act)** creates an EU cybersecurity certification framework in order to ensure that ICT products, services and processes are evaluated in accordance with cybersecurity schemes (i.e. *sets of rules, technical requirements, standards and procedures*) established at the EU level. AV products and services could be subject to such certification schemes.[269] The Cybersecurity Act mandates the European Union Agency for Cybersecurity (ENISA) to prepare EU cybersecurity schemes at the European Commission's request. EU certification schemes must be designed to guarantee that certified ICT products, services and processes meet a minimum set of cybersecurity requirements such as data integrity, confidentiality, authenticity, availability or having sufficient security updates mechanisms. Cybersecurity schemes should also incorporate security by design and by default principles. Depending on the risk level of the certified product, each EU scheme established will specify one or more assurance levels ranging from basic to high. Certification schemes with a high level of assurance are in principle issued only by national authorities and ensure that certificated product is evaluated to minimise the risk of cyberattacks carried out by actors with significant skills and resources.[270] Cybersecurity certification can be made mandatory under national or EU law for specific ICT products, services or processes. Thus, a mandatory cybersecurity certification could mitigate the potential risks associated with the development of AV and increase consumer trust in these products and services. In November 2019, ENISA adopted good practices for the security of connected and automated vehicles which recommend that car manufacturers and service providers encrypt personal data to prevent its disclosure to illegitimate parties.[271]

The **General Data Protection Regulation (GDPR)** established a legal framework for the processing of personal data.[272] Both developing and operating AI-based AV products and services heavily rely on personal data, for instance, for a driver monitoring system. The European Data Protection Board

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265 Also see European Commission (2018). Guide to the Radio Equipment Directive 2014/53, p.17 stating that, 'where radio equipment is installed in vehicles such as cars, it must comply with the requirements of both the RED and all applicable EU acts'.

266 Moreover, the European Commission can establish categories and classes of equipment that must comply with additional requirements and features such as ensuring (i) protection against fraud, (ii) installation of software where compliance of the combination has been demonstrated and (iii) protecting personal data.

267 Article 10.8 RED.

268 Articles 3.3. and 4 RED.

269 Regulation 2019/881 of the European Parliament and of the Council of 17 April 2019 on ENISA (the European Union Agency for Cybersecurity) and on information and communications technology cybersecurity certification, OJ L 151 of 07.06.2019. Part of this Regulation's provision (including on national cybersecurity certification authorities) will apply from 28 June 2021.

270 Article 56 Cybersecurity Act.

271 ENISA (2019). Good practices for security of smart cars.

272 Regulation 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, OJ L 119 of 04.05.2016.

(EDPB) adopted a broad definition of personal data with regard to connected vehicles.[273] While the GDPR mainly contains rules relating to the use of AV products and services (see Section 2 below), some provisions are relevant to the introduction of AV to the market. When determining the means of the data processing, data controllers are required to implement appropriate measures to ensure compliance with the rules and principles of the GDPR (data protection by design principle).[274] When the processing of personal data implies using new technologies, data controllers must assess the risks for the rights and freedoms of natural persons. If such processing operation results in high risks, data controllers must carry out a data protection impact assessment. In some circumstances, data protection impact assessments are mandatory, including when far-reaching automated decisions are based on data processing that includes profiling.[275]

Sector-specific rules on the use of autonomous vehicles

Safety and liability of autonomous vehicles

The **Approval and Market Surveillance of Vehicles Regulation (AMSVR)** contains several provisions that apply during the use of products. First, each Member State must designate an authority for market surveillance to carry checks verifying the compliance of vehicles, systems, components and separate technical units with the requirements of the AMSVR. National authorities can request any information, including access to software and algorithms. National authorities have the power to investigate the compliance of AI-based AV products with safety requirements of EU law. The AMSVR also empowers the European Commission to carry out checks of compliance with the regulation of the EU market approvals granted to vehicles, systems, components and separate technical units.

When national authorities grant market approval for any vehicles, systems, components and separate technical units, they must carry out checks to verify that manufacturers produce products that comply with their initial authorisations. These checks are based on products obtained from the manufacturers' facilities, and the authority can request access to software, algorithms and any information necessary to understand their functioning. Basically, the authorities responsible for types approval must monitor compliance of products with this market approval.

When, based on its checks or notification from type-approval authorities, a market surveillance authority discovers that a vehicle, systems, components and separate technical units present high risks or do not comply with the AMSVR, it must assess the item in question. If the manufacturer fails to remedy for the non-compliance or if the risk requires swift measures, national authorities can withdraw or recall the product.

Lastly, the EU type-approval authorities may impose sanctions on manufacturers that failed to provide access to vehicle OBD information and vehicle repair and maintenance information. These sanctions may include fines or withdrawal of type-approval.

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[273] See EDPB (2020). Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications, open for feedback version, p.12: 'most data associated with connected vehicles will be considered personal data to the extent that it is possible to link it to one or more identifiable individuals. This includes technical data concerning the vehicle's movements (e.g., speed, distance travelled) as well concerning the vehicle's condition (e.g. engine coolant temperature, engine RPM, tyre pressure)'.

[274] Article 25 GDPR.

[275] Article 35 GDPR.

The **Motor vehicles Insurance Directive (MID)** requires that all vehicles registered in the EU hold mandatory third-party liability insurance to cover civil liability in respect of the use of vehicles.[276] The directive defines vehicles as any road motor vehicle intended for travel on land and propelled by mechanical power (except for vehicles using rails), hence this definition may cover any automated or fully automated vehicle. The MID also ensures that third party insurance covers physical damages (including to passengers of the car) and damages to property. However, it does not harmonise liability regimes across Member States. The MID establishes mandatory minimum amounts for physical damages (i.e. €1m per victim or €5m per claim) and damages to property (i.e. €1m per claim).[277] The MID establishes a mechanism to simplify and accelerate the settlement of claims and compensation for victims of vehicle accidents.

Deployment of intelligent transport systems

The **Intelligent Transports Systems (ITS) Directive** establishes a framework for deployment and use of Intelligent Transports Systems, application and services in the field of road transport in the EU.[278] Under the ITS Directive, an ITS is defined as '*system in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport*', which may cover AV products and services.

The ITS Directive identifies four priority areas for development of ITS, which are: (i) use of road, traffic and travel data, (ii) continuity of traffic and freight management services, (iii) road safety and security and (iv) communication between vehicles.[279] The ITS Directive also identifies six priority actions within those areas, for instance, providing EU-wide real-time traffic information services and multimodal travel information services.[280]

To enable the deployment of ITS application and services within these priority areas, the directive empowers the Commission to adopt technical, functional, organisational and service specifications through delegated acts. Member States are required to take the necessary steps to implement these specifications when deploying ITS services and applications. These specifications must be implemented in accordance with a set of principles detailed in Annex II of the ITS Directive (e.g. being cost-efficient, proportionate, delivering interoperability, facilitating intermodality). Hence, the ITS Directive establishes a framework identifying priority areas for applications and services that may be used in support of or in combination with AV products and services. Finally, the ITS Directive contains specific provisions on data protection.[281]

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[276] Directive 2009/103 of the European Parliament and of the Council of 16 September 2009 relating to insurance against civil liability in respect of the use of motor vehicles, and the enforcement of the obligation to insure against such liability, OJ L 263 of 07.10.2009.

[277] Note that a Proposal for a Directive amending MID increase these mandatory minimum amounts for physical damages and damages to properties covered by third party civil liability insurance. See Proposal for a Directive of the European Parliament and of the Council amending Directive 2009/103/EC of the European Parliament and the Council of 16 September 2009 relating to insurance against civil liability in respect of the use of motor vehicles, and the enforcement of the obligation to ensure against such liability, COM(2018) 336 of 24.05.2018.

[278] Directive 2010/40 of the European Parliament and of the Council of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport, OJ L 207 of 06.08.2010.

[279] Article 2 ITS Directive.

[280] Article 3 ITS Directive.

[281] In particular, Member States must ensure that ITS applications and services comply with the GDPR and e-privacy Directive, avoid violations of personal data, its integrity and confidentiality, process personal data only for purposes

The **Commission Delegated Regulation 886/2013 on road safety** specifies conditions for the deployment, data use and procedures related to an EU-wide free (where possible) road safety-related universal traffic information services.[282] Road operators, services providers and specialised broadcasters must provide to road users real-time information, advice and location relating to a set of identified road safety events (e.g. slippery road, obstacles, unprotected accident). To this end, road operators and service providers must develop special means to detect relevant events, identify conditions and collect safety-related traffic data.[283] They must also share and update their data in a fully compatible and interoperable machine-readable format.[284] Member States must create a national digital access point gathering data from road operators and service providers to enable re-use of their data within an adequate timeframe.[285] Thus, this delegated regulation creates useful mechanisms for the safe usage and functioning of AV products and services.

The **Commission Delegated Regulation 2015/962 on traffic information services** specifies conditions for development and provision of EU-wide compatible, interoperable and continuous real-time traffic information.[286] It distinguishes between three types of data: (1) static road data (i.e. data that do not often change such as the location of services area),[287] (2) dynamic road data (i.e. data describing the status of the road and often changing such as availability of parking places)[288] and (3) traffic data (i.e. data on road traffic characteristics such as traffic volume).[289] In addition, it requires that Member States create a digital interface gathering road data and traffic data (including metadata) retained by road authorities and road operators to enable search and re-use of these data.[290] Road authorities and road operators must provide these data through the national interface on a non-discriminatory basis and in an adequate timeframe. Formats for each type of data are also specified. Data may, therefore, be used to develop or operate AV products or services such as real-time itineraries optimisers. Finally, this delegated regulation provides specific rules on the update parameters of each kind of data to enable real-time traffic information services based on up to date data.

The **Commission Delegated Regulation 2017/1926 on travel information** ensures the provision of accurate multimodal travel information services available EU-wide.[291] The delegated regulation distinguishes between three types of data: 1) historic traffic data, 2) static travel and traffic data and 3) dynamic travel and traffic data. Member States must create a digital interface gathering historic traffic data and static travel and traffic data (including relevant metadata) of the transport

linked to their functioning, use anonymous data where possible and process sensitive data on basis of the users' consent.

282 Commission Delegated Regulation 886/2013 of 15 May 2013 supplementing Directive 2010/40 of the European Parliament and of the Council with regard to data and procedures for the provision, where possible, of road safety-related minimum universal traffic information free of charge to users, OJ L 247 of 18.09.2013.

283 Article 6 of the Commission Delegated Regulation 886/2013 on road safety.

284 Article 7 of the Commission Delegated Regulation 886/2013 on road safety in annex.

285 For the definition of 'user of road safety-related minimum universal traffic information' see Article 2.n) of the Commission Delegated Regulation 886/2013 on road safety.

286 Commission Delegated Regulation 2015/962 of 18 December 2014 supplementing Directive 2010/40 of the European Parliament and of the Council with regard to the provision of EU-wide real-time traffic information services, OJ L 157 of 23.06.2015.

287 Article 2.6) of the Commission Delegated Regulation 2015/962 on traffic information services.

288 Article 2.7) of the Commission Delegated Regulation 2015/962 on traffic information services.

289 Article 2.8) of the Commission Delegated Regulation 2015/962 on traffic information services.

290 Articles 3 and 4 of the Commission Delegated Regulation 2015/962 on traffic information services.

291 Commission Delegated Regulation 2017/1926 of 31 May 2017 supplementing Directive 2010/40 of the European Parliament and of the Council with regard to the provision of EU-wide multimodal travel information services, OJ L 272 of 21.10.2017.

authorities transport operators, infrastructure managers and transport on-demand service manager (potentially including mobility as a service provider operating AV-based service) to enable search and re-use of these data. Data must be accessible in the format defined in the regulation. Member States can also decide to provide dynamic data. Data must be accessible on a non-discriminatory basis. Travel information services shall provide routing results to other travel information services upon request (linking services). Linking must be subject to contractual agreements, and costs must be reasonable and proportionate. Finally, reuse of data must be neutral, non-discriminatory and not biased. Criteria used for ranking must be transparent, not based on factors related to user identity and applied without discrimination to all users.

Horizontal rules on the use of autonomous vehicles

While the section above addresses the regulatory framework that directly affects autonomous vehicles, it represents only a fraction of the rules that apply in this space because certain rules that touch on a number of sectors also shape this one. These horizontal rules apply to six broad categories:

- **Empowering consumers.** Rules that help to balance information asymmetries and other market failures as consumers interact with businesses that are providing products and services in relation to CAD.
- **Empowering business users.** As with empowering consumers, these are rules that address market concerns of businesses along a value chain.
- **Security and data.** Rules that address issues around the security of road transportation, in particular around data protection and privacy.
- **Liability rules.** Rules that address who is responsible for failures and accidents within the road transportation sector, both from a business and consumer perspective.
- **Data governance.** Related to the security and data category, rules that address how data should be handled by providers.
- **Intellectual property.** Rules related to protecting the rights of intellectual property.

Empowering consumers in B2C relationships

The **Consumer Rights Directive (CRD)** applies to sales and services contracts between professional traders and consumers (B2C) and ensures that consumers get access to a minimum set of information before being bound by a contract.[292] Among other things, the trader must provide to consumers information about the main characteristics of the goods (including physical goods that incorporate digital content or services or which requires a digital content or services to operate properly) or services, the existence of a legal guarantee of conformity (also applying to digital content and services), the functionalities, interoperability and compatibility of goods, digital content/services.[293] Hence, consumers must, for instance, be informed about the degree of autonomy of any AV products or services (e.g. if the vehicle automated or fully automated, what it means and under which condition automated driving mode can be activated).

The CRD also increases the transparency requirements and grants consumers a 14-days withdrawal right in the case of distances contracts (e.g. when the contract is concluded online).[294] However, the withdrawal right may not apply to digital contents that are not supplied on tangible mediums if the

[292] Directive 2011/83 of the European Parliament and of the Council of 25 October 2011 on consumer rights, OJ L 304 of 22.11.2011. The Directive does not apply to passenger transport services contracts.

[293] Article 5 CRD.

[294] Article 6 CRD.

following conditions are met: (i) the consumer has been informed prior to the conclusion of the contract, (ii) the consumer has acknowledged losing its right, and (iii) the trader has provided a durable medium confirming this fact after the conclusion of the contract.

The **Unfair Commercial Practice Directive (UCPD)** also applies to B2C relationships and prohibits trading practices (including advertising) that are unfair.[295] In particular, the UCPD prohibits misleading actions and omission.[296] Information about main characteristics of goods and services, such as risks, execution, composition, accessories, fitness for purpose, usage, quantity, specification, are considered important elements when assessing the misleading nature of the commercial practice.[297] Practices such as presenting AV products or services as riskless, omitting to inform about some feature limitations of highly automated vehicles or falsely pretend that a vehicle is fully automated can violate the UCPD.

The **Digital Content Directive (DCD)** applies to B2C contracts for the provision of digital content and digital services (including when provided in exchange for consumers personal data).[298] It defines (i) digital content as data produced and supplied in digital form and (ii) digital services as services allowing creation, processing, storing or accessing in digital form or allowing interaction with data uploaded or created by the consumer or other users. AI-based services or applications in AV may fall under this definition (e.g. intelligent real-time road traffic assistant application). As the DCD does not apply to digital contents or services incorporated or interconnected with goods – and which are essential for the performance of the goods – under the sale contract of these goods, it may not apply to digital content mandatory for the proper functioning of fully automated vehicles.[299]

Within its scope, the DCD lays out rules to assess the conformity of digital content and services. To that extent, the content or service must: (i) meet subjective requirements with regard to the contract such as possessing the described functionality, compatibility, interoperability and features, being provided with instruction, customer assistance, and being updated according to the contract;[300] (ii) meet objective requirements for conformity,[301] including: content or services must, in particular, be fit for their purpose with regard to the law, technical standards or specific code of conducts and possess qualities and features (e.g. functionality, continuity and security) that consumer may reasonably expect (including with regard to any advertising); the consumer is informed of any update and security update necessary to ensure that content or services remain conform and (iii) be correctly integrated into consumer digital environment by the trader or possess adequate instruction enabling integration by the consumer.

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295 Directive 2005/29 of the European Parliament and of the Council of 11 May 2005 concerning unfair business-to-consumer commercial practices in the internal market, OJ L 149 of 11.06.2005.

296 Misleading actions are commercial practices that (i) contain false information or information that is likely to deceive consumers with regard to some goods or services and (ii) are likely to distort the economic behaviour of consumers (i.e. make her/him take a transactional decision that she/he would not have taken otherwise such as buying goods or services).

297 Articles 6 and 7 UCPD.

298 Directive 2019/770 of the European Parliament and of the Council of 20 May 2019 on certain aspects concerning contracts for the supply of digital content and digital services, OJ L 136 of 55.05.2019. Member States shall adopt and publish measures necessary to comply with this Directive by 1st July 2021 and apply those measures from 1st January 2022.

299 Article 3 DCD.

300 Article 7 DCD.

301 Article 8 DCD.

The DCD also ensures that traders are liable for lack of conformity of digital content and services and creates different regimes for contracts concerning a single act of supply or continuous supply. For the single act of supply contracts, the trader is liable for any lack of conformity that exists at the time of the supply and becomes apparent within a minimum period of two years. For contracts concerning continuous supply, the trader is liable for any lack of conformity that appears within the entire duration of the contract. In such cases, consumers may request the content or service be brought into conformity, a proportional reduction of the price or, where a major lack of conformity exists, termination of the contract.

Finally, the DCD also contains specific rules on modification of contents/services for continuous supply contracts and allows consumers to obtain termination of the contract if the trader fails to supply content or services.

The **Directive on aspects concerning contracts for the sale of goods (DCSG)** applies to B2C sales contracts of goods.[302] It defines goods as tangible movable items, including items that incorporate or are interconnected with digital content and services mandatory for their proper operation. Thus, many products incorporating digital content or services within the field of AV may fall under these definitions (e.g. an AV or a vehicle component such as a driving monitoring system, child presence detection system). The DCSG also applies to digital content or services incorporated or interconnected with goods – and which are essential for the performance of the goods – provided under the sale contract of these goods.[303] It may, therefore, apply to digital content (e.g. software or operating system) mandatory for the proper functioning of fully automated vehicles.

Within this scope, the DCSG provides rules to assess the conformity of goods. To be considered as conform, goods must: (i) meet subjective requirements regarding the contract that are similar to those of the DCD, including that goods must be supplied with updates according to the contract and (ii) fulfil objective requirements for conformity similar to those of the DCD, including that goods must possess qualities and features (e.g. functionality, compatibility and security) that the consumer may reasonably expect; the consumer is informed of any update and security update necessary to ensure that goods including digital content remain conform.[304] For instance, a good presented as a highly automated vehicle but still requiring driver's supervision in easy driving situation (e.g. highway driving) might be considered as not fulfilling the subjective requirement of conformity. The consumer may also expect that driver monitoring systems detect drowsiness. Also, car traders will have to provide adequate information about the security updates of AV products.

However, the DCSG provides that a trader shall not be liable for the lack of conformity, where the goods contain digital content or services if consumers do not install updates after having been informed of their existence and significance.

Traders are liable for the lack of conformity of goods when a good includes a single act of supply of content or services.[305] In this case, the trader is liable for any lack of conformity that exists at the time of the delivery of the goods and becomes apparent within a minimum period of two years. The same applies to goods that include a continuous supply of digital content or services for a duration of up to two years. For goods that include continuous supply of digital content or services for more than two years, the trader is liable for any lack of conformity that appears within the entire duration of

[302] Directive 2019/771 of the European Parliament and of the Council of 20 May 2019 on certain aspects concerning contracts for the sale of goods, OJ L 136 of 22.05.2019. Member States shall adopt and publish measures necessary to comply with this Directive by 1st July 2021 and apply those measures from 1st January 2022.

[303] Article 3 DCSG.

[304] Article 7 DCSG.

[305] Article 10 DCSG.

the contract. Thus, it may apply to goods with a long lifecycle that need updates during the whole lifecycle such as vehicles. In such cases, consumers may request the replacement or repair of the goods in order to have them brought in conformity. The consumer can also request a proportional reduction of the price or, where the lack of conformity is not minor, termination of the contract.

Empowering business users in B2B relationships

The **E-Commerce Directive (ECD)** creates a legal framework for online services in the internal market and ensures their free movement between Member States.[306] It contains, among others, transparency and information requirements relating to information society services (e.g. providers must communicate clear prices, address, name) and requires that Member States allow the conclusion of contracts by electronic means.

The **regulation on platform-to-business relations (P2B Regulation)** applies to the relationship between online intermediation services (e.g. platforms) and professional users of these services to ensure transparency, fairness and effective redress possibilities.[307] The regulation requires that terms and conditions of an intermediation services provider contain mandatory information (e.g. about grounds for suspension or restriction). Any change of terms and conditions must be notified to the users at least 15 days before being implemented.[308] Restriction or suspension of services for a business user must be reasoned. Termination of service provision must be notified 30 days before taking effect. In any case, the business user must be able to contest the decision.

Terms and condition of intermediation services providers must contain information relating to the parameters used for ranking and description of differentiated treatment if any. Furthermore, terms and conditions must contain a description of technical and contractual access, if any, to personal data and/or other data provided by users when using the service or generated through the use of the service.[309] Terms and conditions must also inform about any transfer of data to third parties and its purpose and possibilities, if any, to opt out of data sharing.

Security and data protection rules

The **Network and Information Systems (NIS) Directive** aims to ensure a high level of security for network and information systems in the EU, meaning the ability to resist to action compromising the availability, confidentiality, authenticity or integrity of such network and systems.[310] It requires that Member States establish a list of operators of essential services (OES) within their territories that are active in important economic sectors, including transportation.[311] Thus, depending on the Member State, AV products or services may fall within the scope of this directive. Member States must identify OES based on the following cumulative criteria: (i) the undertaking furnishes a service essential to maintain critical for economy or society; (ii) the services heavily rely on network and information systems; (iii) a security incident may have important negative effects on the service (e.g. with regard to the number of service users, the potential impact on public safety, the existence of

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306 Directive 2000/31/EC of the European Parliament and of the Council of 8 June 2000 on certain legal aspects of information society services, in particular electronic commerce, in the Internal Market, OJ L 178 of 17.07.2000.

307 Regulation 2019/1150 of the European Parliament and of the Council of 20 June 2019 on promoting fairness and transparency for business users of online intermediation services, OJ L 186 of 11.07.2019. This Regulation is in force and apply from 12 July 2020.

308 Article 3 P2B Regulation.

309 Article 9 P2B Regulation.

310 Directive 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union, OJ L 194 of 19.07.2016.

311 This Annex of the Directive explicitly mentions Road authorities and operator of ITS in the OES category.

alternatives to the service).[312] The operator of services enabling, for instance, truck platooning or operator of a fleet of AV within cities may be considered OES under national law. This may also be the case of undertakings in charge of intelligent road signals that communicate with AV.

The NIS Directive also requires that Member States set security requirements for identified OES.[313] These requirements include at least ensuring that these operators: (i) adopt measures to have an appropriate level of security with regard to the risk of the service and to avoid and minimise security incidents and (ii) notify swiftly of any incident with significant effects on the service continuity. Member States must also impose a similar requirement on digital services such as cloud providers.[314] Finally, the NIS Directive requires that Member States adopt a national strategy defining the strategic objectives and appropriate policy and regulatory measures in relation to cybersecurity and designate a competent national authority.

The **Cybersecurity Act** requires Member States to designate at least one national cybersecurity certification authority to control and ensure that cybersecurity certificate holders comply with cybersecurity schemes. These powers include, among others, requesting information, carrying audits or investigations, withdrawing a certificate in case of non-compliance, requiring cessation of infringement.

The protection of privacy and personal are enshrined by the **EU Charter on Fundamental Rights**.[315] In additions, the **General Data Protection Regulation (GDPR)** contains horizontal rules applying to the processing of personal data in all sectors, including AV products and services. The GDPR provides a set of principles, with which every data processor must comply.[316] In particular, it requires that data processing must be fair and transparent with regard to the data subject and carried out for a clear and specified purpose. The data controller must process only relevant (both in terms of quantity and quality) and accurate data with regard to the stated purpose. Lastly, data must be stored for a limited period, and their integrity and confidentiality must be ensured. Personal data can only be processed on the basis of lawful grounds set out in the GDPR.[317] In addition to the freely given informed consent of the data subject, data can also be processed if it is necessary for the performance of a contract, to cater for the legitimate interest of the controller or to comply with a legal requirement (e.g. the eCall Regulation can be considered as a legal requirement according to EDPB). The EDPB adopted a narrow interpretation of these lawful grounds.[318]

A specific regime applies to some types of data, such as biometric data or health-related data. Processing may be allowed only in specific circumstances, such as the prior explicit consent of the data subject, safeguarding a vital interest of a person or substantial public interest on the basis of EU or national law. Since AV products and services may use such data (e.g. facial or voice recognition to communicate with a vehicle or health data in cases of road accident), compliance with these

312 Article 5 NIS Directive.

313 Article 14 NIS Directive.

314 Article 16 NIS Directive.

315 Articles 7 and 8 EU Charter on Fundamental Rights, OJ C 326 of 26.10.2012.

316 Article 5 GDPR.

317 Article 6 GDPR.

318 Article 29 (2018). Guidelines on Automated individual decision-making and Profiling for the purposes of Regulation 2016/679, p.13; EDBP (2019). Draft Guidelines 2/2019 on the processing of personal data under Article 6(1)(b) GDPR in the context of the provision of online services to data subjects, pp. 14-16; Article 29 (2014). Opinion 8/2014 on the on Recent Developments on the Internet of Things, p.15.

GDPR requirements will be essential. In addition, data relating to offences (e.g. traffic offences) can be processed only under the control of authorities or when authorised by law.[319]

The GDPR provides a set of rights of data subjects with regard to every processing (e.g. right to access, right to be informed). This includes the right to data portability that allows data subjects to obtain their data in a structured, commonly used and machine-readable format from one controller and to have them transmitted to another controller.[320] Data subjects also have the right not to be subjected to solely automated decision-making with legal or far-reaching effects.[321] Such automated decisions can be allowed in specific circumstances (i.e. explicit consent, the performance of a contract or if authorised by law). In this case, controllers must implement safeguard measures and provide meaningful information about the logic of the processing. The question to what extent this right results in an obligation to explain a decision is still debated. Since AV products and services can imply automated decision-making based on personal data and profiling (e.g. deciding that a driver of an AV is in position to take over control of the vehicle), this provision is relevant. The GDPR also specifies that the data controller and processor must take technical and organisational measures to ensure an appropriate level of security to the risk of the processing. These measures include, among other, encryption of data and means to ensure availability and resilience of processing systems and services or availability of personal data.[322]

The GDPR does not apply to data processed by a natural person in the course of a purely personal or household activity.[323] With regard to AV data, the EDPB considers that it may be the case for applications or processes where data remains within the car (i.e. processed locally).[324] The EDPB recommends local processing for biometric data and detailed location data.

The **e-Privacy Directive** applies to the processing of personal data within the field of the electronic communication sector.[325] It ensures the confidentiality of communications and technical data related to these communications (e.g. IP addresses of the users, date, duration) by means of a public communications network and publicly available electronic communications services. Thus, any relevant data transmission between devices (e.g. vehicle, phone, infrastructure component) must remain confidential.[326] In addition, this directive requires that any entity must obtain the user's consent before storing or gaining access to any information in the user's terminal equipment. In line with this requirement, the EDPB considers that a (connected) vehicle must be considered as terminal equipment.[327] Prior consent is not required if these operations are necessary to carry out the transmission of a communication or to provide an information service on the user's request.

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319 Article 10 GDPR.

320 Article 20 GDPR.

321 Article 22 GDPR.

322 In line with this ENISA also considers, in the context of smart vehicles, that encryption of personal data constitutes a good practice in order to avoid unauthorised access. See ENISA (2019). ENISA good practices for security of smart cars, p. 32; ENISA (2016). Cyber security and resilience of smart cars. Good practices and recommendations, p.52.

323 Article 2.2.c GDPR.

324 EDBP, Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications, pp.15-16.

325 Directive 2002/58 of the European Parliament and of the Council of 12 July 2002 concerning the processing of personal data and the protection of privacy in the electronic communications sector, OJ L 201 of 31.07.2002.

326 Article 5 e-Privacy Directive.

327 EDBP, Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications, p.5.

The e-Privacy Directive provides additional requirements for the processing of location data to provide value-added services (i.e. services processing traffic or location data for other purposes than transmitting a communication).[328] Processing of these data must, therefore, be limited to the extent and duration necessary for providing the service and based on the prior informed consent of the user. Users must have the ability to disable the processing of location data temporarily. Lastly, the directive requires that electronic communication services providers adopt, if necessary, together with the electronic network provider, technical and organisational measures to protect the confidentiality and integrity of personal data.

Liability rules

The **Product Liability Directive (PLD)** establishes a strict liability regime of the producer (i.e. the manufacturer of any finished product, raw material or component part) for damages resulting from defective consumer products. This directive applies within the scope of B2C relationships and covers physical damages and damages to property intended to be used or actually used for private purpose.[329]

Under the PLD, a product is defined as any 'movable' even if incorporated into another movable or into an immovable, hence the PLD does not apply to services. While an AV falls under the definition of a product, it is not clear whether stand-alone or embedded software would fall under the definition of a product. AI systems are characterised by a permanent interaction between products and services, and a clear distinction is hard to establish.[330] In an AV, movables and software are constantly interacting and using services (e.g. communication, computation).

The defective nature of a product is assessed with regard to the safety that consumers are entitled to expect, taking into account, product's presentation, reasonably expected use of the product and time when the product was put in circulation.[331] In order to get compensation, the victim of the defective product has to establish the defect of the product and its causal relationship with the damage.[332] Establishing the defective nature of a product may be difficult for AV products due to their technical complexity and, potentially, lack of transparency of algorithms used.

Finally, under the PLD, a producer may not be liable when he/she demonstrates that the defect did not exist at the time when the product was put into circulation or could not be discovered taking into account the technical and scientific state of the art.[333] These limitations of liability also raise difficulties in relation to AV products presenting high technical complexity or designed to adapt based on their use to deliver personalised experiences.

The **E-Commerce Directive (ECD)** contains specific rules concerning the liability of online intermediaries. The directive limits their liability for the content in cases of mere conduit (e.g. internet service providers), caching and hosting. In order to avoid liability for their user's content, the provider must not be aware of the unlawful content's existence and act swiftly to remove or

328 Article 9 e-Privacy Directive.

329 Council Directive 85/374 of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products, OJ L 210 of 07.08.1985.

330 European Commission (2019). Liability and New Technologies, Liability for artificial intelligence and other emerging digital technologies, p.28.

331 Article 6 PLD.

332 Article 4 PLD.

333 Article 7 PLD.

disable access to unlawful content upon obtaining knowledge of it (i.e. notice and takedown).[334] The concept of a hosting service provider has been expanded to online platforms such as marketplaces[335] or social networks.[336] Therefore, it may potentially apply to services within the field of AV, such as journey optimising services based on users' real-time inputs.

Data governance

The **regulation on the free flow of data** applies to the processing of non-personal data and requires that Member States remove legal requirements concerning data localisation.[337] The regulation proposes self-regulatory codes of conduct to facilitate switching services providers (such as cloud providers) and porting data for professional users.[338] These codes of conduct must also ensure that professional users have access to information on the conditions for switching and facilitate the ability for professional users to compare different service offers. Therefore, such codes of conduct could aid the development of AI products and services for AV through facilitating the movement of non-personal data retained by stakeholders.

The **directive on open data and re-use of public sector information (Open Data Directive)** aims at facilitating the re-use – for commercial and non-commercial purposes – of data held by public sector bodies.[339] This directive applies to data held by public undertakings providing public passenger transport services.[340] The Open Data Directive requires that public sector bodies and public undertakings make their data and metadata available, if possible, in formats that are open, machine-readable, accessible, findable and reusable. Public sector bodies must make dynamic data available for re-use via Application Programming Interfaces (API), where possible, immediately after collection.[341]

The re-use of public sector bodies' data shall be free or at marginal costs. Public undertakings may charge fees that are calculated in accordance with transparent, objective and verifiable criteria defined by Member States. Re-use of data cannot in principle be subject to conditions. Member States may, however, use licenses when justified on public interest grounds. Such licenses cannot unduly restrict competition and possibilities of re-use. Conditions on the re-use of data (i.e. costs and licenses) shall apply on a non-discriminatory basis (including to public sector bodies' re-use outside its public interest activities). Public sector bodies and public undertakings cannot grant exclusive rights for re-use of their data.

Moreover, the Open Data Directive introduces the notion of a high-value dataset.[342] This is data that can, when re-used, create substantial benefits for society and economy because they enable the creation of value-added services and applications. High-value datasets must be available for re-use

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334 Article 14 ECD.

335 Case C-324/09, *L'Oréal SA and Others v. eBay International and Others*. EU:C:2011:474, point 110.

336 Case C-360/10, *Belgische Vereniging van Auteurs, Componisten en Uitgevers CVBA (SABAM) v Netlog NV*. EU:C:2012:85, points 27.

337 Regulation 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, OJ L 303 of 28.11.2018.

338 Article 6 Regulation on the free flow of data.

339 Directive 2019/1024 of the European Parliament and of the Council of 20 June 2019 on open data and the re-use of public sector information, OJ L 172 of 26.06.2019. Member states must bring into force the laws, regulations and administrative provisions necessary to comply with the Directive from 17 July 2021.

340 Article 1 Open Data Directive.

341 Article 2.8 Open Data Directive.

342 Article 2.10 Open Data Directive.

in a machine-readable format, trough API, as bulk download and free of charge (even if public undertakings retain the data).[343] High-value datasets include mobility data, hence may lead to access to useful datasets for the development and operation of products and services within the field of AV.

Intellectual property

The **Database Directive** ensures that databases are protected by intellectual property rights.[344] Databases are defined as collections of independent works, data or other materials arranged in a systematic or methodical way and individually accessible by electronic or other means.[345] The Database Directive protects the structure of a database if it constitutes the author's own intellectual creation (i.e. meets the criterion of originality).

Additionally, the directive grants *sui generis* rights for the content of a database to its maker.[346] To benefit from this right, the database maker must be able to demonstrate the existence of a substantial investment in obtaining, verifying or presenting the database content. Investments in the creation of the data are not eligible.[347] The *sui generis* right grants to the database maker the exclusive rights to allow extraction and re-utilisation of substantial parts of a database. Extraction and re-utilisation cover a broad range of actions such as reproducing or making available to the public the content of the database content. Using data and datasets necessary to develop AI-based products or services may, therefore, be subject to the database maker's approval. Finally, the Database Directive contains some exceptions to the *sui generis* right in the context of scientific research. The exceptions refer to the use for illustration purposes in teaching and would have an insignificant impact on the research in the field of AV products and services.

The **InfoSoc Directive** grants to authors exclusive rights to their works if these meet the criterion of originality.[348] The directive, however, does not apply to computer programs. Under the InfoSoc Directive the rightsholders of original works consequently have the exclusive rights to allow or prohibit: (i) the entire or partial, permanent or temporary reproduction of their works by any means (including electronic means);[349] (ii) the communication to the public of their works[350] and (iii) the distribution to the public of their works. The development of AI-based AV products or services may require the reproduction of copyrighted works, which would require prior approval by the author. This directive also foresees exceptions for illustrative purposes in teaching and would have an insignificant impact on the research in the field of AV products and services.

The **Directive on copyright in the digital single market (DSM Directive)** modifies the Database Directive and the InfoSoc Directive and requires that Member States establish two exceptions for

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343 Article 14 Open Data Directive.

344 Directive 96/9 of the European Parliament and of the Council of 11 March 1996 on the legal protection of databases, OJ L 77 of 27.03.1996.

345 Article 1 Database Directive.

346 Article 7 Database Directive.

347 Case C-46/02, *Fixtures Marketing v. Oy Veikkaus*, EU:C:2004:694, point 34; Case C-338/02 *Fixtures Marketing Ltd v. Svenska Spel*. EU:C:2004:696, point 24; Case C-444/02 *Fixtures Marketing v. Organismos prognostikon agonon podosfairou AE (OPAP)*. EU:C:2004:697, point 40; Case C-203/02 *The British Horseracing Board e.a. c. William Hill Organization*. EU:C:2004:695, point 31.

348 Directive 2001/29 of the European Parliament and of the Council of 22 May 2001 on the harmonisation of certain aspects of copyright and related rights in the information society, OJ L 167 of 22.06.2001.

349 Article 2 InfoSoc Directive.

350 Article 3 InfoSoc Directive.

the benefits of text and data mining.[351] The DSM Directive creates exceptions to the exclusive reproduction right under the InfoSoc Directive and to *sui generis* right under the Database Directive. These exceptions may, therefore, benefit the development of AI products and services including in the field of AV.

The first exception allows text and data mining of lawfully accessible contents for the purpose of scientific research pursued by research organisations. It also allows scientific organisations to securely store works and protected content for further research activities, including for verifying results.[352] The second exception benefits the text and data mining activities by any other undertakings, pursued on lawfully accessible contents, even for commercial purposes. Rightsholders have the ability to opt out and signal (including by appropriate technical means) that protected contents cannot be processed for text and data mining for other purposes than scientific research.[353] Additionally, contractual derogation to this second exception is allowed.

The **Computer Programs Directive** grants to authors of computer programs exclusive rights if these programs meet the criterion of originality.[354] The directive ensures that the expression of any form of a computer program (e.g. the source code and the object code of the program) is protected by copyright. Algorithms may nevertheless not be fully or partially protected under this directive, as Recital 11 provides that 'to the extent that logic, algorithms and programming languages comprise ideas and principles, those ideas and principles, those ideas and principles are not protected'.

The Computer Programs Directive grants to the authors of an original software the exclusive rights to allow or prohibit: (i) the permanent or temporary reproduction in part or in whole and by any means of the program (including if reproduction is necessary for loading, running and displaying a program); (ii) translation, adaptation and arrangement of the program; and (iii) distribution of the program.[355] Thus, software that underlies AV products and services can be protected under copyright, and using such software may require the rightsholder's authorisation.

Finally, the Computer Programs Directive contains exceptions to the author's exclusive rights. Among these exceptions, the directive allows the authorised user of a program to observe, study and test the functioning of the software to determine the ideas and principles underlying any of its elements.[356] The directive also allows decompilation (i.e. reverse engineering) by authorised users under specific conditions to ensure interoperability with another computer program.

Summary and principles of the EU regulatory framework

The table below summarises the EU regulatory framework for AV following a life cycle approach. First, the table outlines the rules applicable to the introduction of AV on the market and, second, it outlines the rules on the use of AV. For each step, the table mentions the sector-specific rules applicable to the automotive sector at the start and then the horizontal rules applicable to all sectors of the economy but which can have implication for AV, such as the rules on safety, on transparency and fairness, on security and privacy, on liability, on data governance and on intellectual property.

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[351] Directive 2019/790 of the European Parliament and of the Council of 17 April 2019 on copyright and related rights in the Digital Single Market, OJ L 130 of 17.05.2019. Member states must bring into force the laws, regulations and administrative provisions necessary to comply with the Directive from 17 June 2021.

[352] Article 3 DSM Directive.

[353] Article 4 DSM Directive.

[354] Directive 2009/24 of the European Parliament and of the Council of 23 April 2009 on the legal protection of computer programs, OJ L 111 of 05.05.2009.

[355] Article 4 Computer Programs Directive.

[356] Article 5 Computer Programs Directive.

Table 1: Overview of rules applicable to the introduction and use of AV

	Rules on introducing AV to the market	Rules on using AV
SECTOR-SPECIFIC RULES	**General Safety Regulation 2019/2144 on type-approval requirements for motor vehicles (GVSR)** • Specific definition in context of AV • Specific set of safety systems mandatory to automated and fully automated vehicles • Increase cybersecurity of vehicles: mandatory new advanced safety systems, provide high level technical requirements for advanced safety systems • Data protection and privacy rules for advanced safety systems **Regulation 2018/858 on approval and market surveillance of motor vehicles (AMSVR)** • Type-approval procedure for EU to ensure vehicle safety and compliance with UNECE technical regulations • Contains specific procedure to allow new technologies and concepts • Increases transparency of software and algorithms for technical services and approval authorities • Ensures access to OBD data and repair information for independent operator. **eCall Regulation 2015/758** • Mandatory safety system for cars and light commercial vehicles that contact emergency services in case of road accident • Data protection and privacy requirements for this system	**Regulation 2018/858 on approval and market surveillance of motor vehicles (AMSVR)** • Compliance checks by market surveillance and type-approval authorities • Increases transparency of software and algorithms for market surveillance and approval authorities • Compliance checks by the European Commission • Proportionate remedies in case of non-compliance: corrective and restrictive measures and fines at EU level adopted by the European Commission, specific sanctions relating to refusal to provide access to OBD, repair and maintenance information • Cooperation between national authorities, technical services and the European Commission **Motor Vehicle Insurance Directive 2009/103 (MID)** • Mandatory third-party insurance for civil liability related to use of vehicle covering physical damages and damages to property • Mechanism to accelerate and simplify settlement **Intelligent Transport Systems (ITS) Directive 2010/40** • Identifies priority areas and actions for ITS deployment • Technical, organisational and functional specification adoption trough delegated acts and EU level and implementation of the specifications by Member States • Data protection and privacy requirements for ITS • Ensure applicability of Product Liability Directive rules to use of ITS applications and services set out accordingly to specification adopted by the Commission.

	• Users information (including through car manuals) on data processing	+ Commission Delegated Regulation 886/2013 on road safety related information services + Commission Delegated Regulation 2015/962 on traffic information services + Commission Delegated Regulation 2017/1926 on multimodal travel information services
HORIZONTAL RULES **1. Safety**	**General Product Safety Directive 2001/95 (GPSD)** • Assessment of product safety • Information on safety risks of products **Radio Equipment Directive 2014/53 (RED)** • Set of essential requirements for all radio equipment and additional privacy and safety requirements for specific products through delegated acts • Conformity assessment and technical documentation including information on critical software for operation of products • Safety information (for consumer and end user) describing embedded software and additional information about compliance of radio equipment and software by means of delegated acts	
2. Empowering users		**Unfair Commercial Practice Directive 2005/29 (UCPD)** • Prohibition of misleading actions and misleading omissions of important information regarding main products and services characteristics **Consumer Rights Directive 2011/83 (CRD)** • Mandatory information (including about main characteristics) before consumer is bound by sale or service contracts • Withdrawal right for distance contracts

		Digital Content Directive 2019/770 (DCD) • Mandatory information on important (security) updates and integration of goods/services. • Subjective and objective criterions for conformity assessment of digital content/services • Liability for failure to provide and for non-conformity **Directive on certain aspects of sales contracts of goods 2019/771 (DSCG)** • Mandatory information on important (security) updates and installation of goods. • Subjective and objective criterions for conformity assessment of goods and included digital elements • Liability of traders for non-conformity **E-Commerce Directive 2000/31** • Mandatory general information about information society services **Platform to Business Regulation 2019/1150** • Transparency requirement for terms and conditions of use • Rules on changes in terms and conditions and on data access and sharing • Right to contest platforms decisions
3. Security and privacy	**Cybersecurity Act (Regulation 2019/881)** • Creates a framework for voluntary cybersecurity certification, with possibility to render certification mandatory through EU law or national law • Mandates ENISA to establish cybersecurity schemes • Ensures various cybersecurity features trough certification	**Network and Information Systems Directive 2016/1148** • Obligation to identify Operator of Essential Services (OES) on the basis of specific criteria: Operator of ITS explicitly identified as OES • Appropriate security level with regard to risks of OES and operator of digital services activities

	• Different levels of assurance for cybersecurity schemes **General Data Protection Regulation 2016/679 (GDPR)** • Privacy by design and by default • Assessing risks of processing operation • Mandatory data impact assessment in specific cases • Prior approval of supervisory authority in cases of high risks	• Obligation to notify security incidents under threshold defined by Member States • Investigation powers and power to impose remedies for national authorities and cooperation between national authorities, European Commission and ENISA **Cybersecurity Act (Regulation 2019/881)** • Grants investigation powers to the certification authorities with regard to holders of certificates • Remedies in case of non-compliance with schemes **EU Charter on Fundamental Rights** • Protect privacy and personal data **General Data Protection Regulation 2016/679 (GDPR)** • Principles applying to every data processing: lawfulness grounds for data processing • Transparency vis à vis the users • Set of rights for every data subject (including portability and rectification) • Specific rules on sensitive data and offence-related data • Specific rules on decisions based solely on automated data processing • Liability for damages resulting from data processing • Appropriate level of data security with regard to risks of data processing • Mandatory notification of data breach to authorities and data subjects • Investigation powers of national authorities and proportionate remedies in case of non-compliance and cooperation between data protection authorities **e-Privacy Directive 2002/58** • Access to data in user's equipment based on prior consent

		• Mandatory confidentiality of communications • Rules on processing of traffic and location data for value-added services (including on transparency and possibility to deactivate processing) • Appropriate level of data security
4. Liability		**Product Liability Directive 85/374** • Covers physical damages and damages to private property • Defective nature must be established by victim • Exemptions for defect of technological products **E-Commerce Directive 2000/31** • Liability exemption for some online intermediaries
5. Data governance		**Free flow of Data Regulation 2018/1807** • Prohibition of data localisation for non-personal data • Self-regulatory codes on data portability for professional users and switching of cloud service providers **Open Data Directive 2019/1024** • Rules on re-use of public sector data and information (including in field of transportation) • Rules on the format of data and on licenses use and costs and prohibition of exclusive agreements for data re-use • Ensure the ability to challenge public sector bodies negative decision on data re-use. • Specific rules for re-use of high-value datasets and for identification of high-value datasets (including datasets relating to mobility)
6. Intellectual property		**Database Directive 96/9** • Sui generis right on content for the maker of databases

		• Extraction and re-utilisation of substantial parts of databases subject to prior approval of the maker • Exception for the purpose of illustration in teaching **InfoSoc Directive 2001/29** • Exclusive rights to allow or prohibit reproduction, communication to the public and distribution of original works. • Exception for the purpose of illustration in teaching **Computer Program Directive 2009/24** • Computer software protected by copyright • Exclusive right on reproduction, modification and distribution on computer programs • Rights for legitimate users • Rules on reverse engineering for purpose of interoperability **DSM Directive 2019/790** • Exceptions to exclusive rights under the Database Directive and the InfoSoc Directive for the purpose of text and data mining: • Mandatory for research purposes • Optional for non-research purposes

Proportionality and risk-based approach

The EU regulatory framework for AV has adopted a risk-based approach and proportionality rules, embracing the promotion of innovation and the enforcement system. While the framework appears comprehensive, enforcement lies with the Members States. National authorities are responsible for ensuring the proper functioning of their markets while the European Commission works to preserve the internal market. Below are the approaches and principles of the EU regulatory framework.

Product safety

The AMSVR contains a specific procedure for approval of vehicles, components, systems and technical units that cannot comply with the AMSVR because they implement new technologies or concepts. This specific type-approval is subject to conditions, including in term of safety equivalency of the products. These exemptions are subject to the approval by the European Commission. Yet, until this is obtained, national authorities can issue a provisional approval limited to national territories. Furthermore, when compliant candidate vehicles, systems, components and technical units present high risks, approval authorities can refuse to grant type approval. Also, the GVSR enhances the safety features and systems of all road vehicles. In addition to compliance with all regulations applying to other vehicles, automated and fully automated vehicles must comply with an additional set of technical specifications and integrate specific systems.

As a general rule, market surveillance authorities (under the AMSVR, GSPD, RED) must pursue their activities according to risk assessment principles. Remedies for non-compliance must be proportionate to risks presented by the products concerned. The RED empowers the European Commission to identify classes of radio equipment that must comply with additional requirements (e.g. ensuring compliance of the combination with software, ensuring protection against fraud, ensuring protection of data).

Consumer protection

The CRD and the UCPD ensure transparency and information of consumers. As the complexity of products and services increase, information requirements concerning, for instance, the functionality of products can reasonably be considered more demanding.[357] Even if not explicitly mentioned, important information must be provided to ensure compliance with UCPD rules. Moreover, the DCD and DCSG provide for remedies that are proportionate to the level of non-conformity of the goods and digital contents/services. For instance, a consumer may terminate the contract only in cases where the lack of conformity is not minor.

Cybersecurity

The NIS Directive requires that Member States identify OES based on the impact that interruption of their services may have on the society and economy. In addition, Member States are free to determine the threshold for mandatory notification of security breaches based on their effects and number of users affected. Member States must oblige OES and digital services operators to adopt security measures that are adequate and proportionate to the level of the risks of their activities. Cybersecurity schemes adopted under the Cybersecurity Act will contain different levels of assurance. To obtain a cybersecurity certificate with a high level of assurance, the applicant will need to comply with more requirements. Cybersecurity certificates with a high level of assurance will be granted only by public certification authorities.

Data protection and ownership

[357] In that sense see Commission Staff Guidance on the implementation and application of Directive 2005/29 on Unfair Commercial Practices, SEC (2009)1666, p. 49, stating that complex products may require the provision of more information than simple ones.

The GDPR provides that data controllers must assess the risk of their processing activities and must conduct a data protection impact assessment or request prior authorisation by the competent authority when the data processing activities present high risks. Transparency requirements and empowering mechanisms under the GDPR increase corresponding to the risks of the processing operation. For instance, if the processing implies decisions based solely on automated processing, data controllers must provide additional information and implement safeguard measures. Also, depending on the nature of the data, rules are more demanding (e.g. for sensitive data). Data controllers must adopt security measures that are adequate to the risks of their processing operations for the rights of data subjects. As the risk level rises, the necessary security measures increase, which may, for instance, ensure the resilience of systems or the availability of data and systems. Also, remedies imposed by competent authorities must be proportionate to the gravity of the non-compliance with the GDPR. The E-Privacy Directive allows the processing of location data and traffic data for value-added services only on the basis of prior approval by the user as these data may be personalised.

Liability

The MID ensures that, based on the risk of an activity (i.e. operating a vehicle), civil liability for damages is covered by third-party insurance. Similarly, the GDPR ensures liability of the data controller for damages caused by any data processing operation.

Promotion of innovation

The EU regulatory framework seeks to find a balance between the protection of the legitimate interests of users and consumers and the promotion of competitiveness and innovation. Specific rules and exceptions for AV innovation can often be found in the EU legal framework.

Main rules

The ITS Directive and its delegated regulations constitute an essential general framework for products and services that might be of significant importance for the operation of AV products and services. They create national access points for collection and re-use of specific data resources that might be used in the development of AV products and services.

Access to data plays a crucial role in the development of AV and ITS. The Open Data Directive creates a framework for re-use of data held by public sector bodies and public undertakings. It also creates categories of high-value datasets that can be, in principle, re-used for free. Data related to mobility are considered high-value datasets that may benefit the development of AV products and services.

The DSM Directive facilitates access to content and products protected by intellectual property rights. It creates new exceptions to *sui generis* right of the Database Directive and to the exclusive reproduction right of the InfoSoc Directive. These exceptions permit the use of protected content for text and data mining activities employed in ITS and AV development. The Computer Program Directive contains rules on reverse engineering for interoperability and rules that allow legitimate users to observe and study how software behaves.

Exemptions

The AMSVR contains a specific procedure for type-approval of vehicles that cannot meet the requirements of this regulation because they implement new technologies or concepts. Moreover, the GVSR contains particular requirements for automated and fully automated vehicles. Both regulations refer to many technical regulations and empowers the European Commission to adapt them to keep up with technological development.

The PLD allows Member States to adopt liability exemptions where defective nature of a product cannot be discovered considering the technical and scientific state of the art, which may provide a

useful niche for piloting and testing of AV solutions. The ECD also creates liability exemptions for information society intermediaries to enable the development of services.

Enforcement

The rules related to enforcement of the transparency, information, access and authorisation obligations can be found in all relevant legislation.

Product safety

The AMSVR requires that all Member States have a national authority in charge of market surveillance that pursues safety checks. Type-approval authorities must also carry out compliance checks on the type-approvals they grant. Both national authorities and the European Commission have investigation powers. In cases of non-compliance with the AMSVR, or if the identified risks warrant swift measures, national authorities can adopt various remedies, even withdraw or recall the product from the market. The Commission can also take remedial measures at the EU level and impose administrative fines. Penalties can be imposed in the case of failure to provide OBD data and repair information. Finally, the AMSVR mandates cooperation not only between market surveillance authorities but also between type-approval authorities (including through a dedicated forum established by the European Commission).

The GPSD and the RED require Member States to establish market surveillance authorities that also handle complaints about products. Market surveillance authorities must have sufficient investigation powers to check the safety of the products and adopt remedies that are proportionate to the risk presented by the products (ranging from imposing the use of a specific warning to ordering the recall of a product). National authorities must also collaborate with the European Commission and other national authorities under framework established by the Commission.[358]

Cybersecurity

Cybersecurity is linked to product safety. Under the Cybersecurity Act and the NIS Directive, competent national authorities have investigation powers vis-à-vis OES and digital service providers, and cybersecurity certification authorities can investigate the holders of cybersecurity certificates. Additionally, certification authorities can impose corrective measures in cases of non-compliance with certificates, including withdrawal of the certificate. Under the NIS Directive, national authorities must have necessary powers and means to remedy compliance failures of regulated undertakings.

The Cybersecurity Act also requires cooperation between national authorities (e.g. information sharing and peer review). Similarly, the NIS Directive establishes a cooperation group between Member States, European Commission and ENISA. It also establishes a network for cooperation between national Computer security incident response teams (CSIRTs).

Data protection

The GDPR ensures that national authorities in charge of data protection have investigation powers and can impose corrective measures ranging from issuing warnings to imposing fines. National authorities must also cooperate and can conduct joint operations.

[358] To that extent see Chapter III of Regulation 765/2008 of the European Parliament and of the Council of 9 July 2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products, OJ L 218 of 13.8.2008.

National initiatives of Selected Member States

Several Member States of the EU and other countries have adopted or are adopting ambitious strategies for the deployment of AV. Those strategies include a mix of the adaptation of their national legal framework to allow innovation and testing new AV as well as to ensure an effective protection of users and possible victims of AV as well as specific funding strategies for innovation and its deployment. We mention here three EU countries as examples but other countries of the EU have also adopted interesting and ambitious strategies. Those strategies are often fairly comprehensive and could inspire the EU strategy.

France

In May 2018, France adopted a strategy on autonomous vehicles, which aims at allowing the circulation in France of highly autonomous cars (SAE level 3-4) by 2022.[359] According to this strategy, car manufacturers have to inform drivers about the main automation functionalities of the car and their limits, i.e. which actions are required from the driver.

To achieve those objectives, in December 2019, France adopted the law on the mobility of goods and individuals.[360] With regard to the liability and provision of information to users, the French law mandates the government to adjust current legislation (in particular the French Road Traffic Code) before the end of 2021 to allow the circulation of highly automated (SAE level 3-4) and fully automated (SAE level 5) vehicles. This includes defining the liability regime applicable to automated driving. Under the new mobility law, the government can also specify the information which must be provided prior to the sale or rental of an AV. With regard to access to vehicle data, the new mobility law mandates the government: (i) to make relevant data of connected road vehicles accessible to law enforcement, fire and rescue services to detect and prevent accidents and authorities in charge of mobility to better understand traffic; (ii) in case of an accident, to make incident data accessible to the police and other bodies in charge of investigating accidents and insurance companies; (iii) to allow the remote correction of security defects and the improvement of the security of the vehicle's automation system by allowing private operators to access certain vehicle data. The new law also specifies that autonomous vehicle data collected by law enforcement services to detect and prevent accidents cannot be used as proof of the commission of traffic offences.[361]

Germany

In September 2015, Germany adopted a strategy on automated and connected driving which includes the development of: (i) a legal framework for the deployment of AVs on public roads; (ii) a new mobility digital infrastructure to make it possible to connect vehicles with one another and with the road infrastructure in real time; (iii) research and trialling of appropriate technologies on testbeds in real-life situations.[362]

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359 French Ministry of Interior (2018). Development of Autonomous Vehicles. Report.

360 Loi 2019-1428 du 24 décembre 2019 d'orientation des mobilités. Note that the French Constitutional Court invalidated a provision in this law regarding trials and testing of AVs. The provision would have allowed the government to adopt legislative derogations allowing three-year trial and testing periods to develop new mobility solutions in sparsely populated areas. The Constitutional Court considered that the provision was not precise enough for parliament to delegate legislative powers to the government. However, the testing of AVs can still be authorised by the minister of transport on a case-by-case basis under the 2016 Ordinance on testing of AVs.

361 Article 32 of Loi 2019-1428 du 24 décembre 2019 d'orientation des mobilités.

362 German Federal Ministry of Transport and Digital Infrastructure (n.d.). Automated and Connected Driving.

Germany was one of the first EU Member States to amend its laws in anticipation of AV deployment. The German Road Traffic Act (Straßenverkehrsgesetz, StVG) was modified in 2017 to specifically allow highly and fully automated driving on German roads.[363] The amendments define basic terms to categorise highly and fully automated driving (SAE levels 3 and 4), but do not give a definition to vehicles that do not require a human driver at all. To be admitted to the road, vehicles can be either approved as a whole, including their highly/fully automated driving functions, or such functions can be approved separately. The latter possibility is introduced to allow activation of the preinstalled highly/fully automated driving functions that have not yet been regulated by the applicable international rules. In the absence of such international rules, it is possible to obtain an exemption type-approval from the European Commission, and the amended German law develops a procedure for this.

Highly/fully automated driving is allowed only within the limits defined by individual car manufacturers (e.g. automated driving function may be only allowed on the autobahn). The automated system must inform the driver when automated driving is reaching these limits and prompt him/her to resume steering.

The driver of a vehicle with highly/fully automated driving functions is assigned new rights and obligations by comparison to drivers of conventional vehicles. Most notably, the driver is now allowed to divert his/her attention from traffic, but must remain 'sufficiently alert' to monitor the vehicle and to reassume control of the vehicle when a) the automated systems prompts him/her to do so or b) he/ she notices – or must notice because too obvious circumstances – that the conditions for proper use of the highly/fully automated driving functions are no longer being met. These provisions have been criticised as insufficiently clear (e.g. what 'sufficiently alert' means, when attention can be diverted and what exactly this means), especially because they have bearing on assigning the liability for accident or damage.[364]

However, the amendments to the law did not change the liability regime, but the maximum amounts of liability have been doubled. Experts point out that liability issues need to be resolved urgently to encourage the deployment of automated vehicles.[365] Clarifying when exactly the vehicle holder, driver and manufacturer are responsible needs to be fair.

The amended German Road Traffic Act provides that highly/ fully automated motor vehicles must store location and time data when there is a change in vehicle control between the driver and the automated system. The data must be stored in a black box that must be built-in into each and every vehicle with automated functions. The data from the black box may be used by law enforcement authorities to punish traffic offences and forwarded to third parties if it is necessary to clarify the control of the vehicle and establish liability for accidents and damages. It remains unclear who owns the data and what third parties are meant to have access to them.[366]

This legal framework is currently being reviewed to allow for commercial use of fully automated vehicles (SAE level 4).[367] Meanwhile, the testing of automated vehicles is in the hands of local authorities, and many of them allow companies from all over the world to trial and experiment on public roads.

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[363] See the English translation of the Eight Act amending the Road Traffic Act of 16 June 2017.

[364] Burianski, M. and Theissen, C. (2017). Germany permits automated vehicles. White&Case.

[365] Ibid; Ruttloff, M. (2017). New legal rules on automated driving. Gleiss Lutz.

[366] Burianski, M. and Theissen, C. (2017). Germany permits automated vehicles. White&Case.

[367] Hammerschmidt, C. (2020). German law aims to be first for driverless cars. Eenews Europe.

The Netherlands

Despite being ranked first in terms of preparedness for automated mobility for a number of years, The Netherlands has not yet developed a comprehensive legal framework for automated driving.[368] However, testing of self-driving cars was possible in The Netherlands since 2015[369] per special exemption, and it required a human to be present in the vehicle to take control if necessary. Since 2019, The Netherlands also allows testing of automated vehicles without a driver being physically present. A law was adopted to amend the Dutch Road Traffic Act to permit public road trials of such vehicles.[370] Trials can be conducted in predetermined locations and under pre-defined conditions, including the information to other traffic participants about the trials.

EU-level policy debate

A wide range of policy, strategy and legal documents has shaped the EU-level policies related to the application of AI in transport, starting as early as 2008 when the European Commission first identified intelligent transport systems (ITS) as potential significant contribution to achieve several EU priorities: energy efficiency, greener and cleaner transport and improving road safety and security.[371] Since then the developments in cooperative intelligent transport systems (C-ITS) and, ultimately, cooperative, connective and automated mobility (CCAM) showed the importance of a holistic approach to the regulation of the AI in transport.[372] The EU-level legislation (specifically the Third mobility package) discussed in Chapter 2 and funding arrangements discussed in Chapter 3 are the manifestation of such holistic approach.

2018 saw a new spin of the policy debates on AI in transport building on the legal, economic and technological developments to that date and zooming in on specific issues and identified challenges to further development. The European Commission outlined in detail its vision of connected and automated mobility in the EU in a strategy for mobility of the future and assessed the state of the legislative framework, including its necessary adjustments.[373] The European Commission considered the data governance of the data related to the operation of connected and automated vehicles to be sufficient for the time being, but resolved to monitoring the situation, in particular around the in-vehicle data.[374] Future actions to ensure data sharing to enable fair competition and compliance with data protection rules as well as access of public authorities to these data may be contemplated, depending on the technological and market developments. The

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368 See KPMG (2020). 2020 Autonomous Vehicles Readiness Index; KPMG (2019). 2019 Autonomous Vehicles Readiness Index; KPMG (2018). 2018 Autonomous Vehicles Readiness Index.

369 Decree of 15 June 2015 to amend the Decree on exemption from exceptional transports (development of self-driving car). Bulletin of Acts and Decrees 2015, pp. 248.

370 See Decree of 25 June 2019 establishing the date of entry into force of the Act of 26 September 2018 amending the 1994 Road Traffic Act in connection with enabling experiments with automated systems in motor vehicles and the Decree of 6 December 2018 amending the Decree exemption from exceptional transport and the Vehicle Registration Regulations in connection with enabling experiments with automated systems in motor vehicles.

371 European Commission (2008). Action Plan for the Deployment of Intelligent Transport Systems in Europe. COM(2008) 886 of 16.12.2008.

372 For instance, Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport, OJ L 207 of 6.8.2010; establishment of the C-ITS Deployment Platform; adoption of the C-ITS strategy in European Commission (2016). A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility. COM(2016) 766 of 30.11.2016.

373 European Commission (2018). On the road to automated mobility: An EU strategy for mobility of the future. COM(2018) 283 of 17.05.2018.

374 Ibid., pp. 12-13.

current regulation of cybersecurity of AV was also deemed sufficient,[375] not least due to the adoption of a guidance on the certificate and security policy needed for secure and trustful communication between vehicles and infrastructure for road safety and traffic management.[376]

The European Commission proposed to equip automated vehicles with data recorders (black boxes) that would collect data on who was driving (the driver or the autonomous system) in order to clarify liability in case of accident. However, the European Commission did not see the necessity in revising/ amending liability rules of the Motor Insurance Directive or Product Liability Directive.[377] For the PLD, an interpretative guidance was deemed sufficient.[378]

The European Parliament conducted its own research into different aspects of automated driving. An EPRS study on the EU approach to liability rules and insurance for connected and autonomous vehicles found that most stakeholders thought a revision of liability and insurance rules premature due to the very early stages of AV development.[379] However, there was a wide agreement that additional rules will be necessary in the future, for example, regarding criminal negligence in case of an accident involving AV and taking into account cybersecurity risks when assessing liability. The study also found that access to the vehicles, driving and accident data need to be regulated to ensure accurate and timely resolution of liability issues.

An own-initiative report on autonomous driving came to similar conclusions. The report recommends assessment of the EU rules on liability in the light of AI and adoption of additional instruments.[380] Specifically, the report underlines the need for 'clear legislation' on liability and mentions a possibility of adoption of 'new rules on the basis of which responsibility and liability are allocated'. The report also supports the obligation to install 'event data recorders in line with the revised General Safety Regulation in order to improve accident investigations and to clarify' issues of liability. The report also reiterates the recommendation from the European Parliament's 2017 resolution on civil law rules on robotics that 'there should be no limitation of liability regarding the nature and extent of the damage to be compensated in order to guarantee adequate victim protection'.[381] The findings of the report were adopted by the European Parliament's resolution in January 2019.[382] In its resolution on a comprehensive European industrial policy on AI and robotics, the European Parliament seems to emphasise the need to review liability rules by noting that 'prevalence of autonomous vehicles in the future poses risks to data privacy and technical failures

375 Ibid., p. 12.

376 European Commission (2018). Certificate Policy for Deployment and Operation of European Cooperative Intelligent Transport Systems (C-ITS). Release 1.1.

377 Directive 2009/103/EC of the European Parliament and of the Council of 16 September 2009 relating to insurance against civil liability in respect of the use of motor vehicles, and the enforcement of the obligation to insure against such liability, OJ L 263 of 7.10.2009.

378 European Commission (2018). On the road to automated mobility: An EU strategy for mobility of the future, COM(2018) 283 of 17.05.2018, p. 10. See European Commission (2018). Liability for emerging digital technologies. SWD(2018) 137 of 25.04.2018.

379 Evas, T. (2018). A common EU approach to liability rules and insurance for connected and autonomous vehicles. EPRS.

380 Committee on Transport and Tourism (2018). Report of 5 December 2018 on autonomous driving in European transport, European Parliament.

381 European Parliament resolution of 16 February 2017 with recommendations to the Commission on Civil Law Rules on Robotics, 2015/2103(INL).

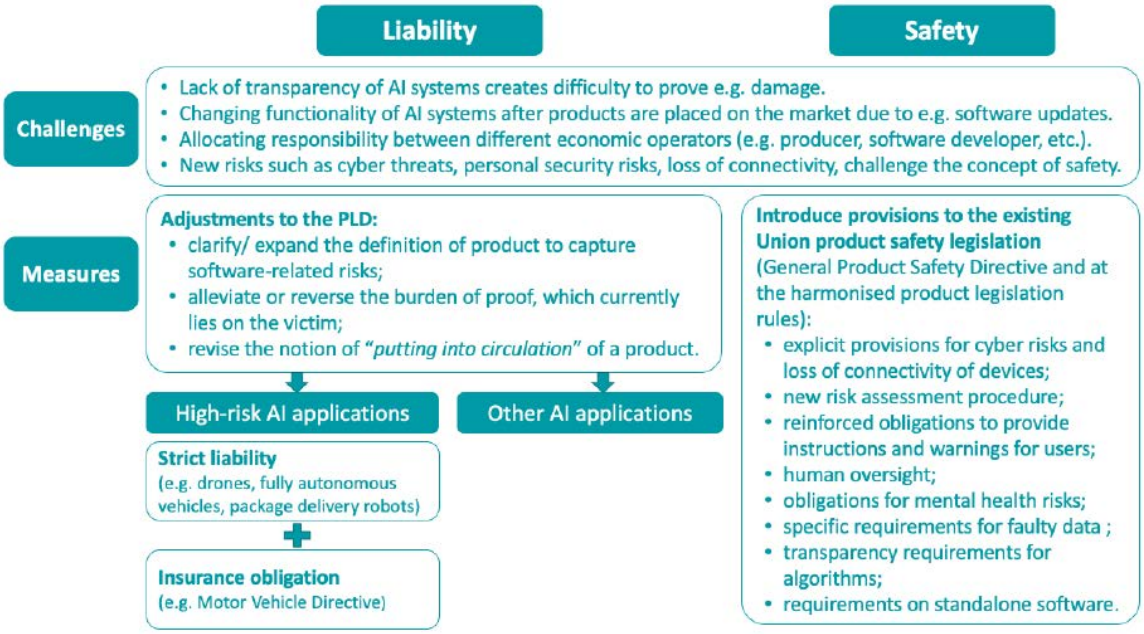
382 European Parliament resolution of 15 January 2019 on autonomous driving in European transport, 2018/2089(INI).

and will shift the liability from the driver to the manufacturer, requiring insurance companies to shift how they incorporate risk into their underwriting'. [383]

The European Commission continued the debate of the appropriate legal/ regulatory framework in its White Paper on AI.[384] While this document addresses AI as a whole, it raises important issues related to application of AI in transport. One of the main issues is a possible adaptation of the current EU rules on safety and liability and the adoption of specific rules for high-risk AI applications, which would be defined on the basis of two cumulative criteria: the sector is which the AI application is employed (and the Commission mentions the transport) and the manner the AI application is used and raise risks (and the Commission mentions risks of injury, death or significant effects for the rights of individuals).[385] On the basis of the two criteria of the Commission, AV could be considered as high-risk application. Those high risk AV application could be subject to additional requirements which could consist of the following features: training data, data and record-keeping, information to be provided, robustness and accuracy, human oversight, specific requirements for certain particular AI applications, such as those used for purposes of remote biometric identification.[386] Those requirement could be enforced with a prior conformity assessment which could be part of the approval of the AV. In addition, the Commission is also examining the fitness of the existing EU liability regime to the deployment of all types (high risk and not) application.

The main issues of the debate are summarised in the figure below.

Figure 13: Potential adjustments to the EU safety and liability framework



Source: Cullen International (2020).

[383] European Parliament resolution of 12 February 2019 on a comprehensive European industrial policy on artificial intelligence and robotics, 2018/2088(INI).

[384] European Commission (2020). White Paper on Artificial Intelligence - A European approach to excellence and trust. COM(2020) 65 of 19.02.2020.

[385] Ibid., p. 17.

[386] Ibid., pp. 18-22.

4.2. Potential gaps and barriers of the EU regulatory framework

The analysis above identified two sector-specific regulatory areas and five horizontal rules that apply to the sector. When examining gaps and barriers in those frameworks, most of the studies and academic papers focus on the following four areas: liability, empowering users (both business and consumer), cybersecurity, and data privacy. In essence, concerns around the legal and regulatory framework focus on the horizontal aspects – revisions to the sector-specific framework are recent and appear to adequately cover current day requirements.[387] The following section addresses the nature of these gaps. In general, a revised legal framework could provide benefit to the adoption of all AI-based products and services, and not only AV.

4.2.1. Liability

The main challenge identified by scholars and lawyers relates to the adaptation of the liability framework to AV in particular[388] and AI-based products and services in general.[389] With regard to liability, two main alternatives are (i) fault-based liability and (ii) strict liability regimes. Fault liability and civil liability are not harmonised at the EU level. With respect to strict liability, harmonisation is limited to damages caused by defective products under the PLD. In addition, the MID allows the compensation for the damages caused by motor vehicles (including AV). However, it does not harmonise the liability rules across EU Member States.

Application of the PLD rules to AV and AI products, in general, remains highly debated. AV products and services rely on software that interacts with services. It is, however, unclear whether embedded and non-embedded software can be considered as 'product' within the scope of the PLD. Thus, it is uncertain that liability for defective products will apply to all circumstances of an accident caused by a defective AV. Chatzipanagiotis and Leloudas recommend to include software within the notion of 'product', even if it is not incorporated in a physical medium, but not the software updates because it would risk undermining the prompt release of updates.[390] Since the PLD does not cover the product monitoring duty, software producers would be liable only for the release of defective updates, not for failure to release updates.

In addition, proving the defective nature of technology-intense products might be complicated in this context.

As suggested by many scholars, further guidance on the PLD or its modification might, therefore, be needed to ensure that liability for defective products continues to apply in the context of AV. Nevertheless, it has to be noted that ITS Directive ensures application of PLD rules to issues related to liability arising from use of ITS application[391] and services deployed in accordance with the

[387] As the needs of the industry and the technology evolve, issues around the legal and regulatory framework may appear. At the moment, however, these gaps are not self-evident.

[388] See Allen & Overy (2017). Autonomous and connected vehicles: navigating the legal issues; Jones Day (2017). Legal Issues Related to the Development of Automated, Autonomous, and Connected Cars; Taeihagh, A. and Si Min Lim, H. (2019). Governing autonomous vehicles: emerging responses for safety, liability, privacy, cybersecurity, and industry risks. *Transport Reviews*, Vol. 39(1), pp. 103-128.

[389] European Commission (2020). Report on the safety and liability implications of Artificial Intelligence, the Internet of Things and robotics.

[390] Chatzipanagiotis, M. and Leloudas, G. (2020). Automated Vehicles and Third-Party Liability: A European Perspective. *University of Illinois Journal of Law, Technology & Policy*, pp. 109-199.

[391] Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport, OJ L 207 of 6.8.2010.

specification adopted by the Commission.[392] Hence, to some extent PLD rules can be applied to ITS services as long as they are deployed in accordance with EU Commission's specifications. At national level, the PLD liability regime can also apply to some services falling under the definition of ITS. For instance, Belgian law seems to enable the application of PLD rules to ITS application or services, even if not deployed in accordance with EU Commission's specifications.

The EPRS notes that AV will shift the existing balance in liability distribution between consumers and producers, further accentuate existing gaps and potentially contribute to legal and administrative costs arising from uncertainty.[393] If the current EU framework is not adjusted, in addition to the existing gaps in the current EU legal framework, the introduction of AV will contribute to the emergence of new gaps and legal grey areas. This is because the current legal framework was not designed to deal with the liability issues of AV, which are technologically complex and stand distinctly apart from the motor vehicles currently on the roads. On the basis of an impact assessment based on seven qualitative criteria (i.e. legal certainty, potential litigation burden, impact on innovation, impact on the level of consumer protection, political acceptance, degree of regulatory intervention needed, and degree of dependence on soft law), the EPRS recommends the introduction of new EU legislation and setting up of a no-fault insurance framework for damages resulting from AVs with an appropriate insurance framework.

In relation to the more general debate on the liability of AI products, the Expert Group on Liability and New Technologies notes that it is necessary to develop a coherent and appropriate response of the legal system to threats to the interests of individuals.[394] The reason for this is that victims of harm caused by the operation of emerging digital technologies receive less or no compensation compared to victims in a functionally equivalent situation involving human conduct and conventional technology. The Expert Group recommends a strict liability regime that lies with the person in control of the risk connected with the operation of emerging digital technologies and benefitting from their operation (i.e. operator). In the situation where two or more operators can be identified strict liability should lie with the operator who has the more control between the person deciding and benefitting from the use of the product and the person continuously defining the features of the technology and providing continuous backend support. In line with this, car manufacturer or companies operating a fleet of automated/ highly automated vehicles could be considered as having more control on AV than car occupants and thus assuming liability for damages resulting from their use.

4.2.2. Empowering users

Most of the transparency requirements related to the characteristics and functionality of products and digital content and services apply only in the B2C context. However, the same information asymmetry existing between a consumer and a trader may also happen between a professional user and a trader when dealing with technology-intense and sophisticated AV products and services. Therefore, more extensive transparency requirements may be needed both in B2C and B2B contexts.[395]

The current legal framework increases transparency with regard to software, algorithms and automated decisions. For instance, the AMSVR empowers technical services providers, market

[392] Article 11 ITS Directive.

[393] Evas, T., A common EU approach to liability rules and insurance for connected and autonomous vehicles. EPRS, 2018.

[394] European Commission (2019). Liability for artificial intelligence and other emerging digital technologies. Report.

[395] For instance, it must be noted that information requirement under the RED also apply in B2B.

surveillance authorities and approval authorities to get access to software and information necessary to understand how it works. Similarly, the GDPR requires increased transparency in cases of decisions based solely on automated processing if such decision imply the processing of personal data. It is, however, debated whether these provisions allow to obtain an explanation of AI decision from the AV manufacturer.[396]

4.2.3. Cybersecurity

Cybersecurity is another important challenge for AV.[397] The NIS Directive only applies to OES and a limited set of digital service providers. Thus, it is questionable whether car manufacturers have cybersecurity requirements under the NIS Directive, at least for AV that still require supervision. The GVSR requires compliance with UNECE technical cybersecurity requirements but their adoption is still pending. Under the Cybersecurity Act, certification processes are voluntary unless provided otherwise by EU law or national law. Finally, in cases of the local processing of personal data, the GDPR and its security requirements may not apply.

4.2.4. Data protection and privacy

Further guidance and rules can be adopted with regard to the processing of biometric data.[398] AV have the potential to collect more – potentially invasive – personal data.[399] In particular, using voice and face recognition technologies presents significant risks for fundamental rights as the collection and usage of these data may occur without person's knowledge and/or full understanding. In this regard, Kindt (2018) claims that the GDPR applies only if the processing is carried out to uniquely identifying the person.[400] Following this interpretation, biometric data may be collected and processed by AV without users' consent, if unique identification is not the purpose of the processing. At the same time, Recital 10 of the GVSR states that 'advanced emergency braking systems, intelligent speed assistance, emergency lane-keeping systems, driver drowsiness and attention warning, advanced driver distraction warning and reversing detection systems should function without using any biometric information of drivers and passengers'.

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396 On the topic of right to explainability under article 22 GDPR, see Kaminski, M. (2018). The right to explanation, explained. *Berkeley Technology Law Journal*, p. 34; Malgieri, G. and Comandé, G. (2017). Why a right to legibility of automated decision-making exists in the general data protection regulation. *International Data Privacy Law*, Vol. 7(4), pp. 243–265; Malgieri, G. (2018). Automated Decision-Making in the EU Member States: The Right to Explanation and Other 'Suitable Safeguards' for Algorithmic Decisions in the EU National Legislations. *Computer law & Security Review*, Vol. 35(5); Wachter, S., Mittelstadt, B. and Floridi L. (2017). Why a right to explanation of automated decision-making does not exist in the general data protection regulation. *International Data Privacy Law*, Vol. 7(2), pp. 76– 99.

397 See also TNO et al. (2019). Safety of non-embedded software: Service, data access, and legal issues of advanced robots, autonomous, connected, and AI-based vehicles and systems. European Commission.

398 See also Punev, A. (2020). Autonomous Vehicles: The Need for a Separate European Legal Framework. European View, Vol. 19(1), pp. 95-102; Taeihagh, A. and Si Min Lim, H. (2019). Governing autonomous vehicles: emerging responses for safety, liability, privacy, cybersecurity, and industry risks. *Transport Reviews*, Vol. 39(1), 103-128. Generally, see ENISA (2017). Cyber security and resilience of smart cars. Good practices and recommendations and ENISA (2019). ENISA good practices for security of smart cars.

399 See Rannenberg K. (2016) Opportunities and Risks Associated with Collecting and Making Usable Additional Data. In: Maurer M., Gerdes J., Lenz B., Winner H. (eds) Autonomous Driving. Springer, Berlin, Heidelberg, pp. 497-517.

400 See Kindt, J. (2018). Having Yes, Using No? About the new legal regime for biometric data. *Computer Law & Security Review*, pp. 532-538.

Table 2: Overview of gaps and barriers in the legal framework

Identified gap	Rules on introducing AV to the market	Rules on using AV
1. Liability and insurance		**I. Insurance** **Motor Vehicle Insurance Directive 2009/103 (MID)** • Does not harmonise liability regimes across EU member States. • Even if motor vehicle under MID can include AV, it does not prevent the driver to be considered as liable for the damages caused. **II. Liability** **Fault-based liability and civil liability** • Not harmonised within the EU. **Product Liability Directive 85/374** • Scope limited to B2C relationship. • Does not applies to services • Qualification of software as 'product' highly debated. • Burden of establishing defective nature of the product lies on the victim. • Defective nature must be established by victim. • Exemptions for defect of technological products and for defects that does not exist at the time when the product is placed on the market. **General Data Protection Regulation 2016/679 (GDPR)** • Liability for any damages resulting of a violation of the Regulation • Liability only in case of processing operation of personal data that trigger GDPR application. **Intelligent Transport Systems (ITS) Directive 2010/40** • Applicability of Product Liability Directive rules to use of ITS limited to the applications and services set out accordingly to specification adopted by the Commission.

		• Does not provide any guidance on the way of assessing defective nature of services (which are in principle excluded of PLD scope).
2. Empowering users	**General Product Safety Directive 2001/95 (GPSD)** • Information on safety risks of products apply only in B2C context **Regulation 2018/858 on approval and market surveillance of motor vehicles (AMSVR)** • Increases transparency of software and algorithms for technical services and approval authorities but does not impose explainability of AV decisions for technical services, approval authorities and users of the vehicle.	**I. Consumer protection** **Unfair Commercial Practice Directive 2005/29 (UCPD)** • Prohibition of misleading actions and misleading omissions of important information regarding main products and services characteristics apply only in B2C context. **Consumer Rights Directive 2011/83 (CRD)** • Mandatory information (including about main characteristics) before consumer is bound by sale or service contracts only in B2C context. **Digital Content Directive 2019/770 (DCD) and Directive on certain aspects of sales contracts of goods 2019/771 (DSCG)** • Mandatory information on important (security) updates and integration of goods/services. **II. Data protection** **General Data Protection Regulation 2016/679 (GDPR)** • Transparency vis à vis the users through information and access rights in B2B and B2C context only if personal data are processed. • Increased transparency in case of decisions based solely on automated processing of personal data. The possibility to obtain explanation of an automated decision on this basis remains debated.
3. Cybersecurity	**Cybersecurity Act (Regulation 2019/881)** • Framework for cybersecurity certification is only voluntary and not mandatory.	**Network and Information Systems Directive 2016/1148** • Obligation for OES (including Operator of ITS) to adopt appropriate security level with regard to risks of their activities. • Qualification of car manufacturer as OES is uncertain and left to the discretion of Member States.

	General Safety Regulation 2019/2144 on type-approval requirements for motor vehicles (GVSR) • Requires compliance of vehicle and vehicle components with UNECE technical regulation on cybersecurity which are not yet in force.	**General Data Protection Regulation 2016/679 (GDPR)** • Appropriate level of data security (including ensuring confidentiality, integrity, availability and resilience of processing systems and services) for data processor and controller apply only in case of processing operation of personal data.
4. Data protection and privacy	**Radio Equipment Directive 2014/53 (RED)** • Possibility of additional privacy and safety requirements for specific Radio equipment products (which can be used in AV) through delegated acts. Such delegated acts are not yet adopted. **General Safety Regulation 2019/2144 on type-approval requirements for motor vehicles (GVSR)** • Data protection and privacy rules for advanced safety systems such as event data recorders and driver drowsiness and attention warnings. • Requirement of processing of personal data 'within a closed loop system' for advanced safety systems such as event data recorders and driver drowsiness and attention warnings. At this stage it remains unclear if this requirement is equivalent to the notion of 'local processing' identified in EDPB guidelines on connected vehicles. • Recital 10 of the regulation seems to exclude processing of biometric data for advanced safety systems even if no unique identification is pursued. This requirement does not appear in the articles of the regulation. **eCall Regulation 2015/758** • Data protection and privacy requirements limited to the scope of eCall systems. Such requirement should also apply to other vehicle systems and car component.	**General Data Protection Regulation 2016/679 (GDPR)** • Specific rules on sensitive data that applies for biometric data only if processed for purpose of uniquely identifying a person. In that sense, GDRP seems to authorise processing of biometric data on the basis of other legal grounds

5. Addressing the potential gaps and barriers of the EU regulatory framework

Key points

Flowing from the potential gaps in the regulatory framework – as well as consideration to the other non-regulatory enablers for the industry – **policy options** around harmonising the liability regime as well as enhancing trust and protection of users were tested. These policy options are meant to address four gaps and barriers, namely (1) liability and insurance; (2) empowering users; (3) Cybersecurity and (4) data protection and privacy.

To address these gaps and barriers, there are three policy options proposed for EU-level: no additional intervention at EU level, increasing the harmonisation of the liability regime, and enhancing trust and protection of users. One of the policy options means that there is no additional intervention foreseen at EU level, and represents the baseline for the analysis. Policy Option 2 focuses on harmonisation of the liability regime. Policy Option 3 builds on the former and extends it to increase trust and protection of users.

5.1. Identifying where EU level action should focus

The previous chapters explored the legal and regulatory framework, with the final section of the previous chapter addressing gaps within that framework that could introduce particular costs of non-Europe should those gaps remain unfilled. In terms of the enablers identified in Chapter 3, the current framework shows that a number of gaps are already being tackled.

5.1.1. Areas where EU-level action is adequate

The development of necessary infrastructure (i.e. roads, 5G connectivity) is shaped by the ITS Directive and policy initiatives around the deployment of very high capacity networks and C-ITS and is financially supported by the CEF and other EU structural funds and 5G PPP. The EU-level funding arrangements were amended to target different stages of technological development: Horizon Europe aims primarily at R&D projects (fundamental research), while the DEP targets the commercialisation stage. The rationale of the EU-level funding has changed from being the main source of investment to becoming a leverage to unlock private investments and attract or complement other public funding. As the EU-level funding is planned according to EU budgetary cycles, it seems to guarantee that in 2021-2027 a next 'AI winter' is unlikely. Last but not least, stronger coordination of national R&D and funding in transport is ensured via STRIA.[401]

The EU's latest funding policy addresses the gaps that were identified in the previous studies, namely coordination of national efforts, close cooperation with the private sector and targeting commercialisation of research. As emphasised in Section 4.1.2, it is difficult to say at this point whether the new funding and competitiveness measures will suffice to maintain or enhance the EU's leading position globally. Most of these measures have just been adopted, are being adopted or are adjusted following the COVID-19 crisis. Therefore, it remains to be seen how these measures unfold in the years to come. Meanwhile, no significant new gaps in this regard could be identified.

As discussed in Section 4.1.3, most sector-specific EU-level legislation, in particular the AVSMR (Regulation 2018/858) and GVSR (General Safety Regulation 2019/2144), have been reformed just recently with a specific view of the AI in transport developments, which will ensure legal certainty

[401] European Commission (2019). STRIA Roadmap on Connected and Automated Transport: Road, Rail and Waterborne.

for developers, vendors and users and, therefore, foster trust in technologies and contribute to the safe deployment of AVs.

The AMSVR allows innovation while ensuring safety as it contains a procedure for type-approval of vehicles that cannot meet the requirements of this regulation due to new technologies or concepts implemented. Under specific conditions, Member States can deliver provisional type-approval limited to their national territory for such vehicles or components. The Commission is empowered to adopt implementing acts in order to grant an EU-wide approval of these vehicles and components.

The AMSVR also increases transparency vis-à-vis software and algorithms used by manufacturers during the entire lifecycle of (automated) vehicles. Before granting market approval, technical services designated by approval authorities can access to any software or algorithm and to information or documentation necessary to understand this software or algorithms. After the vehicle is placed on EU market, the same applies for market surveillance authorities and national authorities that have delivered-type approval to a vehicle or component.

Finally, the AMSVR Annexes ensure compliance of vehicles or components with UNECE technical regulations. Since modification of these annexes is allowed by the AMSVR, compliance and application within the EU of UNECE initiatives relating to AV is also ensured.

The GVSR contains a set of specific rules applicable to automated vehicles and fully automated vehicles that will enable development of safe AV. It mentions systems that will become mandatory for AV such as systems replacing the driver, providing real-time information to the vehicle about its environment, monitoring driver availability to take over control. The GVSR increases protection against unauthorised use and cyberattacks and remote access to in-vehicle data or software modification that endanger vehicle.

The GVSR also makes mandatory systems such as (i) intelligent speed assistance, (ii) driver drowsiness attention and distraction warnings, (iii) event data recorders, (iv) emergency lane keeping and braking systems for most of vehicles and provide related high-level requirements. Such systems can be considered as technical blocks necessary to achieve development of highly of fully automated vehicles.[402]

The Commission is empowered to adopt implementing and delegated acts related to type approval of AV and the above-mentioned systems. Similarly, to the AMSVR, the GVSR allows modification of its annexes in order to ensure application within EU of UNECE initiatives relating to AV.

To ensure that such recent reform of sector-specific regulation is effective in supporting the deployment of safe AV, it will be key that the EU institutions regularly monitor the implementation and the effects of the AMSVR and GVSR. This is mainly the role of the European Commission, but the European Parliament may have an active role also in organising hearing and expert groups or conducting studies. It will be also important that the Commission exercise its delegated and implementing powers in an effective manner to contribute to the deployment of safe AV throughout the whole internal market.

The EU recognised the importance of trust in technology for the development of AI in general, which will have implications for automated vehicles and ITS. Transparent and effective data governance, protection of fundamental rights, cybersecurity of AI applications and ethical development and deployment of technologies are cornerstones of trust that underpin their social acceptance. As

[402] In that sense, recital 10 GVSR stating 'some of those safety systems form the basis of technologies which will also be used for the deployment of automated vehicles".

outlined in Section 4.1.3, general rules of the GDPR and the Cybersecurity Act will play important role for ensuring the desired protections. The Ethics Guidelines of the AI HLEG provide a powerful framework and uniform vision of AI future in Europe. The rules empowering consumers and users (e.g. Platform-to-Business Regulation, Digital Contents Directive, Directive on certain aspects of sales contracts of goods, New Deal for Consumers[403]) in relation to AI developers and vendors will further social acceptance by improving transparency and strengthening contractual rights around the new technologies.

5.1.2. Areas where new EU-level action could be required

Yet the analysis in Section 4.2 also indicated the room for improvement by identifying **significant gaps in the legal and regulatory framework** in relation to enablers of AI in transport. These gaps mainly refer to three issues.

Firstly, **liability** issues are the most important among them. Clear and modern liability regime is an important enabler for technology deployment and take-up as it discusses relevant risks for all actors involved and distributes them in a clear, efficient, and preferably fair, fashion. Currently, the liability regime in the EU is fragmented along national borderlines. Even if AVs are covered by the requirements of the MID, it is not clear whether AV drivers are sufficiently protected and how their liability for damages is regulated. The PLD covers only products and not services. However, it is highly debatable whether software (and therefore AI) can be considered a product, such that the application of the PLD to defective AI is a moot point as well. Furthermore, the burden of proof of the defective nature of the product lies with the victim. In the context of highly sophisticated algorithms and AI, this may be considered an unsurmountable burden, especially considering the lack of transparency in how algorithms and AI and developed and take decisions. In addition, automated vehicles are very complex products, involving many products, services and processes, and also many suppliers. A liability regime needs to send right and clear incentives to different parts of the supply chain, including the end users of the end product – the automated car.

Secondly, **explicability** is a critical challenge for AI in general and a legislative gap that has barely started to be addressed. Currently, there is very little EU legislation imposing algorithmic transparency and explicability. In relation to AI in transport, due to the use and potential impact of this technology, this gap may represent a significant barrier to adoption. It would prevent the effective resolution of the liability issue and may undermine trust and social acceptance of the technology.

It can be argued that the stakes of application of AI in transport are very high by comparison to other sectors and warrant the resolution of liability and explicability issues for automated cars before they hit the roads. By comparison to some other AI applications (at least as they are currently conceived), automated cars will be used by consumers – laypeople of all ages and educational background – directly, without any professional intermediary (as opposed to AI applications in healthcare, banking, administration). One of the most dangerous direct impacts of automated cars is physical damage/ injury to other human beings.

The third issue relates to the **safety and security** of AI applications in transport, including in terms of their protection of fundamental rights. As indicated in Section 4.1.3, data protection and privacy

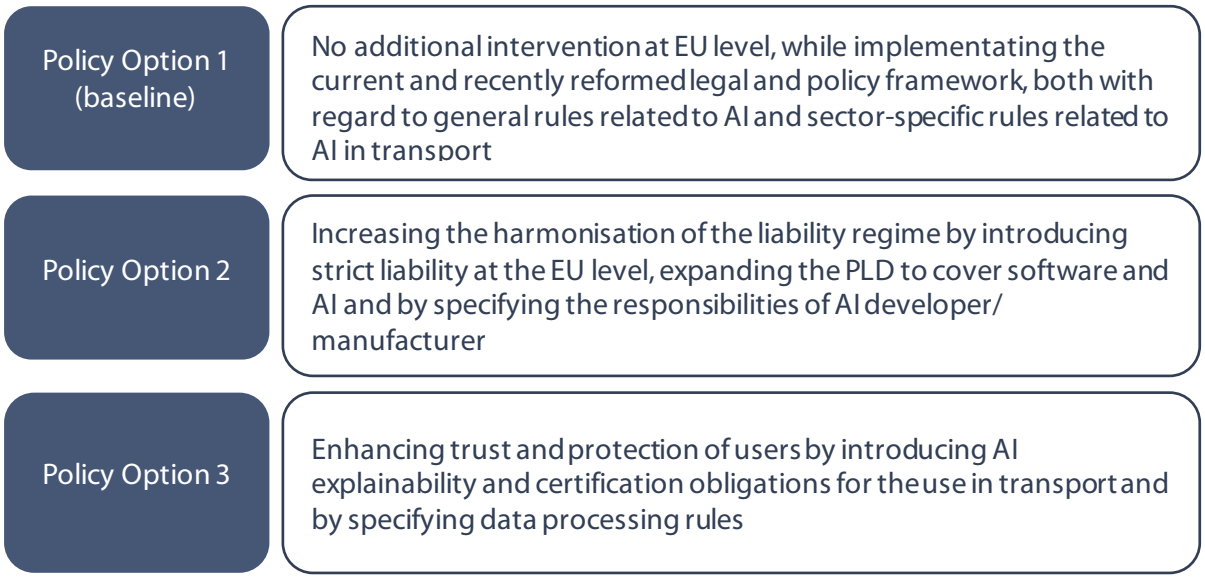
[403] The initiative New Deal for Consumers aims at strengthening the enfocement of EU consumer law and at modernisation of EU consumer protection. It is comprised of a range of activities, including a fitness check of main EU-level legislation for consumer protection and an adoption of the Directive 2019/2161 of the European Parliament and of the Council of 27 November 2019 amending Council Directive 93/13/EEC and Directives 98/6/EC, 2005/29/EC and 2011/83/EU of the European Parliament and of the Council as regards the better enforcement and modernisation of Union consumer protection rules, OJ L 328 of 18.12.2019.

requirements are currently limited to specific products, services or systems (e.g. eCall) but not to others (e.g. radio equipment, black boxes). There is uncertainty about processing of sensitive data in vehicle and access to in-vehicle data in case of accidents. These issues need to be resolved to enable, on the one hand, a more adequate liability regime and, on the other hand, effective protection of users' privacy.

5.2. Policy options to address the potential gaps and barriers

Given the policy gaps identified in Chapter 4 and discussed in further detail above, a number of policy options were identified. One of the suggested policy options is the baseline that includes all relevant and recently adopted legislation. While other policy options suggest specific actions to address the potential gaps and barriers. The policy options are summarised in the figure below:

Figure 14: Proposed policy options



Source: Authors.

Policy Option 1 is based on the legislation that has already been put in place and for which impacts are still accumulating. This policy option does not target any identified gap, but still does address other enablers as discussed in Chapter 3, and as such, there are still impacts to be identified and measured. As mentioned in Chapter 4, recent legislation has addressed the sector-specific gaps that previous studies had identified as concerns. In addition, it is used in the rest of the analysis to compare the net benefits modelled through a CGE model. The other proposed policy options address and close the identified gaps outlined in Chapter 4. Table 14 summarises how suggested policy options would address identified potential gaps.

Table 3: Which gaps are addressed by which policy option?

Gap / Proposed policy option	Policy Option 1	Policy Option 2	Policy Option 3
1. Liability and insurance	No	Yes	Yes
2. Empowering users	No	No	Yes
3. Cybersecurity	No	No	Yes
4. Data protection and privacy	No	No	Yes

Source: Authors.

Policy Option 1: No additional intervention at EU level

A number of sector specific legislation has been adopted just recently and has not yet entered into force:

- The Approval and Market Surveillance of Vehicles Regulation (AMSVR) was adopted in May 2018 and is applicable since 1 September 2020.
- The General Vehicles Safety Regulation (GVSR) was adopted in November 2019 and will apply from 18 July 2022.

Similarly, some of the crucial horizontal legislation has been in force only for a very short time or applied only in part:

- The Cybersecurity Act was adopted in April 2019, but parts of it will apply only from 28 June 2021;
- The Digital Content Directive was adopted in May 2019. Member States have till 1 July 2021 to transpose it and will apply the measures from 1 January 2022;
- The Directive on aspects concerning contracts for the sale of goods has the same transposition and application deadlines as the Digital Content Directive;
- The Directive on better enforcement and modernisation of EU consumer protection was adopted in December 2019. Member States shall transpose it by 28 November 2021, and the measures will apply from 28 May 2022;
- The Open Data Directive adopted in June 2019 must be transposed by 17 July 2021; and
- The Directive on copyright in the digital single market of April 2017 must be transposed by 17 June 2021.

This legislation needs to be transposed and applied at the national level to fully unfold its effect. It is likely to deliver the necessary basis for the development and early deployment of AV while protecting users and consumers, and it will contribute to increase the harmonisation of national approaches towards AV as described in Chapter 4.1.3 (legal analysis).

Policy Option 2: Increasing the harmonisation of liability regime

This option will see AV-related products and services as high-risk AI applications and clarify the application of strict liability to them. At the EU level, legislation on liability related to automated vehicles is updated/ amended to include the following:

- The notion of product in the PLD will be expanded to include software and algorithms.
- The burden of proof should be reversed: the AV user does not need to prove how and why AV software or services failed.
- The manufacturer (AI developer) as a person most in control of all aspects of AV assumes no-fault liability; victim is entitled to a compensation for damages prima facie.
- As a complement, to ensure the said compensation, manufacturers (AI developers) are obliged to take out a liability insurance (similarly to the current motor insurance).

Policy Option 2 focuses on closing the gap around liability issues described above as this is probably the most significant impediment to the deployment of AI in transport that causes uncertainty for AI developers and AV manufacturers and fosters distrust in users. By expanding the PLD to include AI, algorithms and software, the EU will create an adequate legal framework for AI in transport for the whole continent and, thus, send a strong signal to the market. This is likely to encourage more R&D and deployment of AI solutions in Europe. The legal framework will facilitate the development of

new insurance offerings building up trust of users in the new technology and fostering the adoption of AVs. It is likely that insurers will couple their insurance policies to various levels of cybersecurity assurance from AV manufacturers, which will be a market driven way to improve safety and security of vehicles. It is equally possible that insurance products take into account the data protection arrangements of different AVs, which would lead to higher level of privacy. The reversal of the burden of proof and prima facie compensation suggested in Policy Option 2 will serve to strengthen user rights and, thus, empower users in their dealing with the industry.

We have identified three principal channels of impact from the above-mentioned amendments to the legislation on liability related to automated vehicles: consumer demand (for vehicles and for transportation services), intermediate consumption of insurance services by the vehicle manufacturing sector and value of time savings.

Consumer demand can potentially be impacted through the demand for vehicles and for land transport services. The literature contains mixed information on the expected direction of change of the **demand for vehicles**. Some sources indicate that AVs can be expected to see rapid uptake over the coming years, which will probably be reflected in increased demand for vehicles.[404] Other sources like Alonso Raposo et al. expect substantial declines in vehicle ownership on the back of increased efficiency of use of the available fleet. [405] The issue is further complicated by the uncertainty about the pace of replacement of the existing fleet of conventional vehicles with AVs, driver preferences etc. We have therefore decided to keep the impact of option 2 on the demand for vehicles at **zero.**

Conversely, there is a broad consensus that facilitated adoption of AV technologies will result in increased **demand for transportation services**. Estimates of the size of the impact vary depending on the assumptions of the different sources but are in general substantial, starting at 30 % and reaching values in excess of 100 %.[406] To stay on the conservative side, we have taken the size of the impact to be **30 %** in this scenario.

The introduction of mandatory insurance for manufacturers of AVs will be reflected in **increased intermediate consumption** of insurance services by the vehicle manufacturing sector. The size of the impact will depend on the specific way the requirements are introduced. To quantify the impact, we assume that the intermediate consumption will increase by **10 %.**[407] These are commensurate with the estimates in Martens and Garrez on additional insurance costs associated with a stricter liability regime. [408]

Increased adoption of AVs as a result of improved liability regulation can also bring about value of **time savings**. For example, Bertoncello and Wee estimate that AVs can free up to 50 minutes a day for users.[409] Assuming average combined work-and-commute time of 9 hours a day, this results in

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[404] See e.g. Bagloee, S. et al. (2016). Autonomous vehicles: challenges, opportunities, and future implications for transportation policies. *Journal of Modern Transportation,* Vol. 24, pp. 284–303; European Commission (2018). On the road to automated mobility: An EU strategy for mobility of the future, COM(2018) 283 of 17.05.2018.

[405] Alonso Raposo, M. et al. (2017). The r-evolution of driving: from Connected Vehicles to Coordinated Automated Road Transport (C-ART). EUR 28575 EN, Publications Office of the European Union.

[406] Ibid.; Anderson, J. et al. (2016). Autonomous Vehicle Technology: A Guide for Policymakers. RAND Corporation.

[407] We conducted a sensitivity analysis on this assumption, by assuming the increase in intermediate consumption to be 5 % and 15 %. The results of this analysis are included in Annex III.

[408] Marten, B. and Garrez, J. (2019). Cost of non-Europe in robotics and artificial intelligence: Liability, insurance and risk management, EPRS, p. 54.

[409] Bertoncello, M. and Wee, D. (2015). Ten ways autonomous driving could redefine the automotive world. McKinsey & Company.

10 % savings. We have approximated this in the model by reducing the coefficients capturing disutility of labour by 10 %.

Table 15 summarises the main assumptions regarding Policy Option 2.

Table 4: Assumptions for Policy Option 2

Policy option	Demand for vehicles	Demand for transportation services	Intermediate consumption of insurance services	Value of time savings
Policy Option 2	0 %	30 %	10 %	10 %

Source: Authors based on various literature.

For all the channels listed above we assume gradual uptake over the simulation horizon as the impacts are expected to materialise through a progressive adaptation process. This means that the respective magnitudes of the effects are attained in 2030. The shock sizes for the years prior to 2030 are computed by linear interpolation from a starting point of zero in the period preceding the first simulation year. The assumption that the impacts reach full strength at the end of the simulation horizon is justified by the fact that the estimates from the studies used for the shock computation refer to years in the 2030-2050 range.

Policy Option 3: Enhancing trust and protection of users

This option builds on the reform of the liability regime suggested in Option 2, but additionally introduces:

- an **obligation of explainability** of algorithms and AI applications used in automated vehicle. This obligation should ensure transparency and capacity to understand (fully) automated decisions of AV.
- an **obligation of local data processing** at least when sensitive data under the GDPR are involved. This should include, whenever technically possible, an obligation of local data processing/ storage relating to personal data relating to uses habits of the driver/owner of (automated) vehicles as they can reveal life habits of the person.
- whenever technically possible, an **obligation to live processing of personal data** (or very short storage period such as for eCall/ driver monitoring and data event recorder/ black box).
- an **obligation to obtain consent for processing of biometric data** (as per Recital 10 of 2019/2144 Regulation) even if no unique identification purpose is pursued.[410] The aim of this obligation is to ensure people know that sensitive data is being used and processed, even locally. Therefore, the obligation of prior consent could include an explanation about the nature of data processed in the vehicle.
- **mandatory cybersecurity certification** for AVs in the EU market.

EU-level legislation must ensure personal (especially sensitive) data security even if the GDPR does not apply (e.g. in case of live processing and/or local processing as mentioned above). Therefore, the obligation of data and privacy protection will be expanded to include various products, services and systems of automated car (specifically radio equipment, black boxes). Also, adequate information on AV and automated decision-making (transparency and information requirements)

[410] This obligation is suggested as Article 9 GDPR seems to apply only if biometric data are processed for a purpose of unique identification.

will be expanded to include so called professional users (e.g. bus drivers, truck drivers) who currently have lower levels of protection than consumers.

Policy Option 3 addresses in a more targeted manner various gaps around user protection. More directly than Policy Option 2, it increases the transparency and cybersecurity of AI applications developed for and used in transport. It is also proposes sector-specific solutions to data protection and privacy challenges through local and live processing. It also has a more holistic view of AV users and ensures protection for anyone riding an AV.

Policy Option 3 is the second alternative scenario for the quantification of the net benefits. It is cumulative with respect to Policy Option 2 and strengthens the channels of impact present in the latter through the addition of the requirement of implementation that observes a set of ethical principles. Table 16 summarises the main assumptions regarding the policy option.

Table 5: Assumptions for Policy Option 3

	Demand for vehicles	Demand for transportation services	Intermediate consumption of insurance services	Value of time savings
Policy option 3	0	33.18 %	15 %	11.75 %

Source: Authors based on various literature.

To quantify the additional impact of the ethical implementation requirement on **consumer demand** and the supply of labour, we rely on the results from the Delphi survey reported in Evas and Lomba (2020) for the respective channels of impact.[411] More specifically, we use the averaged Delphi responses comparing the implementation of a unified approach (Policy Option 1) to the status quo in Evas and Lomba (2020). The unified approach scenario was chosen as the least common denominator providing a conservative estimate of the potential impact of ethical implementation on the respective economic variables. The impacts computed from the Delphi method results were added to the shocks for Policy Option 2. This led to additional increases in consumer demand and labour by 3.18 and 1.75 percentage points respectively compared to the impact of Policy Option 2. Therefore, the impact on demand for transportation services is set to **33.18 %**; and impact on value of time savings – to **11.75 %**.

The requirement to implement AI technologies in accordance with ethical principles entails additional costs to firms. This is captured by an additional increase in **intermediate consumption** for the vehicle manufacturing sector compared to Policy Option 2. In view of the sensitivity analysis conducted on the shocks to intermediate consumption, the shock value for option 3 was set at **15 %**, compared to 10 % for Policy Option 2. This choice was made to avoid underestimation of the costs incurred in the course of implementation and ensure that this channel of impact is captured in the model in a sufficiently conservative manner.

[411] Evas, T. and Lomba, N. (2020). European framework on ethical aspects of artificial intelligence, robotics and related technologies (European added value assessment), EPRS.

6. Assessing the cost of non-Europe and providing recommendations

Key points

Real economic activity, measured through the changes in real **GDP**, **is expected to increase** by 1.49% in 2030 or by €231 097 million under a new liability regime (Policy Option 2) compared to the no additional EU intervention (Policy Option 1), without taking into account the impact of the COVID-19 pandemic. The differences of real GDP compared to no additional EU intervention are slightly higher under a new regime to increase trust and security (Policy Option 3): it records a deviation of 1.77 % or €274 287 million in 2030.

In terms of employment, both policy options have an overall net **positive impact on employment**, with an extra 5.18 million people employed under Policy Option 2, and 6.14 million people under Policy Option 3. These estimates also do not account for the impact of the COVID-19 pandemic. The changes in private consumption are also estimated to experience sizable effects, deviating by 1.58 % and 1.89 % from the baseline. This indicates potential for improvements in welfare if either policy option is implemented.

In addition to the costs of inaction by not applying a revised liability and cybersecurity regime, Europe may **lose innovative capacity** through an unclear legal framework for AVs as well as there might be **less uptake** from consumers due to uncertainties over liability and data protection.

The preferred policy option is number 3, despite the fact that feasibility is considered to be lower for this option – the potential benefits to not only the road transport sector, but also to other sectors that are hindered by the horizontal gaps and barriers, offset the potential concerns.

In terms of the **cost of non-Europe**, the lower bound costs to the EU economy are €231 097 million and 5.2 million jobs lost while the upper bound costs are potentially €275 287 million and 6.1 million jobs lost.

6.1. Assessing the impact of different policy options

This section assesses how the different policy options affect the EU economy and what kinds of costs and benefits are expected. The impacts are assessed quantitatively and qualitatively. The quantification of impacts is conducted through a computable general equilibrium (CGE) model. The main structure of the model that serves to compute per-period outcomes is augmented with a set of dynamic equations that allow the calculation of the impact of shocks over a specified time horizon at the annual frequency. The CGE model is an open economy one with a tailor-made sectoral breakdown and a government sector. Calibration is carried out using recent data for the EU economy. More information on the model structure and calibration is presented in Annex III.

In addition, the policy options, described in Section 5.2, require a customised sectoral breakdown to capture the specifics of the interventions. For that purpose, the manufacturing sector is split into vehicle manufacturing and other manufacturing. Similarly, transport is divided into land transport (the most disaggregated level available in supply and use tables data) and other transport. The rest of the sectors roughly follow the NACE A*10 industry breakdown, with the exception that several services sectors are aggregated into one, called 'Other services'. Thus, the set of sectors included in the model is Agriculture, Industry, Vehicle manufacturing, Other manufacturing, Construction, Land transport, Other transport, Finance and insurance, and Other services.

Since the analysis focusses on the road transport subsector, an adjustment is needed to map the results for the land transport sector to road transport. This adjustment is implemented by means of a scale-down factor that is applied to the simulation results directly obtained from the model. All deviations from baseline (Policy Option 1), calculated for the rest of the policy options, are multiplied

by the scale-down factor to reduce their magnitude and the results reported below are the adjusted ones.[412]

6.1.1. Policy Option 1: A baseline with no additional intervention at the EU level

Since a number of sector-specific legislation and some horizontal legislation have been recently adopted or have been in force only for a short time, one of the options could be to not intervene additionally at the EU level. Since this legislation needs to be transposed and applied at the national level, the effect of it still needs to be seen.

It is likely to deliver the necessary basis for the development and early deployment of AV while protecting users and consumers, and it will contribute to increase the harmonisation of national approaches towards AV as described in Chapter 4.1.3 (legal analysis).

Economic impact

Table 17 provides information on the growth rates of the main macroeconomic aggregates under **Policy Option 1**. GDP growth is underpinned by strong investment and thus capital growth, coupled with practically flat employment. This implies productivity gains and technology-intensive growth over 2020-2030 period. Private consumption evolves commensurately with output, suggesting that the benefits of increasing income are transferred to the consumer side.

Although Policy Option 1 does not introduce new (or change the existing) legislation, it nonetheless covers a number of approved regulatory measures that become effective at different points in time over the 2020-2030 horizon. Several important caveats must be taken into account when interpreting the results for Policy Option 1. The CGE model used for the quantification of the impacts of various policy options is geared toward the analysis of structural issues and abstracts away from cyclical variations in the economy. For this reason, the results in the first years of the simulation horizon do not reflect the decline in economic activity induced by the COVID-19 pandemic. Additionally, because of the country coverage of the model (see the detailed description in the Annex III), reporting absolute results for the baseline scenario will be misleading. We therefore present the main characteristics of the economy and therefore the impact of no additional intervention through Policy Option 1 in terms of average annual growth rates of the key macroeconomic variables over the 2020-2030 horizon. Finally, the calibration of the CGE model is based on the structure of the EU economy in 2016 and takes on board the expectations on the future economic impact of AI reported by the respondents in the Delphi method survey described above. In that sense, while Policy Option 1 reflects the principle of not including unannounced policy changes that is commonly observed in forecasting exercises, its results should not be interpreted as a pure forecast. The construction of the option makes a deliberate trade-off in sacrificing the most recent data available and the incorporation of cyclical variations in order to incorporate more details on the structure of the economy, as well as to place special emphasis on the expected effects of AI adoption. Therefore, it would be misleading to make direct comparisons with the results of standard forecasting models, which are designed to account for the latest economic developments, typically focus on shorter horizons and do not necessarily strive to account for specific structural changes with long term impact.

[412] The value of the scale-down factor was set at 75 % based on information from Eurostat (2020). Freight transport statistics - modal split.

Table 6: The average annual percentage growth rate of selected macroeconomic variables over the period 2020-2030 under Policy Option 1, EU-27

Sector	GDP	Private consumption	Employment	Capital stock
Annual growth rate	3.04	3.07	0.21	4.82

Source: Authors.

The growing productivity and technology-intensive development are confirmed by the sectoral breakdowns in Table 18. Employment in traditionally labour-intensive sectors like agriculture and construction is expected to decline against the background of growing real value added in the sectors. Most other sectors post mildly positive growth in employment and robust annual increases in value added. Overall, this suggests that the EU economy is expected to move in the direction of a higher value added, technology-intensive sectoral structure.

Table 7: The average annual percentage growth rate of employment and real value added by sector under Policy Option 1 over the period 2020-2030, EU-27

Sector	Growth rate of employment	Growth rate of real value added
Agriculture	-1.2	4.4
Construction	-0.4	3.7
Finance and insurance	0.3	3.6
Industry	0.5	3.0
Land transport	2.7	4.8
Manufacturing (other)	0.4	3.3
Other services	0.4	3.1
Transport (other)	0.0	3.5
Manufacturing of vehicles	-0.1	2.7

Source: Authors.

Despite the positive growth rate of the main macroeconomic variables in the baseline, the dynamics of the economy may still be associated with inefficiencies and opportunity costs. Thus, the baseline situation and its evolution if no additional policy intervention at the EU level occurs should not be assessed in isolation but should be considered counterfactually in comparison with alternative policy packages. The tables reporting percentage deviations from baseline for the other policy options may be used to gauge the size of the net gains from implementing a particular policy package. They also provide an indication of the temporal cost of inaction in the sense that a delayed start leads to missing out on the potential benefits stemming from the implementation of the respective policy option.

Other impacts

Innovation potential

Autonomous vehicles, given their state of development, are still in a development phase and not yet ready for wide adoption. As such, the technology could still face safety challenges, which the old legislative framework failed to address. As testing of AVs moves from closed tracks to the open road, a framework needed to be in place to approve these types of vehicles to legally use the road infrastructure. This issue is much broader than a discussion around legal liabilities for failures of the

technologies, but rather about licensing and a process for approving exactly how these vehicles are allowed to be on the road (for example, whether a driver always needs to be behind the wheel and is alert to potential failures in the vehicle). As mentioned in Chapter 4, the AMSVR and GVSR are designed to allow innovation while ensuring new safety procedures are followed, which removes a key obstacle in the development and testing of the technology.

Increasing physical security and cybersecurity

The new legislative framework provides the necessary components to make AI applications in transport more secure, including mandating new safety systems. It also provides, under the auspices of the European Cybersecurity Agency (ENISA), a framework to ensure the security of the data and various systems of AI. While safety systems required are clear within the legislative framework, ENISA has not yet directly addressed cybersecurity certification of AVs, which would provide consumers with greater confidence in regards to the security of vehicles, though the framework is in place for this certification to be created.

One area of cybersecurity that is not addressed, however, are additional issues around data protection and privacy, which is one of the reasons why cybersecurity remains a gap as discussed in Chapter 4. Some cybersecurity concerns are covered under Policy Option 1, particularly with the NIS Directive and the Cybersecurity Act, the latter of which gives ENISA a mandate to address standards for the industry. However, not all elements of autonomous vehicle are covered by the NIS Directive, and while ENISA has a mandate, its first priority has been to address cloud computing. While cloud computing is a component of autonomous vehicles, it leaves other elements unaddressed, at least for the moment. Perhaps more importantly, however, is data protection and privacy. While GDPR represents a good first step, open questions remain at the level of protection it provides on the massive amounts of data being collected by autonomous vehicles.

Increased consumer trust and improved legal certainty for business users

As the gaps on liability and empowering users remain unaddressed, the consumer trust and legal certainty for business users might not change under Policy Option 1. They might increase somewhat because the current and recently adopted legislation increases transparency with regard to software, algorithms and automated decisions. Therefore the expected impact on consumer trust and certainty for business users will be positive but low.

Feasibility

The feasibility of Policy Option 1 is high because the respective framework is already in place and started to be implemented. Absence of provisions to address the identified gaps at EU level might, however, lead to Member States introducing their own national frameworks. This might result in a more fragmented situation, and thus the legal certainty may hinder the ability of markets address the identified gaps by themselves or may take extra time to do so. This could hinder the speed of application of robotics and AI in transport and result in lower competitiveness.

Proportionality and subsidiarity

As Policy Option 1 is a baseline that comprises all recent legal developments, the criteria of proportionality and subsidiarity have been checked during the EU law-making process according to the better regulation guidelines.

Table 8: Summary of the assessment of Policy Option 1

	Policy Option 1
Enabler targeted	• N/A
Economic net benefits	• The existing framework provides net economic benefits to the EU economy, but a mixed picture for employment. Employment in traditionally labour-intensive sectors like agriculture and construction is expected to decline, while transportation is the only area where any substantial increases of employment would be seen.
Innovation potential	• Some barriers to later stage testing have been removed, providing flexibility to approve the use of AVs on roads in some parts of Europe.
Security and cybersecurity	• The physical security of the vehicle has been improved, mandating certain safety systems. • Some cybersecurity concerns are also addressed under the auspices of ENISA.
Increased consumer trust	• Not addressed by this policy option.
Improved legal certainty to business users	• Not addressed by this policy option.
Feasibility of implementing a policy option	+++
Proportionality and subsidiarity	+++

Notes: feasibility, proportionality and subsidiarity are ranked from low (+), medium (++) to high (+++).
Source: Authors.

6.1.2. Policy Option 2: Increasing the harmonisation of liability regime

The EU could intervene to update and amend the legislation for AV-related products and services clarifying the application of strict liability to them. The goal will be to remove the potential gap identified in the area of liability and insurance.

Economic impacts

Overall, increasing the harmonisation of liability regime through this policy option will yield positive results. Table 20 shows the impact of implementing **Policy Option 2** in 2020 and 2030. GDP, private consumption, employment and capital stock are expected to increase compared to the baseline (i.e. the situation of no additional intervention, Policy Option 1). The dynamics of the deviations reflect the expectation that, if the respective policy package is implemented in the first year of the simulation, it will take several years for the EU economy to fully adjust and the effects will be completely manifested by 2025. From 2025 onwards, the differences from the baseline path stabilise or increase marginally only as a result of the endogenous model dynamics. Annex III provides more details on the sizes of the impacts between 2020 and 2030.

Policy Option 2 anticipated to result in a higher GDP compared to the values under Policy Option 1 (baseline) by 0.06 % in 2020 and 1.49 % in 2030. In absolute values, this means that the GDP will be higher by €7 868 million in 2020 and €231 097 million in 2030 compared to baseline.

The employment is expected to increase by 0.13 % or 0.243 million people in 2020 compared to values under Policy Option 1 (baseline). In 2030, the increase in employment is calculated to reach 2.48 % or 5.181 million compared to baseline.

Additionally, the implementation of this policy option will result in an increase in private consumption and capital stock. The capital stock experiences a smoother growth compared to the growth patterns of GDP and employment. The reason for this is that the capital stock accumulates investments over the entire simulation period. In the first year, the capital stock deviates negligibly from the Policy Option 1 values. In 2030, the capital stock is expected to differ from Policy Option 1 (baseline) by 0.49 %, while private consumption – by 1.58 %.

At a disaggregated level, the impact of increasing harmonisation of liability regime is positive for all sectors on real value added and employment (Tables 19-20). The impacts are positive regardless whether the sectors cover technology producer sectors and technology user sectors.

The only exception is land transport sector, where it will take several years for the EU economy to adjust until the benefits from such a policy initiative could be visible. From 2022 onwards, the differences from the Policy Option 1 (baseline) path will increase in line with the effects in other sectors.

Table 20: Impact of implementing Policy Option 2 on selected macroeconomic variables, percentage and absolute deviations from Policy Option 1, EU-27

Sector (percentage deviations)	2020	2030
GDP	0.06	1.49
Employment	0.13	2.48
Private consumption	0.07	1.58
Capital stock	0.00	0.49

Sector (absolute deviations)	2020	2030
GDP (millions of euros)	7 868	231 097
Employment (thousand persons)	243	5 181
Private consumption	N/A	N/A
Capital stock	N/A	N/A

Note: GDP is reported at constant 2019 prices. Percentage deviations refer to difference from Policy Option 1 in percentages.
Source: Authors.

Table 21: Impact of implementing Policy Option 2 on real value added by sector, in percentage and absolute deviations from Policy Option 1, EU-27

Sector (percentage deviations)	2020	2030
Agriculture	0.02	0.94
Construction	0.07	2.02
Finance and insurance	0.03	1.38
Industry	0.04	1.10
Land transport	-0.12	3.58
Manufacturing (other)	0.11	1.47
Other services	0.07	1.39
Transport (other)	0.07	1.37
Manufacturing of vehicles	0.09	1.29

Sector (absolute deviations)	2020	2030
Agriculture	39	2 254
Construction	366	14 821
Finance and insurance	134	9 440
Industry	137	4 707
Land transport	- 291	11 686
Manufacturing (other)	1 754	31 202
Other services	4 494	123 583
Transport (other)	215	5 286
Manufacturing of vehicles	189	3 754

Note: Percentage deviations refer to difference from Policy Option 1 in percentages.
Source: Authors.

Table 22: Impact of implementing Policy Option 2 on employment by sector, in percentage and absolute deviations from Policy Option 1, EU-27

Sector (percentage deviations)	2020	2030
Agriculture	0.10	2.59
Construction	0.14	3.81
Finance and insurance	0.06	2.56
Industry	0.14	2.57
Land transport	-0.29	8.37
Manufacturing (other)	0.20	2.33
Other services	0.12	2.14
Transport (other)	0.17	2.54
Manufacturing of vehicles	0.22	2.60

Sector (absolute deviations)	2020	2030
Agriculture	9	250
Construction	5	130
Finance and insurance	3	126
Industry	5	88
Land transport	- 17	511
Manufacturing (other)	54	665
Other services	171	3 218
Transport (other)	8	124
Manufacturing of vehicles	6	69

Note: Percentage deviations refer to difference from Policy Option 1 in percentages.
Source: Authors.

Other impacts

Increased consumer trust

The lack of clarity over liability can cause significant concerns for consumers that may be held liable for faults in the self-driving – and to an extent, potentially self-maintaining – systems of an AV. From a consumer's perspective, there is an understanding that in case of driver error, the driver of the vehicle can be liable for damages: where the driver does not exist, it should be clear to consumers where liability should lie, both from the consumer's obligation to other parties in an accident and to the manufacturers of the product and service combinations of the AV. This policy option would provide benefit to consumers.

Legal certainty for business users

For companies – particularly SMEs – a clear liability regime is critical to access finance, because private finance require due diligence with respect to contingent liabilities.[413] At a more general level, the increasing importance of software in the overall performance of the vehicle – something which the existing legal framework does not cover – provides a source of uncertainty for manufacturers that rely on other providers to provide the package of technologies required for an AV to operate safely. A revised legal regime can help clarify liability within value chains.

Innovation potential

Related to the legal certainty provided to business users, a clear framework provides suppliers with the confidence to understand where their liabilities begin and end. An unclear liability regime may cause certain parts of the value chain to avoid particular innovations if it remains unclear who bears responsibility for a failure. Critically, AVs will likely involve modules – combinations of software and hardware – that come from different manufacturers. For example, the self-driving system may rely on information not provided by the manufacturer of the vehicle itself to operate safely, which leaves open the question of who is ultimately responsible.

[413] Delponte, L (2018). European Artificial Intelligence (AI) leadership, the path for an integrated vision. Study for the ITRE Committee of the European Parliament, p. 20.

Security and cybersecurity

This policy option provides no new protections to security and cybersecurity, though clarified liabilities could potentially cause stakeholders to pay it more attention.

Feasibility of the policy option

Feasibility of Policy Option 2 can be considered high. A consensus seems to emerge between scholars, experts and other stakeholders about the need to set up a clear harmonised EU-wide liability framework for AI in transport. This option is likely to be supported by the insurance industry as well, due to the rich business opportunities it offers. Stakeholders will be also favouring the market-driven approach to cybersecurity, data protection and user empowerment that will be triggered thanks to this option. Compared to Policy Option 1; however, harmonisation across Member States will take additional effort.

Proportionality and subsidiarity

Proportionality and subsidiarity of this policy option are expected to be high. Policy Option 2 proposes to increase the harmonisation of the liability regime in the EU – an intervention that enhances the efforts of individual Member States and reduces fragmentation of the Single Market. Policy Option 2 builds on the existing EU interventions in the field of liability for road vehicles, where the current legal instruments (directives) proved to be proportionate and effective. Another future directive on liability is highly likely to be considered a proportionate intervention as well.

Table 23: Summary of the assessment of Policy Option 2

	Policy Option 2
Enabler targeted	• Liability and insurance • Technology • Research and Development
Economic net benefits	• Increase in GDP by 1.49 % or €231 097 million in 2030 compared to Policy Option 1 • Increase in employment by 2.48 % or 5.181 million people in 2030 compared to Policy Option 1
Innovation potential	• Provide clarity to providers for AVs that may be combining systems
Security and cybersecurity	• Same protections as provided under Policy Option 1
Increased consumer trust	• Assure consumers that AVs will not introduce unclear liability issues for which they will be responsible
Improved legal certainty to business users	• Provide the necessary information required for funding SMEs • Clarify liability amongst providers that need to interact for AVs
Feasibility of implementing a policy option	++
Proportionality and subsidiarity	+++

Notes: feasibility, proportionality and subsidiarity are ranked from low (+), medium (++) to high (+++).
Source: Authors.

6.1.3. Policy Option 3: Enhancing trust and protection of users

The gaps related to empowering users, cybersecurity, data protection and privacy could be closed by this policy option.

Economic impact

Overall, enhancing trust and protection of users through this policy option will yield positive results. Table 24 shows the impact of implementing Policy Option 3 in 2020 and 2030. GDP, private consumption, employment and capital stock are expected to increase compared to Policy Option 1 (baseline or the situation of no additional intervention). Similarly, to the dynamics of Policy Option 2, if Policy Option 3 is implemented in the first year of the simulation (2020), it will take several years for the EU economy to fully adjust and the effects will be completely manifested by 2025. From 2025 onwards, the differences from Policy Option 1 (baseline) path stabilise or increase marginally only as a result of the endogenous model dynamics. Annex III provides more details on the sizes of the impacts between 2020 and 2030.

Policy Option 3 is anticipated to result in a higher GDP compared to Policy Option 1 by 0.08 % in 2020 and 1.77 % in 2030. In absolute values, this means that the GDP will be higher by €10 305 million in 2020 and €275 287 million in 2030 compared to the values in Policy Option 1 (baseline). Overall, the differences compared to the baseline are higher compared to the differences under the implementation of Policy Option 2.

The employment is expected to increase by 0.16 % or 0.315 million people in 2020 compared to values in Policy Option 1 (baseline). In 2030, the increase in employment is calculated to reach 2.94 % or 6.147 million compared to Policy Option 1 (baseline). Similarly, to the differences in GDP between Policy Option 2 and 3, the anticipated differences are higher compared to the ones under Policy Option 2.

Additionally, the implementation of this policy option will result in an increase in private consumption and capital stock. In the first year, the capital stock deviates negligibly from the baseline. Private consumption and capital stock will rise by 1.89 % and 0.6 % respectively in 2030.

At a disaggregated level, the impact of increasing harmonisation of liability regime is positive for all sectors on real value added and employment (Tables 23-24). The impacts are positive regardless whether the sectors cover technology producer sectors and technology user sectors. Similarly, to the impact of Policy Option 2, land transport sector will experience an adjustment period in the first two years after Policy Option 3 is implemented. From 2022 onwards, the differences from the Policy Option 1 (baseline) path will increase in line with the effects in other sectors.

Table 9: Impact of implementing Policy Options 3 on selected macroeconomic variables, percentage and absolute deviations from Policy Option 1, EU-27

Sector (percentage deviations)	2020	2030	Sector (absolute deviations)	2020	2030
GDP	0.08	1.77	GDP (millions of euros)	10 305	275 287
Employment	0.16	2.94	Employment (thousand persons)	315	6 147
Private consumption	0.09	1.89	Private consumption	N/A	N/A
Capital stock	0.00	0.6	Capital stock	N/A	N/A

Note: GDP is reported at constant 2019 prices. Percentage deviations refer to difference from Policy Option 1 in percentages.
Source: Authors.

Table 10: Impact of implementing Policy Option 3 on real value added by sector, in percentage and absolute deviations from Policy Option 1, EU-27

Sector (percentage deviations)	2020	2030
Agriculture	0.03	1.15
Construction	0.10	2.41
Finance and insurance	0.04	1.67
Industry	0.05	1.32
Land transport	-0.08	4.06
Manufacturing (other)	0.13	1.77
Other services	0.08	1.67
Transport (other)	0.09	1.64
Manufacturing of vehicles	0.10	1.54

Sector (absolute deviations)	2020	2030
Agriculture	57	2 730
Construction	558	17 599
Finance and insurance	231	11 352
Industry	180	5 666
Land transport	- 197	13 208
Manufacturing (other)	2 103	37 343
Other services	5 792	147 601
Transport (other)	268	6 289
Manufacturing of vehicles	227	4 476

Note: Percentage deviations refer to difference from Policy Option 1 in percentages.
Source: Authors.

Table 11: Impact of implementing Policy Option 3 on employment by sector, in percentage and absolute deviations from Policy Option 1, EU-27

Sector (percentage deviations)	2020	2030
Agriculture	0.14	3.11
Construction	0.21	4.52
Finance and insurance	0.10	3.07
Industry	0.18	3.07
Land transport	-0.19	9.44
Manufacturing (other)	0.24	2.78
Other services	0.15	2.55
Transport (other)	0.21	3.01
Manufacturing of vehicles	0.26	3.08

Sector (absolute deviations)	2020	2030
Agriculture	13	300
Construction	7	155
Finance and insurance	5	151
Industry	6	105
Land transport	- 11	577
Manufacturing (other)	64	794
Other services	216	3 836
Transport (other)	9	147
Manufacturing of vehicles	7	82

Note: Percentage deviations refer to difference from Policy Option 1 in percentages.
Source: Authors.

Other impacts

Improving consumer trust

Consumer confidence in AVs involve both the performance of the vehicles as well as confidence in what will be done with the vast amounts of data that will be accumulated. Consumers may choose to avoid vehicles because they worry about the ultimate safety of the vehicle, but they may also be concerned about how data about their movements will be used in other contexts. Clarification of data protection processes, both in securing the vehicle and ensuring that data is only used for a specific set of purposes, will help to increase consumer confidence, and hence uptake, of the vehicle.

Increasing cybersecurity (in general)

While the Cybersecurity Act and other legal elements described in Chapter 4 illustrate how cybersecurity issues are already being addressed in the context of AV, clarifying data usage will also – as a corollary – reduce the likelihood of data breaches that can causes economic losses for both businesses and consumers.

Improved legal certainty for business users

As Policy Option 3 would include the same changes to the regulatory framework for liability as Policy Option 2, the improvements for business users would be similar to this other policy option.

Feasibility of the policy option

Feasibility of this Policy option is going to be low. First, there is still lack of clarity and consensus on what exactly the explicability of algorithms and AI means and how it can be implemented in practical terms.[414] Second, cybersecurity certification has so far intended to be voluntary, and many stakeholders oppose a mandatory solution for it, both on the grounds of practicality (i.e. there are no capacities to quickly certify the whole industry) and because it is not clear how to certify such a complex product as a car. Last, many stakeholders may feel overwhelmed with recent GDPR requirements, consider them sufficient for the moment and oppose further tightening of the rules. Some researchers estimate that the heavy data protection and privacy rules and high costs of compliance with them complicate AI research and deployment in the EU.[415]

Proportionality and subsidiarity

This policy option offers the possibility to address all identified gaps to the adoption of AI-based products and services in transport. Providing unified approach to it would create a better environment for operation within the Single Market (i.e. enhancing the harmonisation and consistency of the legal framework across the EU). In addition, since the gaps are horizontal, there could be some spill over impacts on the adoption of all AI-based products and services. Therefore, the subsidiarity of this policy option is considered to be high. Proportionality ultimately depends on the legal instrument chosen. However, considering that this policy option proposes to patch gaps in the existing legislation, proportionality is also likely to be high.

Table 12: Summary of the assessment of Policy Option 3

	Policy Option 3
Enabler targeted	• Ethical framework for AI • Liability and insurance • Technology • Research and development
Economic net benefits	• Increase in GDP by 1.77 % or €275 287 million in 2030 compared to Policy Option 1 • Increase in employment by 2.94 % or 6.147 million people in 2030 compared to Policy Option 1

414 Robbins, S. (2019). A Misdirected Principle with a Catch: Explicability for AI. *Minds and Machines* 29, pp. 495-514.

415 Castro, D., and Chivot, E. (2019). The EU Needs to Reform the GDPR To Remain Competitive in the Algorithmic Economy. Research paper by Center for Data Innovation; Martin, N., Matt, C., Niebel, C. et al. (2019). How Data Protection Regulation Affects Startup Innovation. *Information Systems Frontiers* 21, pp. 1307–1324.

Innovation potential	• No added benefit over Policy Option 2
Security and cybersecurity	• Decrease the amount of private data lost when data breaches occur
Increased consumer trust	• Increase confidence that an AV will not be subject to bad actors • Increase confidence that data will be used for limited purposes
Improved legal certainty to business users	• No added benefit over Policy Option 2
Feasibility of implementing a policy option	+
Proportionality and subsidiarity	+++

Notes: feasibility, proportionality and subsidiarity are ranked from low (+), medium (++) to high (+++). Source: Authors.

6.2. Assessing the cost of non-Europe

6.2.1. The key enablers revisited

One of the assumptions of this study is that artificial intelligence is a key enabler of autonomous vehicles – the benefits (and potential costs) of artificial intelligence derive from the fact that the technology is an essential component for new applications in the road transport sector. AI applications help make sense of data more efficiently, meaning that autonomous vehicles can better make sense of their complex surroundings, but also help to make consumer and business-level applications that make trips more efficient. Many experts seem clear that artificial intelligence represents one of these key components.[416] As such, the benefits afforded by artificial intelligence are in how it enables autonomous transportation.

While artificial intelligence should be viewed as a key enabling technology, it is not the only enabler for autonomous vehicles, as outlined in this report. A combination of physical infrastructure, technological development, financial support and a regulatory framework all play a role in supporting artificial intelligence and how it can promote autonomous vehicles.

Table 13: Summary of key enablers for AI-enabled autonomous vehicles

Enablers	Type of enabler	Key component of the enabler
Roads	Infrastructure	Levels 3-5 of autonomous driving requires additional infrastructure, developing and installing sensors to collect road and traffic information, compute it and share it with vehicles.
Connectivity		Vehicles need to position themselves against other vehicles (vehicle-to-vehicle or V2V communication) and to plan and navigate routes.

[416] McKinsey Center for Future Mobility (2017). Smart Moves Required - The Road Towards Artificial Intelligence in Mobility.

Technology		While AI technologies exist in support of autonomous vehicles, their maturity level remains limited. Autonomous vehicles, despite their potential, are still in testing phases.
Public and private-sector investment	Financial support	It is well documented how levels of investment and venture capital have influenced the development of AI in general, and both the public and private sector play a role in financing further development of the technology.
State-aid and competition rules		Related to public-sector investment, state aid and competition rules need to see that funding is distributed in a way that does not distort the internal market of the EU.
Ethical framework for AI	Regulatory framework	Without social acceptance, consumers and even businesses may reject a new technology. They may show distrust of autonomous vehicles themselves, or may distrust how data collected from those vehicles are being used. An ethical framework can help to drive acceptance and uptake of the technology.
Liability and insurance		As addressed at length in this report, liability need to be sufficiently clear in an AI context so that the use of such vehicles can actually start with low legal risks for those involved.
Research, development, and innovation policies		More than just financing, R&D&I policies direct the efforts of researchers – both public and private – in where to invest research effort. Recent efforts, for example, by the EU to divert research to technologies with higher technology readiness levels is in direct response to concerns that Europe produces good theoretical research, but fails to commercialise those efforts.

Source: Authors.

In understanding the cost of non-Europe, analysing the gaps in the enabler framework, it becomes clear that enablers need to be separated into two categories: legal gaps which the EU could fill by altering the regulatory framework and priority gaps where the EU might change, for example, priorities on how best to support the technology. In the latter case, the regulatory framework does not need adjustment, but rather, it is a question of allocation of additional resources to the specific priorities. The EU, for example, already has the legal mechanisms in place to further support 5G development along key corridors, but budget allocations might need to be considered.

As outlined in Chapter 4, four key gaps in the legal framework have been identified. On this basis, several policy options were developed to conduct a cost of non-Europe analysis to quantify the potential net benefits. In other words, we assessed quantitatively and qualitatively net costs, resulting from the lack of EU action. The policy options were put forward and assessed in terms of their benefits and costs, feasibility and impacts. Table 29 summarises the benefits (and costs) of each of the proposed policy options. Overall, the preferred policy option is Policy Option 3 enhancing trust and protection of users. While feasibility of this policy option is lower than focussing strictly on the liability regime, consumer trust and cybersecurity remain key to uptake. Additionally, given that these are horizontal issues influencing more than just the road transport sector, there are additional costs of non-Europe that are not captured in this analysis, which need to be kept in mind when taking this policy option path.

Table 14: Summary of policy options assessments

	PO 1: baseline/no additional intervention at EU level	PO 2: Liability regime	PO 3: Trust and protection of users
New enabler targeted	n/a	• Road infrastructure • Technology • Liability and insurance • Research, development and innovation policies	• Road infrastructure • Technology • Ethical framework for AI • Liability and insurance • Research, development and innovation policies
Innovation potential	+	++	+++
Security and safety of the vehicle	++	++	++
Cybersecurity of the vehicle	+	+	+++
Increased consumer trust	+	++	+++
Improved legal certainty	+	+++	+++
Feasibility of implementing a policy option	+++	++	+
Proportionality and subsidiarity	+++	+++	+++

Notes: feasibility, proportionality and subsidiarity are ranked from low (+), medium (++) to high (+++).
Source: Authors.

The qualitative and quantitative analysis focus on the costs and benefits of improving the regulatory environment in terms of the given enablers, a more specific set of recommendations – based on a literature review that fed this research paper's understanding of the gaps of the various gaps – is provided in the table below.

6.2.2. Estimated direct costs, lower and upper bounds

The cost of non-Europe refers to the costs borne by the EU citizens, public organisations, businesses due to the identified potential gaps and barriers. The suggested Policy Options 2 and 3 address the identified gaps to various extent, while Policy Option 1 proposes no additional intervention at the EU level. Therefore, the costs of non-Europe are calculated as benefits that Policy Option 2 and 3 bring individually over Policy Option 1.

Table 30: Estimated direct cost of non-Europe, in 2030, EU-27

	Lower bound	Upper bound
GDP (millions of euros)	€231 097	€275 287
Employment (million persons)	5.181	6.147

Note: the lower bound (upper bound) estimate refers to the benefits that Policy Option 2 (3) brings additionally to Policy Option 1 as quantified using CGE model.
Source: Authors.

6.2.3. Key recommendations to regaining the costs of Non-Europe

As mentioned earlier in this report, Policy Option 3 potentially brings the biggest benefit to enable the uptake of artificial intelligence in the road transportation industry. While this policy options faces greater political obstacles of aligning Member States, the overall benefit to this industry as well as spin-off benefits to other high-tech endeavours within the EU indicate that the effort would pay dividends.

More specific recommendations on how to alter the legal framework in line with the wider goals elucidated by Policy Option 3 are outlined in Table 31.

Table 31: Key recommendation to alter the legal framework

Gap in framework	Recommendation
Liability	Contissa, Lagioia and Sartor argue that, while the trend of transferring liability from the individual to the enterprise has been observed for quite a long time, new AI technologies accelerate this trend.[417] They recommend an increased duty of care, resulting in a higher liability risk for (i) the operator; (ii) the organisation employing the operator, both for vicarious liability and organisational liability; and, finally, (iii) the producer of the technology, since higher complexity in the human-machine interface would increase the risk of technological failure.
	TNO et al. suggest the introduction of an ad-hoc EU legislation implementing a Risk Management Approach.[418] This approach would hold accountable the party that is best positioned to minimise risks, ensure compliance, as well as acquire insurance. The Risk Management Approach, in combination with strict (or absolute) liability, would identify a clearly responsible party (one-stop-shop) easing prima facie victim compensation, and subsequent distribution of all associated costs along the value chain.
	Finally, the GDPR liability regime may also be applied to some damages caused by AV. As underlined by Struder and De Werra, the GDPR also introduced a strict liability regime for damages resulting of a violation of the regulation rules (including data accuracy principle and data security requirements).[419] For instance, when transiting between automated to manual mode, an AV could falsely consider a driver as in the

[417] Contissa G., F. Lagioia and G. Sartor (2018). Liability and automation: legal issues in autonomous cars. *Networks Industries Quarterly*, Vol. 20(2), pp. 21-26.

[418] TNO et al. (2019). Safety of non-embedded software: Service, data access, and legal issues of advanced robots, autonomous, connected, and AI-based vehicles and systems. European Commission.

[419] Studer E. and de Werra, J. (2017). Regulation Cybersecurity - What civil liability in case of cyber-attacks?. *Expert Focus*, Vol. 17(8), pp. 511–517.

	position to take over control of a semi-autonomous vehicle. The data controller may be held liable for damages of such solely automated decision based on personal data. Nevertheless, this scenario requires that data processing operation is not pursued only locally to trigger the GDPR's application.[420]
Empowering users	Considering the significant risks inherent to AV that may not always make decisions based on personal data, it may be necessary to introduce a general rule that AV decisions must be explainable.
Cybersecurity	In awaiting of mandatory cybersecurity technical regulations, car manufacturers might be considered as OES to ensure the cybersecurity of vehicles or special certification schemes for AV and their components could be established. Considering the nature of risks inherent to AV products and services, or at least for vehicles, compliance with a certification scheme of a high level of assurance could be made mandatory by EU or national law.
Data protection	The use of biometric data should be prohibited even if no unique identification is pursued. Delegated acts related to these safety features and systems should be adopted to clarify the issue and close the gap, also prohibiting the use of biometric data for these systems, if necessary.
	The RED empowers the European Commission to establish classes of radio equipment that must be constructed incorporating safeguards for the protection of personal data and privacy user and supporting certain features ensuring protection from fraud. A delegated act to this end could be adopted for AV because radio equipment will be used by/in AV for communication between vehicles and infrastructure or between different vehicles.
	The GVSR requires that driver drowsiness and attention warning, advanced driver distraction warning and Event Data Recorder process data and operate on a closed-loop system. As closed-loop systems might not necessarily mean local processing of data (i.e. processing within the vehicle), further guidance might be necessary regarding the processing of such personal data. Delegated acts relating to these safety systems should address this question.
	The eCall Regulation contains guarantees ensuring data protection and privacy. Equivalent guarantees could also apply to advanced safety systems under the GVSR.

Source: Authors

[420] EDBD considers local processing of personal data as falling out the scope of GDPR. See Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications.

Annex I References

Legal and policy documents

5G-PPP, 5G Strategic Deployment Agenda for Connected and Automated Mobility in Europe. Initial proposal, 2019.

AI HLEG, A Definition of AI: Main Capabilities and Disciplines, 2019.

AI HLEG, Ethics Guidelines for Trustworthy Artificial Intelligence, 2019.

Article 29, Guidelines on Automated individual decision-making and Profiling for the purposes of Regulation 2016/679, 2018.

Article 29, Opinion 8/2014 on the on Recent Developments on the Internet of Things.

Autorité de la concurrence and Bundeskartellamt, Algorithms and competition – White paper, 2019.

Case C-360/10, *Belgische Vereniging van Auteurs, Componisten en Uitgevers CVBA (SABAM) v Netlog NV*. EU:C:2012:85.

Case C-324/09, *L'Oréal SA and Others v. eBay International and Others*. EU:C:2011:474.

Case C-444/02 *Fixtures Marketing v. Organismos prognostikon agonon podosfairou AE (OPAP)*. EU:C:2004:697.

Case C-338/02 *Fixtures Marketing Ltd v. Svenska Spel*. EU:C:2004:696.

Case C-203/02 *The British Horseracing Board e.a. c. William Hill Organization*. EU:C:2004:695.

Case C-46/02, *Fixtures Marketing v. Oy Veikkaus*, EU:C:2004:694.

Charter on Fundamental Rights of the European Union, OJ C 326 of 26.10.2012.

Commission Delegated Regulation 2017/1926 of 31 May 2017 supplementing Directive 2010/40 of the European Parliament and of the Council with regard to the provision of EU-wide multimodal travel information services, OJ L 272 of 21.10.2017.

Commission Delegated Regulation 2015/962 of 18 December 2014 supplementing Directive 2010/40 of the European Parliament and of the Council with regard to the provision of EU-wide real-time traffic information services, OJ L 157 of 23.06.2015.

Commission Delegated Regulation 886/2013 of 15 May 2013 supplementing Directive 2010/40 of the European Parliament and of the Council with regard to data and procedures for the provision, where possible, of road safety-related minimum universal traffic information free of charge to users, OJ L 247 of 18.09.2013.

Commission Staff Guidance on the implementation and application of Directive 2005/29 on Unfair Commercial Practices, SEC (2009)1666.

Council Directive 85/374 of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products, OJ L 210 of 07.08.1985.

Decree of 25 June 2019 establishing the date of entry into force of the Act of 26 September 2018 amending the 1994 Road Traffic Act in connection with enabling experiments with automated systems in motor vehicles and Decree of 6 December 2018 amending the Decree exemption from exceptional transport and the Vehicle Registration Regulations in connection with enabling experiments with automated systems in motor vehicles. Bulletin of Acts and Decrees 2019.

Decree of 15 June 2015 to amend the Decree on exemption from exceptional transports (development of self-driving car). Bulletin of Acts and Decrees 2015.

Directive 2019/1024 of the European Parliament and of the Council of 20 June 2019 on open data and the re-use of public sector information, OJ L 172 of 26.06.2019.

Directive 2019/2161 of the European Parliament and of the Council of 27 November 2019 amending Council Directive 93/13/EEC and Directives 98/6/EC, 2005/29/EC and 2011/83/EU of the European

Parliament and of the Council as regards the better enforcement and modernisation of Union consumer protection rules, OJ L 328 of 18.12.2019.

Directive 2019/790 of the European Parliament and of the Council of 17 April 2019 on copyright and related rights in the Digital Single Market, OJ L 130 of 17.05.2019.

Directive 2019/771 of the European Parliament and of the Council of 20 May 2019 on certain aspects concerning contracts for the sale of goods, OJ L 136 of 22.05.2019.

Directive 2019/770 of the European Parliament and of the Council of 20 May 2019 on certain aspects concerning contracts for the supply of digital content and digital services, OJ L 136 of 55.05.2019.

Directive 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union, OJ L 194 of 19.07.2016.

Directive 2014/53 of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment, OJ L 153 of 22.05.2014.

Directive 2011/83 of the European Parliament and of the Council of 25 October 2011 on consumer rights, OJ L 304 of 22.11.2011.

Directive 2010/40 of the European Parliament and of the Council of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport, OJ L 207 of 06.08.2010.

Directive 2009/103 of the European Parliament and of the Council of 16 September 2009 relating to insurance against civil liability in respect of the use of motor vehicles, and the enforcement of the obligation to insure against such liability, OJ L 263 of 07.10.2009.

Directive 2009/24 of the European Parliament and of the Council of 23 April 2009 on the legal protection of computer programs, OJ L 111 of 05.05.2009.

Directive 2005/29 of the European Parliament and of the Council of 11 May 2005 concerning unfair business-to-consumer commercial practices in the internal market, OJ L 149 of 11.06.2005.

Directive 2002/58 of the European Parliament and of the Council of 12 July 2002 concerning the processing of personal data and the protection of privacy in the electronic communications sector, OJ L 201 of 31.07.2002.

Directive 2001/95 of the European Parliament and of the Council of 3 December 2001 on general product safety, OJ L 11 of 15.01.2002.

Directive 2001/29 of the European Parliament and of the Council of 22 May 2001 on the harmonisation of certain aspects of copyright and related rights in the information society, OJ L 167 of 22.06.2001.

Directive 2000/31/EC of the European Parliament and of the Council of 8 June 2000 on certain legal aspects of information society services, in particular electronic commerce, in the Internal Market, OJ L 178 of 17.07.2000.

Directive 96/9 of the European Parliament and of the Council of 11 March 1996 on the legal protection of databases, OJ L 77 of 27.03.1996.

EDBP, Draft Guidelines 2/2019 on the processing of personal data under Article 6(1)(b) GDPR in the context of the provision of online services to data subjects.

EDBP, Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications.

Eight Act amending the Road Traffic Act of 16 June 2017.

ENISA, Good practices for security of smart cars, 2019.

ENISA, Cyber security and resilience of smart cars. Good practices and recommendations, 2016

ERTRAC Working Group, Connected Automated Driving Roadmap, 2019.

European Commission, White Paper on Artificial Intelligence - A European approach to excellence and trust. COM(2020) 65 of 19.02.2020.

European Commission, Guidelines on the exemption procedure for the EU approval of automated vehicles, 2019.

European Commission, STRIA Roadmap on Connected and Automated Transport: Road, Rail and Waterborne, 2019.

European Commission, Certificate Policy for Deployment and Operation of European Cooperative Intelligent Transport Systems (C-ITS). Release 1.1, 2018.

European Commission, Guide to the Radio Equipment Directive 2014/53, 2018.

European Commission, Liability for emerging digital technologies. SWD(2018) 137 of 25.04.2018.

European Commission, Proposal for a Regulation of the European Parliament and of the Council establishing the Connecting Europe Facility and repealing Regulations (EU) No 1316/2013 and (EU) No 283/2014, COM(2018) 438 of 06.06.2018.

European Commission, Proposal for a Regulation of the European Parliament and of the Council establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination, COM(2018) 435 of 06.06.2018.

European Commission, Proposal for a Regulation of the European Parliament and of the Council establishing the Digital Europe programme for the period 2021-2027, COM(2018) 434 of 06.06.2018.

European Commission, Proposal for a Directive of the European Parliament and of the Council amending Directive 2009/103/EC of the European Parliament and the Council of 16 September 2009 relating to insurance against civil liability in respect of the use of motor vehicles, and the enforcement of the obligation to ensure against such liability, COM(2018) 336 of 24.05.2018.

European Commission, On the road to automated mobility: An EU strategy for mobility of the future. COM(2018) 283 of 17.05.2018.

European Commission, A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility. COM(2016) 766 of 30.11.2016.

European Commission, Space Strategy for Europe. COM(2016) 704 of 26.10.2016.

European Commission, 5G for Europe: an Action Plan. COM(2016) 588 of 14.09.2016

European Commission, Action Plan for the Deployment of Intelligent Transport Systems in Europe. COM(2008) 886 of 16.12.2008.

European Council, Conclusions of the Special meeting of the European Council (17, 18, 19, 20 and 21 July 2020). EUCO 10/20.

European Parliament resolution of 12 February 2019 on a comprehensive European industrial policy on artificial intelligence and robotics, 2018/2088(INI).

European Parliament resolution of 15 January 2019 on autonomous driving in European transport, 2018/2089(INI).

European Parliament resolution of 16 February 2017 with recommendations to the Commission on Civil Law Rules on Robotics, 2015/2103(INL).

Loi 2019-1428 du 24 décembre 2019 d'orientation des mobilités.

Regulation 2019/2144 of the European Parliament and of the Council of 27 November 2019 on type-approval requirements for motor vehicles and their trailers, and systems, components and separate technical units intended for such vehicles, as regards their general safety and the protection of vehicle occupants and vulnerable road users, OJ L 325 of 16.12.2019.

Regulation 2019/1150 of the European Parliament and of the Council of 20 June 2019 on promoting fairness and transparency for business users of online intermediation services, OJ L 186 of 11.07.2019.

Regulation 2019/881 of the European Parliament and of the Council of 17 April 2019 on ENISA (the European Union Agency for Cybersecurity) and on information and communications technology cybersecurity certification, OJ L 151 of 07.06.2019.

Regulation 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, OJ L 303 of 28.11.2018.

Regulation 2018/858 of the European Parliament and of the Council of 30 May 2018 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, OJ L 151 of 14.06.2018.

Regulation 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, OJ L 119 of 04.05.2016.

Regulation 2015/758 of the European Parliament and of the Council of 29 April 2015 concerning type-approval requirements for the deployment of the eCall in-vehicle system based on the 112 service, OJ L 123 of 19.05.2015.

Regulation 765/2008 of the European Parliament and of the Council of 9 July 2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products, OJ L 218 of 13.8.2008.

Academic and other research

Abduljabbar, R. et al., Applications of Artificial Intelligence in Transport: An Overview, *Sustainability*, 2019, Vol. 11(1).

ACEA, Economic and Market Report: EU Automotive Industry, 2019.

Acheampong, R.A. et al., Literature review on the social challenges of autonomous transport. STSM Report for COST Action CA16222 'Wider Impacts and Scenario Evaluation of Autonomous and Connected Transport (WISE-ACT), 2018.

Alonso Raposo, M. et al., The future of road transport - Implications of automated, connected, low-carbon and shared mobility, EUR 29748 EN, Publications Office of the European Union, Luxembourg, 2019.

Alonso Raposo, M. et al., The r-evolution of driving: from Connected Vehicles to Coordinated Automated Road Transport (C-ART). EUR 28575 EN, Publications Office of the European Union, 2017.

Alvarez, L., Eyes on the Road: Surveillance Logics in the Autonomous Vehicle Economy, *Surveillance & Society,* 2019, Vol. 17(1/2), pp. 198-204.

Anderson, J. et al., Autonomous Vehicle Technology: A Guide for Policymakers. RAND Corporation, 2016.

Anderson, M., The Self-Driving Car Is a Surveillance Tool, IEEE Spectrum, 2019.

Asselin-Miller, N. et al., Study on the Deployment of C-ITS in Europe: Final Report, European Commission, 2016.

Bagloee, S. et al., Autonomous vehicles: challenges, opportunities, and future implications for transportation policies. *Journal of Modern Transportation,* Vol. 24, 2016, pp. 284–303.

Batura, O., Pankowska, P., Regeczi, D., Vassilev, A. and Yagafarova, A., Framework on ethical aspects of artificial intelligence, robotics and related technologies. EPRS, 2020.

Bayen, A. and Shastry, M., 'Intelligent Transportation Systems and Infrastructure', *Berkley Institute of Transport Studies,* 2017.

Berkley Institute of Transportation Studies, Intelligent Transportation Systems and Infrastructure, 2017.

Bughin et al., NOTES FROM THE AI FRONTIER: MODELING THE IMPACT OF AI ON THE WORLD ECONOMY, Mckinsey Global Institute, 2018.

Capgemini, Accelerating automotive's AI transformation: How driving AI enterprise-wide can turbo-charge organizational value, 2019.

Castro, D., and Chivot, E. The EU Needs to Reform the GDPR To Remain Competitive in the Algorithmic Economy. Research paper by Center for Data Innovation, 2019.

Castro, D., McLaughlin, M. and Chivot, E., Who Is Winning the AI Race: China, the EU or the United States? Research paper by Center for Data Innovation, 2019.

CE Delft, Handbook on the external costs of transport, European Commission, 2019.

Chatzipanagiotis, M. and Leloudas, G., Automated Vehicles and Third-Party Liability: A European Perspective. *University of Illinois Journal of Law, Technology & Policy*, 2020, pp. 109-199.

Claypool, H., Bin-Nun, A. and Gerlach, J., Self-Driving Cars: The Impact on People with Disabilities, The Ruderman White Paper, 2017.

Clements, L. and Kockelman, K., 'Economics effects of Automated Vehicles', *Transportation Research Record,* 2017.

Committee on Transport and Tourism, Report of 5 December 2018 on autonomous driving in European transport, European Parliament, 2018.

Cummings, M., Rethinking the maturity of artificial intelligence in safety-critical settings, AI Magazine, 2020.

de Concini, A., Financing innovation in clean and sustainable mobility: Study on access to finance for the innovative road transport sector, European Commission, 2018.

Després, J. et al., An analysis of possible socio-economic effects of a Cooperative, Connected and Automated Mobility (CCAM) in Europe effects of automated driving on the economy, employment and skills, European Commission, 2018.

DHL and IBM, Artificial intelligence in logistics, 2018.

EBRD, Disruptive technology and innovation in transport, 2018.

Ecorys, CBO, IDATE, VVA and WIK Consult, Supporting the implementation of CEF2 Digital. Study for the European Commission, 2020.

European Bank for Reconstruction and Development, Disruptive technology and innovation in transport, 2019.

European Commission, EU R&D - The 2019 EU Industrial R&D, 2019.

European Commission, Connected and Automated Transport: Studies and reports, 2017.

European Commission, EU R&D - The 2018 EU Industrial R&D, 2018.

European Commission, EU transport in figures Statistical pocketbook 2019, 2019.

European Commission, Report on the safety and liability implications of Artificial Intelligence, the Internet of Things and robotics, 2020.

European Commission, Road transport: A change of gear, 2012.

European Commission, Road transport: A change of gear, 2018.

European Commission, The 2017 EU Industrial R&D Investment Scoreboard, 2017.

European Commission, Transport in the European Union: Current trends and issues, 2019.

European Commission. Liability and New Technologies, Liability for artificial intelligence and other emerging digital technologies, Report, 2019.

European Committee of the Regions, State of play of connected and automated driving and future challenges and opportunities for Europe's Cities and Regions, 2018.

European Court of Auditors, Towards a successful transport sector in the EU: challenges to be addressed, 2018.

European Union, United Nations, UTF and OECD, Glossary for transport statistics, 5th edition, 2019.

Evas, T. and Lombo, N., European framework on ethical aspects of artificial intelligence, robotics and related technologies (European added value assessment), EPRS, 2020.

Evas, T., A common EU approach to liability rules and insurance for connected and autonomous vehicles. EPRS, 2018.

Floridi, L., 'On Human Dignity as a Foundation for the Right to Privacy', *Philosophy & Technology*, 2016, Vol. 29, pp. 307–312.

French Ministry of Interior, Development of Autonomous Vehicles. Report, 2018.

Glancy, D., 'Privacy in Autonomous Vehicles', *Santa Clara Law Review*, 2012, Vol. 52(4).

Grigoratos, T. and Martini, G., Non-exhaust traffic related emissions. Brake and tyre wear PM, European Commission, 2014.

Haque, A. and Brakewood, C., 'A synthesis and comparison of American automated shuttle pilot projects', *Case Studies on Transport Policy*, 2020, Vol. 8(3), pp. 928-937.

Hosoe, N., Gasawa, K. and Hashimoto, H., Textbook of Computable General Equilibrium Modelling: Programming and Simulations. Palgrave Macmillan, 2010.

IBM, Automotive 2030: Racing toward a digital future, n.d.

ICCT, European vehicle market statistics. Pocketbook 2019/20, 2019.

International Transport Forum, Managing the Transition to Driverless Road Freight Transport, 2017.

Kaminski, M., The right to explanation, explained. *Berkeley Technology Law Journal*, 2018.

Kindt, J., Having Yes, Using No? About the new legal regime for biometric data. *Computer Law & Security Review*, 2018, pp. 532-538.

Kofferman, N., (The right to) personal autonomy in the case law of the European Court of Human Rights, Leiden University, 2010.

KPMG, 2018 Autonomous Vehicles Readiness Index, 2018.

KPMG, 2019 Autonomous Vehicles Readiness Index, 2019.

KPMG, 2020 Autonomous Vehicles Readiness Index, 2020.

KPMG, R&D in the automotive sector, 2018.

Litman, T., Autonomous Vehicle Implementation Predictions: Implications for Transport Planning, Victoria Transport Policy Institute, 2020.

Liyanage, S. et al., 'Flexible Mobility On-Demand: An Environmental Scan', *Sustainability*, 2019, Vol. 11(5).

Machin, M. et al., On the use of artificial intelligence techniques in intelligent transportation systems, 2018 IEEE Wireless Communications and Networking Conference Workshops (WCNCW), 2018.

Malgieri, G. and Comandé, G., Why a right to legibility of automated decision-making exists in the general data protection regulation. *International Data Privacy Law*, Vol. 7(4), 2017, pp. 243–265.

Malgieri, G., Automated Decision-Making in the EU Member States: The Right to Explanation and Other 'Suitable Safeguards' for Algorithmic Decisions in the EU National Legislations. *Computer law & Security Review*, 2018, Vol. 35(5).

Manyika, J. et al., Disruptive technologies: Advances that will transform life, business, and the global economy, McKinsey Global Institute, 2013.

Marten, B. and Garrez, J., Cost of non-Europe in robotics and artificial intelligence: Liability, insurance and risk management, EPRS, 2019.

Martin, N., Matt, C., Niebel, C. et al. How Data Protection Regulation Affects Startup Innovation. *Information Systems Frontiers* 2019, Vol. 21, pp. 1307–1324.

McKinsey Center for Future Mobility, Race 2050 - A vision for the European automotive industry, 2019.

McKinsey Center for Future Mobility. Smart Moves Required - The Road Towards Artificial Intelligence in Mobility, 2017.

McKinsey, Distraction or disruption? Autonomous trucks gain ground in US logistics, 2018.

McKinsey, How China will help fuel the revolution in autonomous vehicles, 2019.

McKinsey, The trends transforming mobility's future, 2019.

Morales, F. et al. 'Automatic Prediction of Maintenance Intervention Types in Roads using Machine Learning and Historical Records', *SAGE Journal of Transportation Research Board*, 2018, Vol. 2672(44), pp. 43-54.

Mosquet, X. and Pélata, P., Reinforcing the attractiveness and competitiveness of France in tomorrow's automotive industry and mobility, General Council on Economy, Industry, Energy and Technologies, 2019.

National Research Council, Developments in Artificial Intelligence. Funding a Revolution: Government Support for Computing Research, The National Academies Press, 1999.

Nordhoff, S. et al., 'Acceptance of Driverless Vehicles: Results from a Large Cross-National Questionnaire Study', *Journal of Advanced Transportation,* 2018.

Nunes, A. and Hernandez, K., 'Autonomous Vehicles and Public Health: High Cost or High Opportunity Cost', *Transportation Research Part A: Policy and Practice,* 2019, Vol. 138, pp. 28 –36.

OECD, Artificial intelligence in society, 2019.

OECD, Private Equity Investment in Artificial Intelligence. OECD Going Digital Policy Note, OECD, Paris, 2018.

Pakusch, C. et al., Unintended Effects of Autonomous Driving: A Study on Mobility Preferences in the Future' *Sustainability*, 2018, Vol. 10(7).

Patella, S., Aletta, F. and Mannini, L., Assessing the impact of Autonomous Vehicles on urban noise pollution, De Gruyter, 2019.

Pew Research Center, Artificial Intelligence and the Future of Humans, 2018.

Punev, A., Autonomous Vehicles: The Need for a Separate European Legal Framework. *European View*, Vol. 19(1), 2020, pp. 95-102.

PwC, Five trends transforming the automotive industry', 2019.

PwC, The macroeconomic impact of artificial intelligence, 2018.

Ramahandry, T., Edge computing: Battle between cloud providers, industrials and telcos, *IDATE DigiWorld*, 2019.

Rannenberg K., Opportunities and Risks Associated with Collecting and Making Usable Additional Data. In: Maurer M., Gerdes J., Lenz B., Winner H. (eds) Autonomous Driving. Springer, Berlin, Heidelberg, 2016, pp. 497-517.

Renda, A., Artificial Intelligence: Ethics, governance and policy challenges, CEPS, 2019.

Robbins, S. A Misdirected Principle with a Catch: Explicability for AI. *Minds and Machines* 2019, Vol. 29, pp. 495-514.

Rohr, C. and Dunkerley, F., Exploring the Social and Economic Impacts of a Common EU Approach to Liability Rules for Connected and Autonomous Vehicles, RAND Europe, 2019.

Roland Berger, Autonomous driving, 2014.

Roland Berger, Reconnecting the rural: Autonomous driving as a solution for non-urban mobility, 2018.

Ryan, M., 'The Future of Transportation: Ethical, Legal, Social and Economic Impacts of Self-driving Vehicles in the Year 2025', *Science and Engineering Ethics*, 2019, Vol. 26, pp. 1185–1208.

SAE International, Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicle, 2017.

Schröder-Hinrichs, J. et al., Transport 2040: Automation, Technology, Employment - The Future of Work, World Maritime University, 2019.

Schroten, A. et. al., Overview of transport infrastructure expenditures and costs, European Commission, 2019.

Shashank, A. et al., Accessible Personal Transportation for People with Disabilities Using Autonomous Vehicles, Purdue University, n.d.

Simpson, C. et al., Mobility 2030: Transforming the mobility landscape, KPMG International, 2019.

Spulber, A. and Wallace, R., Impact of Automated Vehicle Technologies on Driver Skills., Center for Automotive Research, n.d.

Stanley, B. and Gyimesi, K., A New Relationship—People and Cars, IBM Institute for Business Value, 2016.

Taeihagh, A. and Hazel, S., 'Governing Autonomous Vehicles: Emerging Responses for Safety, Liability, Privacy, Cybersecurity, and Industry Risks', *Transport Reviews*, 2019, Vol. 39(1), pp. 103-128.

Taeihagh, A. and Si Min Lim, H., Governing autonomous vehicles: emerging responses for safety, liability, privacy, cybersecurity, and industry risks. *Transport Reviews*, Vol. 39(1), 2019, pp. 103-128.

Taiebat, M., Stolper, S. and Xu, M., 'Forecasting the Impact of Connected and Automated Vehicles on Energy Use: A Microeconomic Study of Induced Travel and Energy Rebound', *Applied Energy Journal*, 2019.

Thierer, A. and Hagemann, R., 'Removing Roadblocks to Intelligent Vehicles and Driverless Cars', *Wake Forest Journal of Law & Policy*, 2014, Vol. 5, pp. 339-391.

Thomas, J. et al., 'Predicting Light Duty Vehicle Fuel Economy as a Function of Highway Speed', *SAE International*, 2013, Vol. 6(2), pp. 859–875.

TNO et al., Safety of non-embedded software: Service, data access, and legal issues of advanced robots, autonomous, connected, and AI-based vehicles and systems. European Commission, 2019.

Transport Systems Catapult, Market forecast for connected and autonomous vehicles in UK, 2017.

U.S. Energy Information Administration, Autonomous Vehicles: Uncertainties and Energy Implications, 2018.

U.S. Energy Information Administration, Study of the Potential Energy Consumption Impacts of Connected and Automated Vehicles, 2017.

UNESCO and ITU, Preliminary study on the ethics of artificial intelligence, 2019.

Vetzo, M., Gerards, J. and Nehmelman, R., Algoritmes en grondrechten, Utrecht University/Boom Juridisch, 2018.

Vladislav M. et al., Megatrends – a Way to Identify the Future Transport Challenges. Working Paper of the H2020 research and innovation programme 'Intentify future Transport Research NeeDs (INTEND)', 2018.

Wachter, S., Mittelstadt, B. and Floridi L., Why a right to explanation of automated decision-making does not exist in the general data protection regulation. *International Data Privacy Law*, Vol. 7(2), 2017, pp. 76–99.

Wadud, Z., MacKenzie, D. and Leiby, P., 'Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles', *Elsevier*, 2016, Vol. 18(1), pp. 1-18.

Wagner B. et al., Algorithms and human rights: Study on the human rights dimensions of automated data processing techniques and possible regulatory implications, Council of Europe, 2018.

Walker, J., The Self-Driving Car Timeline – Predictions from the Top 11 Global Automakers, EMERJ research, 2020.

Weinrib, J., Dignity and Autonomy, Max Planck Encyclopedia of Comparative Constitutional Law, 2019.

West, D., Moving Forward: Self-Driving Vehicles in China, Europe, Japan, Korea, and the United States, Brookings Center for Technology Innovation, 2016.

WIFO, SPI. VTT and Ecorys, Public Support Measures for Connected and Automated Driving, European Commission, 2017.

World Economic Forum and Accenture, Digital Transformation of Industries: Automotive Industry, 2017.

World Economic Forum, Executive Opinion Survey, 2018.

World Maritime University, Transport 2040: Automation, Technology, Employment - The Future of Work, 2019.

Zhang, Y. et al., 'Identifying degradation patterns of lithium ion batteries from impedance spectroscopy using machine learning', *Nature Communications*, 2020.

Other sources

ACEA, €54 billion spent on R&D by EU auto sector per year, latest data show, 2020.

ACEA, Commercial vehicles EU, n.d.

ACEA, Fact sheet: Buses, 2017.

ACEA, Facts about the automobile industry, n.d.

ACEA, Fuel types of new vans: diesel 92.8%, electric 1.2%, alternative fuels 1.3% market share in 2019, 2020. Press release.

ACEA, Key Figures, n.d.

ACEA, Passenger cars EU, n.d.

ACEA, Research and Innovation, n.d.

ACEA, The EU automobile industry: engine of innovation, employment, trade and growth, 2019. Video.

ACEA, Vehicle in use statistics, n.d.

Allen & Overy, Autonomous and connected vehicles: navigating the legal issues, 2017.

Association for Advancing Automation, Work in the Automation Age, n.d.

Barua, S., Flood of Data Will Get Generated in Autonomous Cars. AutoTech Review, n.d.

BBC, Blackpool pothole-fixing artificial intelligence 'saves £1m', 2020.

Bertoncello, M. and Wee, D., Ten ways autonomous driving could redefine the automotive world. McKinsey & Company, 2015.

Bullis, K., 'How Vehicle Automation will Cut Fuel Consumption', *MIT's Technology Review*, 2011.

Burianski, M. and Theissen, C., Germany permits automated vehicles. White&Case, 2017

Cambridge Dictionary, Definition of 'Transport', Cambridge University Press, 2020.

CBS, Parking fee revenues estimated at 660 million euros in 2014, 2014.

CNBC, Mercedes robo-taxi service gets underway in California, 2019.

Coren, M., There's a new subscription business model arriving for cars, Quartz, 2017.

Dastin, J, Exclusive: Amazon rolls out machines that pack orders and replace jobs, Reuters, 2019.

Davies, A. and Marshall, A., Are We There Yet? A Reality Check on Self-Driving Cars, 2019, Wired.

De Telegraaf, Slimme camera moet brug redden, 2018.

Dmitriev, S., Autonomous cars will generate more than 300 TB of data per year, Tuxera, 2017.

EEA, Front-running cities changing transport, improving quality of life, 2016.

EEA, Passenger and freight transport demand in Europe, n.d.

EEA, Vehicle ownership and truck intensity, 2019.

EGSA, EGNOS and Galileo for ITS and road transport: High flexibility, low investment, 2017.

English, T., Will AI and Generative Design Steal our Engineering Jobs, Interesting Engineering, 2020.

European Commission, Automotive industry, n.d.

European Commission, Clean transport, Urban transport, n.d.

European Commission, Commission presents European Skills Agenda for sustainable competitiveness, social fairness and resilience. Press release, 2020.

European Commission, EU boosts investment in 5G hardware innovation and trialling 5G-based connected and automated mobility, 2020.

European Commission, Spring 2020 Economic Forecast, 2020.

European Commission, 30 Digital Innovation Hubs focused on Artificial Intelligence selected for a training programme, 2019.

European Commission, Member States and Commission to work together to boost artificial intelligence 'made in Europe'. Press release, 2018.

Eurostat, Freight transport statistics - modal split, 2020.

Eurostat, Passenger transport statistics, 2020.

Eurostat, Number of electric cars is on the rise, 2019.

Eurostat, Statistical Classification of Economic Activities in the European Community, Rev. 2 (NACE Rev. 2), Methodologies and Working papers, 2008.

Flash Eurobarometer, Europeans' satisfaction with urban transport, European Commission, 2014.

FleetOwner, TuSimple plans freight deliveries without drivers in 2021, 2019.

Földesi, E., Disabled people spoke about their benefits and requirements on autonomous cars, Medium, 2017.

Form, A. et al, 5G: a key requirement for autonomous driving—really?, Kearney, n.d.

GCS-Europe, Galileo: a critical component for autonomous driving, 2019.

German Federal Ministry of Transport and Digital Infrastructure, Automated and Connected Driving, n.d.

GSA, First Galileo-enables autonomous vehicle successfully demonstrated, 2019.

Guillot, G., Are supply chain jobs at risk of automation?, SupplychainDive, 2018.

Halsey, A., Driverless cars promise far greater mobility for the elderly and people with disabilities, The Washington Post, 2017.

Hammerschmidt, C., German law aims to be first for driverless cars. Eenews Europe, 2020

Hiltzik, M., Column: Uber and Lyft increase traffic and pollution. Why do cities let it happen?, Los Angeles Times, 2020.

Inside GNAA, Brussels View: Driverless Merging Ahead, 2020.

IRU, Tackling driver shortage in Europe, 2019.

IRU, Tackling the driver shortage crisis, 2018.

Jones Day, Legal Issues Related to the Development of Automated, Autonomous, and Connected Cars, 2017.

Koetaier, J., Self-driving Cars In 10 Years: EU Expects 'Fully Automated' Cars by 2030. 2019. Forbes.

KPMG, The clockspeed dilemma, 2015.

Lafrance, A., How Self-Driving Cars Will Threaten Privacy, The Atlantic, 2016.

Lopez. S., Column: Cabbies hit by LAXit pickup squeeze are planning their own exit, Los Angeles Times, 2020.

Madiega, T., EU guidelines on ethics in artificial intelligence: Context and implementation, EPRS, 2019.

Marshall, A. and Davies, A., Lots of lobbies and zero zombies: How self-driving cars will reshape cities, Wired, 2018.

McKinsey & Company, Autonomous driving, n.d.

McKinsey & Company, Ten ways autonomous driving could redefine the automotive world, 2015.

Miller, R., Rolling Zettabytes: Quantifying the Data Impact of Connected Cars, Data Center Frontier, 2020.

O'Brien M, As robots slowly take over Amazon's warehouses, are they causing more harm than good?, Independent, 2019.

Peter, M., Reducing the Traffic Headache: Three Technology Solutions Cities Should Consider., Thales Group, n.d. Accessed the 29/9/20.

Peters, J., The future of autonomous vehicles runs off roads and on to farms, construction sites and mines, TechCrunch, 2019.

PwC, Mobility insights: Tackling the growing issue of congestion in urban areas, n.d.

Pyper, J., Self-Driving Cars Could Cut Greenhouse Gas Pollution, Scientific America, 2014.

Reid, H., Ostad, E., European startups navigate long, winding road to self-driving future. Reuters, 2019.

Roland Berger, Automotive disruption, n.d. Accessed on 29/9/20.

Ruttloff, M., New legal rules on automated driving. Gleiss Lutz, 2017.

Statista, Total turnover in the transport sector in the European Union (EU-28) in 2016, by mode of transport, 2020.

Statistica, Number of employees in the transport industry in the EU-28 2016, by sector, 2020.

The Guardian, Germany launches world's first autonomous tram in Potsdam, 2018.

The Telegraph, World's first driverless bus service begins carrying passengers in French city of Lyon, 2016.

The Verge, Self-driving truck convoy completes its first major journey across Europe, 2016.

The Verge, Waymo's robot taxi service is improving, but riders still have complaints, 2019.
Transforming transport, Mobility Meets Big Data, 2017.
Udemans, C., AutoX, NEVS to deploy robotaxis in Europe next year, TechNode, 2019.
Via-ID, Who are the European startups of Mobility?, 2018.
Weiss, C., Gaenzle, S. and Römer, M., How automakers can survive the self-driving era, Kearney, n.d.
World Bank, GDP growth (annual %) - Euro area, 2019.
Ynformed, Using Artificial Intelligence for road safety: a smarter way of maintenance, 2020.

Annex II Relevant provisions of legal acts

Specific provision applying to AV

Regulation 2019/2144 on type-approval requirements for motor vehicles and their trailers, and systems, components and separate technical units intended for such vehicles, as regards their general safety and the protection of vehicle occupants and vulnerable road users

Article 3: Definitions

'**intelligent speed assistance**' means a system to aid the driver in maintaining the appropriate speed for the road environment by providing dedicated and appropriate feedback

'advanced driver distraction warning' means a system that helps the driver to continue to pay attention to the traffic situation and that warns the driver when he or she is distracted

'advanced emergency braking system' means a system which can automatically detect a potential collision and activate the vehicle braking system to decelerate the vehicle with the purpose of avoiding or mitigating a collision

'emergency lane-keeping system' means a system that assists the driver in keeping a safe position of the vehicle with respect to the lane or road boundary, at least when a lane departure occurs or is about to occur and a collision might be imminent

'automated vehicle' means a motor vehicle designed and constructed to move autonomously for certain periods of time without continuous driver supervision but in respect of which driver intervention is still expected or required

'fully automated vehicle' means a motor vehicle that has been designed and constructed to move autonomously without any driver supervision

'driver availability monitoring system' means a system to assess whether the driver is in a position to take over the driving function from an automated vehicle in particular situations, where appropriate

'vehicle platooning' means the linking of two or more vehicles in a convoy using connectivity technology and automated driving support systems which allow the vehicles to maintain automatically a set, close distance between each other when connected for certain parts of a journey and to adapt to changes in the movement of the lead vehicle with little to no action from the drivers

Article 6: Advanced vehicle systems for all motor categories

Motor vehicles shall be equipped with the following advanced vehicle systems:

(a) **intelligent speed assistance**; […]

(c) **driver drowsiness and attention warning**

(d) **advanced driver distraction warning** […]

Intelligent speed assistance shall meet the following minimum requirement: […]

> (c) the dedicated and appropriate feedback **shall be based on speed limit information obtained through the observation of road signs and signals, based on infrastructure signals or electronic map data, or both, made available in-vehicle** […].

Driver drowsiness and attention warning and advanced driver distraction warning systems **shall be designed in such a way that those systems do not continuously record nor retain any data other than what is necessary in relation to the purposes for which they were collected or otherwise processed within the closed-loop system**. Furthermore, those data **shall not be accessible or made available to third parties at any time and shall be immediately deleted after processing**. Those systems shall also be designed to avoid overlap and shall not prompt the driver separately and concurrently or in a confusing manner where one action triggers both systems.

Article 9: Specific requirements relating to buses and trucks

Vehicles of categories M2, M3, N2 and N3 **shall be equipped with advanced systems that are capable of detecting pedestrians and cyclists located in close proximity to the front or nearside of the vehicle and of providing a warning or avoiding collision** with such vulnerable road users.

Article 11: Specific requirements relating to automated vehicles and fully automated vehicles

In addition to the other requirements of this Regulation and of the delegated acts and implementing acts adopted pursuant to it that are applicable to vehicles of the respective categories, **automated vehicles and fully automated vehicles shall comply with the technical specifications** set out in the implementing acts referred to in paragraph 2 **that relate to**:

> (a) **systems to replace the driver's control of the vehicle, including signalling, steering, accelerating and braking**;
>
> (b) systems **to provide the vehicle with real-time information on the state of the vehicle and the surrounding area**;
>
> (c) **driver availability monitoring systems**;
>
> (d) **event data recorders for automated vehicles**;
>
> (e) **harmonised format for the exchange of data** for instance for multi-brand vehicle platooning;
>
> (f) systems to provide safety information to other road users.

However, those technical specifications relating to driver availability monitoring systems, referred to in point (c) of the first subparagraph, shall not apply to fully automated vehicles.

Specific provisions applying to transport with impact on AV

Regulation 2018/858 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles

Article 3: Definitions

'type-approval' means the procedure whereby an approval authority certifies that a type of vehicle, system, component or separate technical unit satisfies the relevant administrative provisions and technical requirements;

'system' means an assembly of devices combined to perform one or more specific functions in a vehicle and that is subject to the requirements of this Regulation or any of the regulatory acts listed in Annex II;

'component' means a device that is intended to be part of a vehicle, that can be type-approved independently of a vehicle and that is subject to the requirements of this Regulation or any of the regulatory acts listed in Annex II where the specific regulatory act makes express provision to that effect;

'separate technical unit' means a device that is intended to be part of a vehicle that can be type-approved separately, but only in relation to one or more specified types of vehicle and that is subject to the requirements of this Regulation or any of the regulatory acts listed in Annex II where the specific regulatory act makes express provisions to that effect;

'manufacturer' means a natural or legal person who is responsible for all aspects of the type-approval of a vehicle, system, component or separate technical unit, or the individual vehicle approval, or the authorisation process for parts and equipment, for ensuring conformity of production and for market surveillance matters regarding that vehicle, system, component, separate technical unit, part and equipment produced, irrespective of whether or not that person is directly involved in all stages of the design and construction of that vehicle, system, component or separate technical unit concerned;

'vehicle repair and maintenance information' means all information, including all subsequent amendments and supplements thereto, that is required for diagnosing, servicing and inspecting a vehicle, preparing it for road worthiness testing, repairing, re-programming or re-initialising of a vehicle, or that is required for the remote diagnostic support of a vehicle or for the fitting on a vehicle of parts and equipment, and that is provided by the manufacturer to his authorised partners, dealers and repairers or is used by the manufacturer for the repair and maintenance purposes;

'vehicle on-board diagnostic (OBD) information' means the information generated by a system that is on board a vehicle or that is connected to an engine, and that is capable of detecting a malfunction, and, where applicable, is capable of signalling its occurrence by means of an alert system, is capable of identifying the likely area of malfunction by means of information stored in a computer memory, and is capable of communicating that information off-board;

Article 5: Technical requirements

Vehicles, systems, components and separate technical units **shall comply with the requirements of the regulatory acts listed in Annex II**.

Article 8: Obligation of market surveillance authorities

Market surveillance authorities shall **require economic operators to make available to the authorities such documentation, information and other technical specifications, including access to software and algorithms, that the authorities consider necessary for the purpose of carrying out the market surveillance activities**.

Article 13: General obligations of manufacturers

5. Manufacturers shall ensure that their vehicles, systems, components and separate technical units **are not designed to incorporate strategies or other means that alter the performance exhibited during test procedures** in such a way that they do not comply with this Regulation when operating under conditions that can reasonably be expected in normal operation. […]

10. Without prejudice to Article 9(5) and subject to the protection of commercial secrets and the preservation of personal data pursuant to Union and national law, **manufacturers of vehicles shall make available data which is needed for testing by third parties for possible non-compliance, including all parameters and settings that are necessary** to accurately replicate the test conditions that were applied at the time of the type-approval testing.

Article 14: Obligations of manufacturers concerning their vehicles, systems, components, separate technical units, parts and equipment that are not in conformity or that present a serious risk

Where a vehicle, system, component, separate technical unit, part or equipment that has been placed on the market or that has entered into service is not in conformity with this Regulation or where the type-approval has been granted on the basis of incorrect data, the manufacturer shall immediately **take the corrective measures necessary to bring that vehicle, system, component, separate technical unit, part or equipment into conformity, to withdraw it from the market or to recall it, as appropriate**.

Article 15: Obligations of manufacturer's representatives

The manufacturer's representative shall perform the tasks specified in the mandate received from the manufacturer. That mandate shall at least, provide for the representative to: […]

> (b) **provide an approval authority, following a reasoned request from that authority, with all information, documentation and any other technical specifications, including access to software and algorithms, that are necessary to demonstrate the conformity of production** of a vehicle, system, component or separate technical unit;

Article 25: Additional information to be provided with an application for EU type-approval

The approval authority and technical services shall have the access to the software and algorithms of the vehicle that they consider to be necessary for the purpose of carrying out their activities.

The approval authority and technical services may also require the manufacturer to supply documentation or any additional information needed to allow the approval authority or technical services to develop an appropriate level of understanding of the systems, including the system development process and the system concept, as well as the functions of software and algorithms that are necessary to verify compliance with the requirements of this Regulation, to take a decision on which tests are required or to facilitate the execution of those tests.

Article 26 General provisions on conduct of procedures for EU type-approval:

The approval authority shall refuse to grant an EU type-approval where it finds that a type of vehicle, system, component or separate technical unit that complies with the applicable requirements nonetheless presents a serious risk to safety or may seriously harm the environment or public health. In such case, it shall immediately send to the approval authorities of the other Member States and to the Commission a detailed file explaining the reasons for its decision and setting out the evidence for its findings.

Article 31: Conformity of production arrangements

In order to verify that a vehicle, system, component or separate technical unit conforms to the approved type, the approval authority or the technical services shall:

(a) if a range of values is provided for in the test procedures laid down in the relevant regulatory acts listed in Annex II, set the values in a random manner within the provided range when carrying out checks or tests; and

(b) **have access to the software, algorithms, documentation and any additional information in accordance with Article 25(4).**

Article 39: Exemptions for new technologies or new concepts

1. The **manufacturer may apply for an EU type-approval in respect of a type of vehicle, system, component or separate technical unit that incorporates new technologies or new concepts that are incompatible with one or more regulatory acts listed in Annex II.**

2. The approval authority shall grant the EU type-approval referred to in paragraph 1 where all of the following conditions are met:

(a) the application for the EU type-approval states the reasons why the new technologies or new concepts make the vehicles, systems, components or separate technical units incompatible with one or more regulatory acts listed in Annex II;

(b) the application for the EU type-approval describes the safety and environmental implications of the new technology or new concept and the measures taken in order to ensure at least an equivalent level of safety and environmental protection to that provided by the requirements in respect of which an exemption is sought;

(c) test descriptions and results are presented proving that the condition in point (b) is met.

3. The granting of EU type-approvals exempting new technologies or new concepts shall be subject to the authorisation by the Commission.

The Commission shall adopt implementing acts to decide whether to grant the authorisation referred to in the first subparagraph of this paragraph. Those implementing acts shall be adopted in accordance with the examination procedure referred to in Article 83(2).

4. Pending adoption of implementing acts referred to in paragraph 3, the approval authority may grant a provisional EU type-approval, valid only in the territory of the Member State of that approval authority, in respect of a type of vehicle covered by the exemption sought. The approval authority shall inform the Commission and the other Member States thereof without delay by means of a file containing the information referred to in paragraph 2.

The provisional nature and the limited territorial validity of the EU type-approval shall be apparent from the heading of the EU type-approval certificate and the heading of the certificate of conformity.

5. Approval authorities of other Member States may accept the provisional EU type-approval referred to in paragraph 4 within their territory, provided they inform the approval authority that granted the provisional EU type-approval of their acceptance in writing.

6. Where appropriate, the implementing acts referred to in paragraph 3 shall specify whether authorisations are subject to any restrictions, in particular with regard to the maximum number of vehicles covered. In all cases, the EU type-approval shall be valid for at least 36 months.

7. Where the Commission adopts implementing acts referred to in paragraph 3 to refuse to grant the authorisations, the approval authority shall immediately inform the holder of the provisional EU type-approval referred to in paragraph 4 that the provisional EU type-approval approval shall be revoked six months after the date of the implementing act.

However, vehicles that have been manufactured in conformity with the provisional EU type-approval before it ceased to be valid may be placed on the market, be registered or enter into service in any Member State that has accepted the provisional EU type-approval in accordance with paragraph 5.

Article 57: UN Regulations required for EU type-approval

1. **UN Regulations or amendments thereto which the Union has voted in favour of, or that the Union applies and that are listed in Annex II, shall be part of the requirements for the EU type-approval** of vehicles, systems, components or separate technical units.

2. Where the Union has voted in favour of a UN Regulation or amendments thereto for the purpose of whole-vehicle type-approval, the Commission shall adopt delegated acts in accordance with Article 82, supplementing this Regulation by making that UN Regulation or the amendments thereto compulsory or amending this Regulation.

Those delegated acts shall specify the dates from which that UN Regulation or amendments are to be compulsory, and shall include transitional provisions, where appropriate, and, where applicable for the purposes of EU type-approval, first registration and entry into service of vehicles and making available on the market of systems, components and separate technical units.

Article 61: Manufacturers' obligations to provide vehicle OBD information and vehicle repair and maintenance information

1. **Manufacturers shall provide to independent operators unrestricted, standardised and non-discriminatory access to vehicle OBD information, diagnostic and other equipment, tools including the complete references, and available downloads, of the applicable software and vehicle repair and maintenance information. Information shall be presented in an easily accessible manner in the form of machine-readable and electronically processable datasets. Independent operators shall have access to the remote diagnosis services used by manufacturers and authorised dealers and repairers**.

2. Until the Commission has adopted a relevant standard through the work of the European Committee for Standardisation (CEN) or a comparable standardisation body, the vehicle OBD information and vehicle repair and maintenance information shall be presented in an easily accessible manner that can be processed with reasonable effort by independent operators.

The vehicle OBD information and the vehicle repair and maintenance information shall be made available on the websites of manufacturers using a standardised format or, if this is not feasible, due

to the nature of the information, in another appropriate format. For independent operators other than repairers, the information shall also be given in a machine-readable format that is capable of being electronically processed with commonly available information technology tools and software and which allows independent operators to carry out the task associated with their business in the aftermarket supply chain.

4. **The details of the technical requirements for access to vehicle OBD information and vehicle repair and maintenance information, in particular technical specifications on how vehicle OBD information and vehicle repair and maintenance information are to be provided, are laid down in Annex X**.

5. Manufacturers shall also make training material available to independent operators and authorised dealers and repairers.

6. Manufacturers shall ensure that the vehicle OBD information and the vehicle repair and maintenance information are always accessible, except as required for maintenance purposes of the information system.

Manufacturers shall make any subsequent amendments and supplements to vehicle OBD information and vehicle repair and maintenance information available on their websites at the same time they are made available to authorised repairers.

7. For the purposes of manufacturing and servicing of OBD-compatible replacement or service parts and diagnostic tools and test equipment, manufacturers shall provide the relevant vehicle OBD information and vehicle repair and maintenance information on a non-discriminatory basis to any interested manufacturer or repairer of components, diagnostic tools or test equipment.

8. For the purposes of the design, manufacturing and the repair of automotive equipment for alternative-fuel vehicles, manufacturers shall provide the relevant vehicle OBD information and vehicle repair and maintenance information on a non-discriminatory basis to any interested manufacturer, installer or repairer of equipment for alternative-fuel vehicles.

9. Where repair and maintenance records of a vehicle are kept in a central database of the vehicle manufacturer or on its behalf, independent repairers shall have access to such records free of charge and shall be able to enter information on repair and maintenance which they have performed.

10. This Chapter shall not apply to vehicles that are covered by individual vehicle approvals.

11. The Commission is empowered to adopt delegated acts in accordance with Article 82, amending Annex X to take account of technical and regulatory developments or prevent misuse by updating the requirements concerning the access to vehicle OBD information and vehicle repair and maintenance information, including the repair and maintenance activities supported by wireless wide area networks and by adopting and integrating the standards referred to in paragraph 2 of this Article. The Commission shall take into account current information technology, foreseeable vehicle technology developments, existing ISO standards and the possibility of a worldwide ISO standard.

Article 62: Obligations with regard to holders of several type-approvals

1. **The manufacturer responsible for the respective type-approval of a system, component or separate technical unit** or for a particular stage of a vehicle shall be responsible, in the event of a mixed type-approval, a step-by-step type-approval or a multi-stage type-approval, for communicating to both the final manufacturer and the independent operators the repair and

maintenance information relating to the particular system, component or separate technical unit or to the particular stage.

2. In the case of multi-stage type-approval, the final manufacturer shall be responsible for providing access to vehicle OBD information and vehicle repair and maintenance information regarding its own manufacturing stage or stages and the link to the previous stage or stages.

Article 63: Fees for access to vehicle repair and maintenance information

1. **The manufacturer may charge reasonable and proportionate fees for access to vehicle repair and maintenance information other than the records referred to in Article 61(10). Those fees shall not discourage access to such information by failing to take into account the extent to which the independent operator uses it.** Access to vehicle repair and maintenance information shall be offered free of charge to national authorities, the Commission and technical services.

2. The manufacturer shall make available vehicle repair and maintenance information, including transactional services such as reprogramming or technical assistance, on an hourly, daily, monthly, and yearly basis, with fees for access to such information varying in accordance with the respective periods of time for which access is granted.

In addition to time-based access, manufacturers may offer transaction-based access for which fees are charged per transaction and not based on the duration for which access is granted.

Where the manufacturer offers both systems of access, independent repairers shall choose systems of access, which may be either time-based or transaction-based.

Regulation 2019/2144 on type-approval requirements for motor vehicles and their trailers, and systems, components and separate technical units intended for such vehicles, as regards their general safety and the protection of vehicle occupants and vulnerable road users

Article 4: General obligations and technical requirements

Manufacturers shall also ensure that vehicles, systems, components and separate technical units comply with the applicable requirements listed in Annex II with effect from the dates specified in that Annex, with the detailed technical requirements and test procedures laid down in the delegated acts and with the uniform procedures and technical specifications laid down in the implementing acts adopted pursuant to this Regulation, **including the requirements relating to**: […].

> (d)on-board instruments, electrical system, vehicle lighting and **protection against unauthorised use including cyberattacks;**
>
> **(e) driver and system behaviour**; and […]

Article 6: Advanced vehicle systems for all motor vehicle categories

Event data recorders shall meet the following requirements in particular:

> (a) **the data that they are capable of recording and storing with respect of the period shortly before, during and immediately after a collision shall include the vehicle's speed, braking, position and tilt of the vehicle on the road, the state and rate of activation of all its safety systems, 112-based eCall in-vehicle system, brake activation and relevant input parameters of the on-board active**

safety and accident avoidance systems, with high level of accuracy and ensured survivability of data;

(b) they cannot be deactivated;

(c) the way in which they are capable of recording and storing data shall be such that:

(i) they **operate on a closed-loop system**

(ii) **the data that they collect is anonymised and protected against manipulation and misuse**; and

(iii) the data that they collect enables precise vehicle type, variant and version, and in particular the active safety and accident avoidance systems fitted to the vehicle, to be identified; and

(d) the data that they are capable of recording can be made available to national authorities, on the basis of Union or national law, only for the purpose of accident research and analysis, including for the purposes of type approval of systems and components and in compliance with Regulation (EU) 2016/679, over a standardised interface.

Regulation 2015/758 concerning type-approval requirements for the deployment of the eCall in-vehicle system based on the 112 service (eCall Regulation)

Article 3: Definitions

*'**eCall**' means an in-vehicle emergency call to 112, made either automatically by means of the activation of in-vehicle sensors or manually, which carries a minimum set of data and establishes an audio channel between the vehicle and the eCall PSAP via public mobile wireless communications network*

Article 6: Rules on privacy and data protection

1. This Regulation is without prejudice to Directives 95/46/EC and 2002/58/EC. Any processing of personal data through the 112-based eCall in-vehicle system shall comply with the personal data protection rules provided for in those Directives.

2. The personal data processed pursuant to this Regulation shall **only be used for the purpose of handling the emergency situations** referred to in the first subparagraph of Article 5(2).

3.The personal data processed pursuant to this Regulation **shall not be retained longer than necessary for the purpose of handling the emergency situations** referred to in the first subparagraph of Article 5(2). Those data shall be fully deleted as soon as they are no longer necessary for that purpose.

4. Manufacturers shall ensure that the 112-based eCall in-vehicle system **is not traceable and is not subject to any constant tracking.**

5. Manufacturers shall ensure that, **in the internal memory of the 112-based eCall in-vehicle system, data are automatically and continuously removed**. Only the retention of the last three locations of the vehicle shall be permitted in so far as it is strictly necessary to specify the current location and the direction of travel at the time of the event.

6.Those data **shall not be available outside the 112-based eCall in-vehicle system to any entities before the eCall is triggered**.

7.Privacy enhancing technologies shall be embedded in the 112-based eCall in-vehicle system in order to provide eCall users with the appropriate level of privacy protection, as well as the **necessary safeguards to prevent surveillance and misuse**.

8.The MSD sent by the 112-based eCall in-vehicle system shall include only the minimum information as referred to in the standard EN 15722:2011 'Intelligent transport systems – eSafety – eCall minimum set of data (MSD)'. No additional data shall be transmitted by the 112-based eCall in-vehicle system. **That MSD shall be stored in such a way as to make its full and permanent deletion possible**.

9.**Manufacturers shall provide clear and comprehensive information in the owner's manual about the processing of data carried out through the 112-based eCall in-vehicle system**. That information shall consist of:

(a)the reference to the legal basis for the processing;

(b)the fact that the 112-based eCall in-vehicle system is activated by default;

(c)the arrangements for data processing that the 112-based eCall in-vehicle system performs;

(d) the specific purpose of the eCall processing, which shall be limited to the emergency situations referred to in the first subparagraph of Article 5(2);

(e)the types of data collected and processed and the recipients of that data;

(f)the time limit for the retention of data in the 112-based eCall in-vehicle system;

(g)the fact that there is no constant tracking of the vehicle;

(h)the arrangements for exercising data subjects' rights as well as the contact service responsible for handling access requests;

(i)any necessary additional information regarding traceability, tracking and processing of personal data in relation to the provision of a TPS eCall and/or other added value services, which shall be subject to explicit consent by the owner and in compliance with Directive 95/46/EC. Particular account shall be taken of the fact that differences may exist between the data processing carried out through the 112-based eCall in-vehicle system and the TPS eCall in-vehicle systems or other added value services.

10.In order to avoid confusion as to the purposes pursued and the added value of the processing, the information referred to in paragraph 9 shall be provided in the owner's manual separately for the 112-based eCall in-vehicle system and the TPS eCall systems prior to the use of the system.

11.**Manufacturers shall ensure that the 112-based eCall in-vehicle system and any additional system providing TPS eCall or an added-value service are designed in such a way that no exchange of personal data between them is possible**. The non-use of a system providing TPS eCall or an added-value service or the refusal of the data subject to give consent to the processing of his or her personal data for a TPS eCall service or an added value service shall not create any adverse effects on the use of the 112-based eCall in-vehicle system.

Directive 2010/40 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport (ITS Directive)

Article 2: Priority areas

1. For the purpose of this Directive the following **shall constitute priority areas for the development and use of specifications and standard**s:

— I. Optimal use of road, traffic and travel data,

— II. Continuity of traffic and freight management ITS services,

— III. ITS road safety and security applications,

— IV. Linking the vehicle with the transport infrastructure.

2. The scope of the priority areas is **specified in Annex I**.

Article 3: Priority actions

Within the priority areas the following shall constitute priority actions for the development and use of specifications and standards, as set out in Annex I:

(a)the provision of **EU-wide multimodal travel information services**;

(b)the provision of **EU-wide real-time traffic information services**;

(c)**data and procedures for the provision, where possible, of road safety related minimum universal traffic information free of charge to users**;

(d)the harmonised provision for an interoperable EU-wide eCall;

(e)the provision of information services for safe and secure parking places for trucks and commercial vehicles;

(f)the provision of reservation services for safe and secure parking places for trucks and commercial vehicles.

Article 4: Definitions

'**Intelligent Transport Systems' or 'ITS'** means systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport

'ITS application' means an operational instrument for the application of ITS;

'ITS service' means the provision of an ITS application through a well-defined organisational and operational framework with the aim of contributing to user safety, efficiency, comfort and/or to facilitate or support transport and travel operations;

Delegated Regulation 886/2013 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to data and procedures for the provision, where possible, of road safety-related minimum universal traffic information free of charge to users

Article 2: Definitions

*'**user of road safety-related minimum universal traffic information**' means any legal or natural person participating in the provision of road safety-related minimum universal traffic information services, such as public and private road operators, traffic managers, service providers, and broadcasters dedicated to traffic information.*

*'**road safety-related minimum universal traffic information service**' means a real-time traffic information service that provides an agreed minimum road safety-related content and which can be accessed at minimum effort by a maximum of end users.*

*'**road safety-related traffic data**' means data necessary for providing the road safety-related minimum universal traffic information service and collected via any private or public source;*

Article 7: Availability, exchange and reuse of data

1. Public and/or private road operators and/or service providers shall share and exchange the data they collect pursuant to Article 6. For that purpose, they shall make these data available in the DATEX II (CEN/TS 16157) format or any fully compatible and interoperable with DATEX II machine-readable format through an access point.

2. Member States shall manage a national access point to the data referred to in paragraph 1, which regroups the access points established by public and/or private road operators and/or service providers operating on their territory.

3. **These data shall be accessible for exchange and reuse by any user of road safety-related minimum universal traffic information**:

(a) on a non-discriminatory basis;

(b) within the Union irrespective of the Member State of establishment;

(c) in accordance with access rights and procedures defined in Directive 2003/98/EC;

(d) within a timeframe that ensures the timely provision of the information service;

(e) through the national access point.

4. Public and private road operators and service providers shall ensure the timely renewal and quality of data made available through their access point

Delegated Regulation 2015/962 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide real-time traffic information services

Article 2: Definitions

'static road data' means road data that do not change often or on a regular basis, listed in point 1 of the Annex;

'dynamic road status data' means road data that change often or on a regular basis and describe the status of the road, as listed in point 2 of the Annex;

'traffic data' means data on road traffic characteristics, as listed in point 3 of the Annex;

'real-time traffic information' means information derived from any static road data, dynamic road status data, traffic data, or the combination thereof, provided

by any road authorities, road operators or service providers, for users and end-users, through any communication means;

'real-time traffic information service' means an ITS service that provides users, and end-users, immediately with real-time traffic information;

'service provider' means any public or private provider of a real-time traffic information service, excluding a mere conveyer of information, to users and end-users;

Article 3: National access points

Each Member State shall set up a national access point. The national access point shall constitute a single point of access for users to the road and traffic data, including data updates, provided by the road authorities, road operators and service providers and concerning the territory of a given Member State.

Commission Delegated Regulation 2017/1926 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide multimodal travel information services

Article 2: Definitions

'dynamic travel and traffic data' mean data relating to different transport modes that changes often or on a regular basis, as listed in the Annex;

'static travel and traffic data' mean data relating to different transport modes that does not change at all or does not change often, or change on a regular basis, as listed in the Annex;

'travel information service' means an ITS service, including digital maps, that provides users, and end-users, with travel and traffic information of at least one transport mode;

'historic traffic data' means traffic characteristics depending on the hour, day, season based on previous measurements, including rate of congestion, average speeds, average travel times, as listed in the Annex;

'transport on demand' means a passenger transport service which is characterised by flexible routing such as car-sharing, car-pooling, bike-sharing, ride-sharing, taxi, dial-a-ride services. These services usually require interaction between the transport on demand service provider and end-users before delivery;

'multimodal travel information' means information derived from any static or dynamic travel and traffic data, or both, for users and end-users, through any communication means, covering at least two modes of transport and allowing the possibility to compare transport modes;

Article 3: National access points

Each Member State shall set up a national access point. **The national access point shall constitute a single point of access for users to at least the static travel and traffic data and historic traffic data of different transport modes, including data updates, as set out in the Annex, provided by the transport authorities, transport operators, infrastructure managers or transport on demand service providers** within the territory of a given Member State.

Article 4: Accessibility, exchange and reuse of static travel and traffic data

APIs that provide access to static travel and traffic data listed in the Annex via the national access point shall be publicly accessible allowing users and end-users to register to obtain access.

Horizontal instruments with implication on AV

Directive 2001/95 on general product safety (GPSD)

Article 2

'safe product' shall mean any product which, under normal or reasonably foreseeable conditions of use including duration and, where applicable, putting into service, installation and maintenance requirements, does not present any risk or only the minimum risks compatible with the product's use, considered to be acceptable and consistent with a high level of protection for the safety and health of persons, taking into account the following points in particular:

> (i) the characteristics of the product, including its composition, packaging, instructions for assembly and, where applicable, for installation and maintenance;
>
> (ii) the effect on other products, where it is reasonably foreseeable that it will be used with other products;
>
> (iii) the presentation of the product, the labelling, any warnings and instructions for its use and disposal and any other indication or information regarding the product;
>
> (iv) the categories of consumers at risk when using the product, in particular children and the elderly.

The feasibility of obtaining higher levels of safety or the availability of other products presenting a lesser degree of risk shall not constitute grounds for considering a product to be 'dangerous';

Article 3

Producers **shall be obliged to place only safe products on the market**.

Directive 2014/53 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment (RED)

Article 2: Definitions

> **'radio equipment'** means an electrical or electronic product, which intentionally emits and/or receives radio waves for the purpose of radio communication and/or radiodetermination, or an electrical or electronic product which must be completed with an accessory, such as antenna, so as to intentionally emit and/or receive radio waves for the purpose of radio communication and/or radiodetermination;
>
> **'radio waves'** means electromagnetic waves of frequencies lower than 3 000 GHz, propagated in space without artificial guide;

Article 3: Essential requirements

Radio equipment within certain categories or classes shall be so constructed that it complies with the following essential requirements:[…]

> (c) radio equipment can be connected to interfaces of the appropriate type throughout the Union;

(d) radio equipment does not harm the network or its functioning nor misuse network resources, thereby causing an unacceptable degradation of service;

(e) radio equipment incorporates safeguards to ensure that the personal data and privacy of the user and of the subscriber are protected;

(f) radio equipment supports certain features **ensuring protection from fraud**;[…]

(i) radio equipment supports certain features in order to ensure that software can only be loaded into the radio equipment where the compliance of the combination of the radio equipment and software has been demonstrated.

The Commission shall be empowered to adopt delegated acts in accordance with Article 44 specifying which categories or classes of radio equipment are concerned by each of the requirements set out in points (a) to (i) […].

Article 4: Provision of information on the compliance of combinations of radio equipment and software

Manufacturers of radio equipment and of software allowing radio equipment to be used as intended shall provide the Member States and the Commission with information on the compliance of intended combinations of radio equipment and software with the essential requirements set out in Article 3. Such information shall result from a conformity assessment carried out in accordance with Article 17, and shall be given in the form of a statement of compliance which includes the elements set out in Annex VI. Depending on the specific combinations of radio equipment and software, the information shall precisely identify the radio equipment and the software which have been assessed, and it shall be continuously updated.

Article 10: Obligations of manufacturers

Manufacturers shall ensure that the radio equipment is accompanied by instructions and safety information in a language which can be easily understood by consumers and other end-users, as determined by the Member State concerned. Instructions shall include the information required to use radio equipment in accordance with its intended use. **Such information shall include, where applicable, a description of accessories and components, including software, which allow the radio equipment to operate as intended**. Such instructions and safety information, as well as any labelling, shall be clear, understandable and intelligible. […]

Article 21: Technical documentation

The technical documentation shall contain all relevant data or details of the means used by the manufacturer to ensure that radio equipment complies with the essential requirements set out in Article 3. It shall, at least, contain the elements set out in Annex V

Annexes

Annex V, point a): The technical documentation shall, wherever applicable, contain at least the following elements:

(a) **a general description of the radio equipment including: […]**

(ii)versions of software or firmware affecting compliance with essential requirements; […]

Article 43: Formal non-compliance

> […] **where a Member State makes one of the following findings, it shall require the relevant economic operator to put an end to the non-compliance concerned: […**
>
> **(h) information on the intended use of radio equipment, the EU declaration of conformity or usage restrictions as set out in Article 10(8), (9) and (10) does not accompany the radio equipment**; […]

Directive 85/374 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products (PLD)

Article 4

The injured person shall be required to prove **the damage, the defect and the causal relationship** between defect and damage

Article 6

product is defective when it does not provide the safety which a person is entitled to expect, taking all circumstances into account, including:

> (a) the presentation of the product;
>
> (b) the use to which it could reasonably be expected that the product would be put;
>
> (c) the time when the product was put into circulation.

Article 7

The producer shall not be liable as a result of this Directive if he proves: […]

> (b) that, having regard to the circumstances, it is probable that **the defect which caused the damage did not exist at the time when the product was put into circulation** by him or that this defect came into being afterwards; or
>
> (e) that the state of scientific and technical knowledge at the time when he put the product into circulation was not such as to enable the existence of the defect to be discovered; or […]

Regulation 2019/881 of the European Parliament and of the Council of 17 April 2019 on ENISA (the European Union Agency for Cybersecurity) and on information and communications technology cybersecurity certification (Cybersecurity Act)

Article 1 Subject matter and scope

With a view to **ensuring the proper functioning of the internal market while aiming to achieve a high level of cybersecurity, cyber resilience and trust within the Union**, this Regulation lays down: […]

> (b)**a framework for the establishment of European cybersecurity certification schemes for the purpose of ensuring an adequate level of cybersecurity for ICT products, ICT services and ICT processes in the Union**, as well as for the purpose

of avoiding the fragmentation of the internal market with regard to cybersecurity certification schemes in the Union.

Article 2: Definitions

'cybersecurity' means the activities necessary to protect network and information systems, the users of such systems, and other persons affected by cyber threats;

'cyber threat' means any potential circumstance, event or action that could damage, disrupt or otherwise adversely impact network and information systems, the users of such systems and other persons

'European cybersecurity certification scheme' means a comprehensive set of rules, technical requirements, standards and procedures that are established at Union level and that apply to the certification or conformity assessment of specific ICT products, ICT services or ICT processes;

'European cybersecurity certificate' means a document issued by a relevant body, attesting that a given ICT product, ICT service or ICT process has been evaluated for compliance with specific security requirements laid down in a European cybersecurity certification scheme;

Article 46: European cybersecurity certification framework

1. The European cybersecurity certification framework shall be established in order to improve the conditions for the functioning of the internal market by increasing the level of cybersecurity within the Union and enabling a harmonised approach at Union level to European cybersecurity certification schemes, with a view to creating a digital single market for ICT products, ICT services and ICT processes.

2. The European cybersecurity certification framework shall provide for a mechanism to establish European cybersecurity certification schemes and to attest that the ICT products, ICT services and ICT processes that have been evaluated in accordance with such schemes comply with **specified security requirements for the purpose of protecting the availability, authenticity, integrity or confidentiality of stored or transmitted or processed data or the functions or services offered by, or accessible via, those products, services and processes throughout their life cycle**.

Article 51: Security objectives of European cybersecurity certification schemes

A European cybersecurity certification scheme shall be designed to achieve, as applicable**, at least the following security objectives**:

(a)to protect stored, transmitted or otherwise processed data against accidental or unauthorised storage, processing, access or disclosure during the entire life cycle of the ICT product, ICT service or ICT process;

(b)to protect stored, transmitted or otherwise processed data against accidental or unauthorised destruction, loss or alteration or lack of availability during the entire life cycle of the ICT product, ICT service or ICT process;

(c)that authorised persons, programs or machines are able only to access the data, services or functions to which their access rights refer;

(d)to identify and document known dependencies and vulnerabilities;

(e)to record which data, services or functions have been accessed, used or otherwise processed, at what times and by whom;

(f)to make it possible to check which data, services or functions have been accessed, used or otherwise processed, at what times and by whom;

(g)to verify that ICT products, ICT services and ICT processes do not contain known vulnerabilities;

(h)to restore the availability and access to data, services and functions in a timely manner in the event of a physical or technical incident;

(i)that ICT products, ICT services and ICT processes are **secure by default and by design**;

(j)that ICT products, ICT services and ICT processes are provided with up-to-date software and hardware that do not contain publicly known vulnerabilities, and are provided with mechanisms for secure updates.

Article 52 Assurance levels of European cybersecurity certification schemes

1. **A European cybersecurity certification scheme may specify one or more of the following assurance levels for ICT products, ICT services and ICT processes: 'basic', 'substantial' or 'high'**. The assurance level shall be commensurate with the level of the risk associated with the intended use of the ICT product, ICT service or ICT process, in terms of the probability and impact of an incident.

2. European cybersecurity certificates and EU statements of conformity shall refer to any assurance level specified in the European cybersecurity certification scheme under which the European cybersecurity certificate or EU statement of conformity is issued.

3. The security requirements corresponding to each assurance level shall be provided in the relevant European cybersecurity certification scheme, including the corresponding security functionalities and the corresponding rigour and depth of the evaluation that the ICT product, ICT service or ICT process is to undergo.

4. The certificate or the EU statement of conformity shall refer to technical specifications, standards and procedures related thereto, including technical controls, the purpose of which is to decrease the risk of, or to prevent cybersecurity incidents.

5. A European cybersecurity certificate or EU statement of conformity **that refers to assurance level 'basic' shall provide assurance that the ICT products, ICT services and ICT processes for which that certificate or that EU statement of conformity is issued meet the corresponding security requirements, including security functionalities, and that they have been evaluated at a level intended to minimise the known basic risks of incidents and cyberattacks.** The evaluation activities to be undertaken shall include at least a review of technical documentation. Where such a review is not appropriate, substitute evaluation activities with equivalent effect shall be undertaken.

6. A European cybersecurity certificate **that refers to assurance level 'substantial' shall provide assurance that the ICT products, ICT services and ICT processes for which that certificate is issued meet the corresponding security requirements, including security functionalities, and that they have been evaluated at a level intended to minimise the known cybersecurity risks, and the risk of incidents and cyberattacks carried out by actors with limited skills and resources**. The evaluation activities to be undertaken shall include at least the following: a review

to demonstrate the absence of publicly known vulnerabilities and testing to demonstrate that the ICT products, ICT services or ICT processes correctly implement the necessary security functionalities. Where any such evaluation activities are not appropriate, substitute evaluation activities with equivalent effect shall be undertaken.

7. A European cybersecurity certificate **that refers to assurance level 'high' shall provide assurance that the ICT products, ICT services and ICT processes for which that certificate is issued meet the corresponding security requirements, including security functionalities, and that they have been evaluated at a level intended to minimise the risk of state-of-the-art cyberattacks carried out by actors with significant skills and resources. The evaluation activities to be undertaken shall include at least the following: a review to demonstrate the absence of publicly known vulnerabilities; testing to demonstrate that the ICT products, ICT services or ICT processes correctly implement the necessary security functionalities at the state of the art; and an assessment of their resistance to skilled attackers, using penetration testing.** Where any such evaluation activities are not appropriate, substitute activities with equivalent effect shall be undertaken.

Article 56: Cybersecurity certification

1. ICT products, ICT services and ICT processes that have been certified under a European cybersecurity certification scheme adopted pursuant to Article 49 shall be presumed to comply with the requirements of such scheme.

2. **The cybersecurity certification shall be voluntary, unless otherwise specified by Union law or Member State law**.

Directive 2016/1148 concerning measures for a high common level of security of network and information systems across the Union (NIS Directive)

Article 1: Subject matter and scope

[…] this Directive: […]

(d) **establishes security and notification requirements for operators of essential services and for digital service provider** […]

Article 4: Definitions

'network and information system' mean:

(a)an electronic communications network within the meaning of point (a) of Article 2 of Directive 2002/21/EC;

(b)any device or group of interconnected or related devices, one or more of which, pursuant to a program, perform automatic processing of digital data; or

(c) digital data stored, processed, retrieved or transmitted by elements covered under points (a) and (b) for the purposes of their operation, use, protection and maintenance;

'security of network and information systems' means the ability of network and information systems to resist, at a given level of confidence, any action that compromises the availability, authenticity, integrity or confidentiality of stored or

transmitted or processed data or the related services offered by, or accessible via, those network and information systems;

'operator of essential services' means a public or private entity of a type referred to in Annex II, which meets the criteria laid down in Article 5(2);

'digital service' means a service within the meaning of point (b) of Article 1(1) of Directive 2015/1535 […] which is of a type listed in Annex III

Article 5: Identification of operators of essential services

The **criteria for the identification of the operators of essential services**, as referred to in point (4) of Article 4, shall be as follows:

(a) an entity provides a service which is essential for the maintenance of critical societal and/or economic activities;

(b) the provision of that service depends on network and information systems; and

(c) an incident would have significant disruptive effects on the provision of that service.

Article 6: Significant disruptive effect

Article 6, §1: **When determining the significance of a disruptive effect** as referred to in point (c) of Article 5(2), **Member States shall take into account at least the following cross-sectoral factors:**

(a)the number of users relying on the service provided by the entity concerned;

(b)the dependency of other sectors referred to in Annex II on the service provided by that entity;

(c)the impact that incidents could have, in terms of degree and duration, on economic and societal activities or public safety;

(d)the market share of that entity;

(e)the geographic spread with regard to the area that could be affected by an incident;

(f) the importance of the entity for maintaining a sufficient level of the service, taking into account the availability of alternative means for the provision of that service.

Article 7: National strategy on the security of network and information systems

Each Member State shall adopt a national strategy on the security of network and information systems defining the strategic objectives and appropriate policy and regulatory measures with a view to achieving and maintaining a high level of security of network and information systems and covering at least the sectors referred to in Annex II and the services referred to in Annex III. […]

Article 14: Security requirements and incident notification

Member States shall ensure that operators of essential services take appropriate and proportionate technical and organisational measures to manage the risks posed to the

security of network and information systems which they use in their operations. Having regard to the state of the art, those measures shall ensure a level of security of network and information systems appropriate to the risk posed.

2. Member States shall ensure that operators of essential services take appropriate measures to prevent and minimise the impact of incidents affecting the security of the network and information systems used for the provision of such essential services, with a view to ensuring the continuity of those services.

3. Member States shall ensure that operators of essential services notify, without undue delay, the competent authority or the CSIRT of incidents having a significant impact on the continuity of the essential services they provide. Notifications shall include information enabling the competent authority or the CSIRT to determine any cross-border impact of the incident. Notification shall not make the notifying party subject to increased liability.

4. **In order to determine the significance of the impact of an incident, the following parameters in particular shall be taken into account:**

(a)the number of users affected by the disruption of the essential service;

(b)the duration of the incident;

(c)the geographical spread with regard to the area affected by the incident.

5. On the basis of the information provided in the notification by the operator of essential services, the competent authority or the CSIRT shall inform the other affected Member State(s) if the incident has a significant impact on the continuity of essential services in that Member State. In so doing, the competent authority or the CSIRT shall, in accordance with Union law or national legislation that complies with Union law, preserve the security and commercial interests of the operator of essential services, as well as the confidentiality of the information provided in its notification. Where the circumstances allow, the competent authority or the CSIRT shall provide the notifying operator of essential services with relevant information regarding the follow-up of its notification, such as information that could support the effective incident handling. At the request of the competent authority or the CSIRT, the single point of contact shall forward notifications as referred to in the first subparagraph to single points of contact of other affected Member States.
6. After consulting the notifying operator of essential services, the competent authority or the CSIRT may inform the public about individual incidents, where public awareness is necessary in order to prevent an incident or to deal with an ongoing incident.

Article 16: Security requirements and incident notification

Member States shall ensure that digital service providers identify and take appropriate and proportionate technical and organisational measures to manage the risks posed to the security of network and information systems which they use in the context of offering services referred to in Annex III within the Union. Having regard to the state of the art, those measures shall ensure a level of security of network and information systems appropriate to the risk posed, and shall take into account the following elements:

(a)the security of systems and facilities;

(b)incident handling;

(c)business continuity management;

(d)monitoring, auditing and testing;

(e)compliance with international standards.

2. Member States shall ensure that digital service providers take measures to prevent and minimise the impact of incidents affecting the security of their network and information systems on the services referred to in Annex III that are offered within the Union, with a view to ensuring the continuity of those services.

3. Member States shall ensure that digital service providers notify the competent authority or the CSIRT without undue delay of any incident having a substantial impact on the provision of a service as referred to in Annex III that they offer within the Union. Notifications shall include information to enable the competent authority or the CSIRT to determine the significance of any cross-border impact. Notification shall not make the notifying party subject to increased liability.

4. **In order to determine whether the impact of an incident is substantial, the following parameters in particular shall be taken into account:**

(a)the number of users affected by the incident, in particular users relying on the service for the provision of their own services;

(b)the duration of the incident;

(c)the geographical spread with regard to the area affected by the incident;

(d)the extent of the disruption of the functioning of the service;

(e)the extent of the impact on economic and societal activities.

The obligation to notify an incident shall only apply where the digital service provider has access to the information needed to assess the impact of an incident against the parameters referred to in the first subparagraph.

5. Where an operator of essential services relies on a third-party digital service provider for the provision of a service which is essential for the maintenance of critical societal and economic activities, any significant impact on the continuity of the essential services due to an incident affecting the digital service provider shall be notified by that operator.

6. Where appropriate, and in particular if the incident referred to in paragraph 3 concerns two or more Member States, the competent authority or the CSIRT shall inform the other affected Member States. In so doing, the competent authorities, CSIRTs and single points of contact shall, in accordance with Union law, or national legislation that complies with Union law, preserve the digital service provider's security and commercial interests as well as the confidentiality of the information provided.

7. After consulting the digital service provider concerned, the competent authority or the CSIRT and, where appropriate, the authorities or the CSIRTs of other Member States concerned may inform the public about individual incidents or require the digital service provider to do so, where public awareness is necessary in order to prevent an incident or to deal with an ongoing incident, or where disclosure of the incident is otherwise in the public interest.

Annexes

TYPES OF ENTITIES FOR THE PURPOSES OF POINT (4) OF ARTICLE 4 : […] 2. Transport […] (d) Road transport:

> **- Road authorities as defined in point (12) of Article 2 of Commission Delegated Regulation (EU) 2015/962 responsible for traffic management control**
>
> **- Operators of Intelligent Transport Systems as defined in point (1) of Article 4 of Directive 2010/40/EU** […]

Directive 2005/29 concerning unfair business-to-consumer commercial practices in the internal market (UCPD)

Article 6: Misleading actions

A commercial practice **shall be regarded as misleading if it contains false information and is therefore untruthful or in any way, including overall presentation, deceives or is likely to deceive the average consumer**, even if the information is factually correct**, in relation to one or more of the following elements, and in either case causes or is likely to cause him to take a transactional decision that he would not have taken otherwise**: […]

> (b) the **main characteristics of the product, such as** its availability, **benefits, risks, execution, composition, accessories,** after-sale customer assistance and complaint handling, method and date of manufacture or provision, delivery, **fitness for purpose, usage**, quantity, specification, geographical or commercial origin or **the results to be expected from its use, or the results and material features of tests or checks carried out on the product**;

Article 7: Misleading omissions

A commercial practice **shall be regarded as misleading if, in its factual context, taking account of all its features and circumstances** and the limitations of the communication medium**, it omits material information that the average consumer needs, according to the context, to take an informed transactional decision and thereby causes or is likely to cause the average consumer to take a transactional decision that he would not have taken otherwise.**

Directive 2011/83 on consumer rights (CRD)

Article 3: Scope

Article 3, §3, (k): This Directive **shall not apply to contracts**: […]

> (k)**for passenger transport services**, with the exception of Article 8(2) and Articles 19, 21 and 22.

Article 5: Information requirements for contracts other than distance or off-premises contracts

Before the consumer is bound by a contract other than a distance or an off-premises contract, or any corresponding offer, **the trader shall provide the consumer with the following information in a clear and comprehensible manner**, if that information is not already apparent from the context:

> (a)**the main characteristics of the goods or services**, to the extent appropriate to the medium and to the goods or services; […]

(e)in addition to **a reminder of the existence of the legal guarantee of conformity for goods, digital content and digital services**, the existence and the conditions of after-sales services and commercial guarantees, where applicable […]

(g)where applicable, the functionality, including applicable technical protection measures, of goods with digital elements, digital content and digital services;

(h)where applicable, any relevant compatibility and interoperability of goods with digital elements, digital content and digital services that the trader is aware of or can reasonably be expected to have been aware of […]

Article 6: Information requirements for distance and off-premises contract

the consumer is bound by a distance or off-premises contract, or any corresponding offer, **the trader shall provide the consumer with the following information in a clear and comprehensible manner** […]

(k) where a right of withdrawal is not provided for in accordance with Article 16, the information that the consumer will not benefit from a right of withdrawal or, where applicable, the circumstances under which the consumer loses his right of withdrawal;

(l)a reminder of the existence of a legal guarantee of conformity for goods, digital content and digital services […]

Directive 2019/770 on certain aspects concerning contracts for the supply of digital content and digital services (Digital content and services Directive)

Article 2: Definitions

'**digital content**' means data which are produced and supplied in digital form;

'digital service' means:

(a)a service that allows the consumer to create, process, store or access data in digital form; or

(b) a service that allows the sharing of or any other interaction with data in digital form uploaded or created by the consumer or other users of that service

'goods with digital elements' means any tangible movable items that incorporate, or are inter-connected with, digital content or a digital service in such a way that the absence of that digital content or digital service would prevent the goods from performing their functions;

'functionality' means the ability of the digital content or digital service to perform its functions having regard to its purpose;

Article 3: Scope

This Directive **shall not apply to digital content or digital services which are incorporated in or inter-connected with goods within the meaning of point (3) of Article 2, and which are provided with the goods under a sales contract concerning those goods, irrespective of whether such digital content or digital service is supplied by the seller or by a third party**. In the event of doubt as to whether the supply of incorporated or inter-connected digital content or

an incorporated or inter-connected digital service forms part of the sales contract, the digital content or digital service shall be presumed to be covered by the sales contract.

Article 7: Subjective requirements for conformity
In order to conform with the contract, the digital content or digital service shall, in particular, where applicable:

(a)be of the description, quantity and quality, and possess the functionality, compatibility, interoperability and other features, as required by the contract;

(b) be fit for any particular purpose for which the consumer requires it and which the consumer made known to the trader at the latest at the time of the conclusion of the contract, and in respect of which the trader has given acceptance;

(c) be supplied with all accessories, instructions, including on installation, and customer assistance as required by the contract; and

(d) be updated as stipulated by the contract.

Article 8: Objective requirements for conformity

1. **In addition to complying with any subjective requirement for conformity, the digital content or digital service shall**:

(a)be fit for the purposes for which digital content or digital services of the same type would normally be used, taking into account, where applicable, any existing Union and national law, technical standards or, in the absence of such technical standards, applicable sector-specific industry codes of conduct;

(b)be of the quantity and possess the qualities and performance features, including in relation to functionality, compatibility, accessibility, continuity and security, normal for digital content or digital services of the same type and which the consumer may reasonably expect, given the nature of the digital content or digital service and taking into account any public statement made by or on behalf of the trader, or other persons in previous links of the chain of transactions, particularly in advertising or on labelling unless the trader shows that:

(i)the trader was not, and could not reasonably have been, aware of the public statement in question;

(ii)by the time of conclusion of the contract, the public statement had been corrected in the same way as, or in a way comparable to how, it had been made; or

(iii)the decision to acquire the digital content or digital service could not have been influenced by the public statement;

(c)where applicable, be supplied along with any accessories and instructions which the consumer may reasonably expect to receive; and

(d)comply with any trial version or preview of the digital content or digital service, made available by the trader before the conclusion of the contract.

2. The **trader shall ensure that the consumer is informed of and supplied with updates, including security updates, that are necessary to keep the digital content or digital service in conformity,** for the period of time:

(a)during which the digital content or digital service is to be supplied under the contract, where the contract provides for a continuous supply over a period of time; or

(b)that the consumer may reasonably expect, given the type and purpose of the digital content or digital service and taking into account the circumstances and nature of the contract, where the contract provides for a single act of supply or a series of individual acts of supply.

3. **Where the consumer fails to install, within a reasonable time, updates supplied by the trader in accordance with paragraph 2, the trader shall not be liable for any lack of conformity resulting solely from the lack of the relevant update**, provided that:

(a)the trader informed the consumer about the availability of the update and the consequences of the failure of the consumer to install it; and

(b)the failure of the consumer to install or the incorrect installation by the consumer of the update was not due to shortcomings in the installation instructions provided by the trader.

4. Where the contract provides for a continuous supply of digital content or digital service over a period of time, the digital content or digital service shall be in conformity throughout the duration of that period.

Article 11: Liability of the trader

1. The trader shall be liable for any failure to supply the digital content or digital service in accordance with Article 5.

2. **Where a contract provides for a single act of supply or a series of individual acts of supply, the trader shall be liable for any lack of conformity under Articles 7, 8 and 9 which exists at the time of supply**, without prejudice to point (b) of Article 8(2).

If, under national law, the trader is only liable for a lack of conformity that becomes apparent within a period of time after supply**, that period shall not be less than two years from the time of supply**, without prejudice to point (b) of Article 8(2). […].

3. **Where the contract provides for continuous supply over a period of time, the trader shall be liable for a lack of conformity under Articles 7, 8 and 9, that occurs or becomes apparent within the period of time during which the digital content or digital service is to be supplied under the contract** […].

Directive 2019/771 on certain aspects concerning contracts for the sale of goods

Article 2: Definitions

'**goods**' means: […]

(b) any tangible movable items that incorporate or are inter-connected with digital content or a digital service in such a way that the absence of that digital content or digital service would prevent the goods from performing their functions ('goods with digital elements');

Article 3: Scope

This Directive shall not apply to contracts for the supply of digital content or digital services. It shall, however**, apply to digital content or digital services which are incorporated in or inter-connected with goods in the meaning of point (5)(b) of Article 2, and are provided with the goods under the sales contract, irrespective of whether such digital content or digital service is supplied by the seller or by a third party.** In the event of doubt as to whether the supply of incorporated or inter-connected digital content or an incorporated or inter-connected digital service forms part of the sales contract, the digital content or digital service shall be presumed to be covered by the sales contract.

Article 7: Objective requirements for conformity

1. **In addition to complying with any subjective requirement for conformity, the goods shall**:

> (a) be fit for the purposes for which goods of the same type would normally be used, taking into account, where applicable, any existing Union and national law, technical standards or, in the absence of such technical standards, applicable sector-specific industry codes of conduct;
>
> (b) where applicable, be of the quality and correspond to the description of a sample or model that the seller made available to the consumer before the conclusion of the contract;
>
> (c)where applicable, be delivered along with such accessories, including packaging, installation instructions or other instructions, as the consumer may reasonably expect to receive; and
>
> (d) be of the quantity and possess the qualities and other features, including in relation to durability, functionality, compatibility and security normal for goods of the same type and which the consumer may reasonably expect given the nature of the goods and taking into account any public statement made by or on behalf of the seller, or other persons in previous links of the chain of transactions, including the producer, particularly in advertising or on labelling. […]

3. **In the case of goods with digital elements, the seller shall ensure that the consumer is informed of and supplied with updates, including security updates, that are necessary to keep those goods in conformity**, for the period of time:

> (a)that the consumer may reasonably expect given the type and purpose of the goods and the digital elements, and taking into account the circumstances and nature of the contract, where the sales contract provides for a single act of supply of the digital content or digital service; or
>
> (b) indicated in Article 10(2) or (5), as applicable, where the sales contract provides for a continuous supply of the digital content or digital service over a period of time.

4. **Where the consumer fails to install within a reasonable time updates supplied in accordance with paragraph 3, the seller shall not be liable for any lack of conformity resulting solely from the lack of the relevant update**, provided that:

> (a)the seller informed the consumer about the availability of the update and the consequences of the failure of the consumer to install it; and

(b)the failure of the consumer to install or the incorrect installation by the consumer of the update was not due to shortcomings in the installation instructions provided to the consumer.

Article 10: Liability of the seller

1. **The seller shall be liable to the consumer for any lack of conformity which exists at the time when the goods were delivered and which becomes apparent within two years of that time.** Without prejudice to Article 7(3), this paragraph shall **also apply to goods with digital elements**.

2. **In the case of goods with digital elements, where the sales contract provides for a continuous supply of the digital content or digital service over a period of time, the seller shall also be liable for any lack of conformity of the digital content or digital service that occurs or becomes apparent within two years of the time when the goods with digital elements were delivered. Where the contract provides for a continuous supply for more than two years, the seller shall be liable for any lack of conformity of the digital content or digital service that occurs or becomes apparent within the period of time during which the digital content or digital service is to be supplied** under the sales contract.

Directive 2002/58 concerning the processing of personal data and the protection of privacy in the electronic communications sector (e-privacy Directive)

Article 2: Definitions

'traffic data' means any data processed for the purpose of the conveyance of a communication on an electronic communications network or for the billing thereof;

'location data' means any data processed in an electronic communications network or by an electronic communications service, indicating the geographic position of the terminal equipment of a user of a publicly available electronic communications service;

'value added service' means any service which requires the processing of traffic data or location data other than traffic data beyond what is necessary for the transmission of a communication or the billing thereof;

Article 3: Services concerned

1. This Directive shall **apply to the processing of personal data in connection with the provision of publicly available electronic communications services in public communications networks** in the Community**, including public communications networks supporting data collection and identification devices**

Article 5: Confidentiality of the communications

Member States shall ensure the confidentiality of communications and the related traffic data by means of a public communications network and publicly available electronic communications services, through national legislation. In particular, they shall prohibit listening, tapping, storage or other kinds of interception or surveillance of communications and the related traffic data by persons other than users, without the consent of the users concerned, except when legally authorised to do so in accordance with Article 15(1). This paragraph shall not prevent technical storage which is necessary for the conveyance of a communication without prejudice to the principle of confidentiality.

3. **Member States shall ensure that the storing of information, or the gaining of access to information already stored, in the terminal equipment of a subscriber or user is only allowed on condition that the subscriber or user concerned has given his or her consent, having been provided with clear and comprehensive information**, in accordance with Directive 95/46/EC, inter alia, about the purposes of the processing. This **shall not prevent any technical storage or access for the sole purpose of carrying out the transmission of a communication over an electronic communications network, or as strictly necessary in order for the provider of an information society service explicitly requested by the subscriber or user to provide the service.**

Article 6: Traffic data

For the purpose of marketing electronic communications services or **for the provision of value-added services, the provider of a publicly available electronic communications service may process the data referred to in paragraph 1 to the extent and for the duration necessary for such services or marketing, if the subscriber or user to whom the data relate has given his or her prior consent. Users or subscribers shall be given the possibility to withdraw their consent** for the processing of traffic data at any time.

Article 9: Location data other than traffic data

1. Where location data other than traffic data, relating to users or subscribers of public communications networks or publicly available electronic communications services, can be processed, such data **may only be processed when they are made anonymous, or with the consent of the users or subscribers to the extent and for the duration necessary for the provision of a value-added service.** The service provider must **inform the users or subscribers, prior to obtaining their consent, of the type of location data other than traffic data which will be processed, of the purposes and duration of the processing and whether the data will be transmitted to a third party for the purpose of providing the value-added service**. Users or subscribers shall be given the possibility to withdraw their consent for the processing of location data other than traffic data at any time.

2. Where consent of the users or subscribers has been obtained for the processing of location data other than traffic data, the **user or subscriber must continue to have the possibility, using a simple means and free of charge, of temporarily refusing the processing of such data** for each connection to the network or for each transmission of a communication.

Regulation 2016/679 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data (GDPR)

Article 2: Scope

1. This Regulation **applies to the processing of personal data wholly or partly by automated means** and to the processing other than b

y automated means of personal data which form part of a filing system or are intended to form part of a filing system.2. This Regulation **does not apply to the processing of personal data: […]**

(c)by a natural person in the course of a purely personal or household activity;

Article 4: Definitions

'personal data' means any information relating to an identified or identifiable natural person ('data subject'); an identifiable natural person is one who can be

identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person;

'processing' means any operation or set of operations which is performed on personal data or on sets of personal data, whether or not by automated means, such as […]

'profiling' means any form of automated processing of personal data consisting of the use of personal data to evaluate certain personal aspects relating to a natural person, in particular to analyse or predict aspects concerning that natural person's performance at work, economic situation, health, personal preferences, interests, reliability, behaviour, location or movements;

'controller' means the natural or legal person, public authority, agency or other body which, alone or jointly with others, determines the purposes and means of the processing of personal data; where the purposes and means of such processing are determined by Union or Member State law, the controller or the specific criteria for its nomination may be provided for by Union or Member State law;

'biometric data' means personal data resulting from specific technical processing relating to the physical, physiological or behavioural characteristics of a natural person, which allow or confirm the unique identification of that natural person, such as facial images or dactyloscopic data;

Article 5: Principles relating to processing of personal data

1. Personal data shall be:

(a)processed lawfully, fairly and in a transparent manner in relation to the data subject ('**lawfulness, fairness and transparency**');

(b)collected for specified, explicit and legitimate purposes and not further processed in a manner that is incompatible with those purposes; further processing for archiving purposes in the public interest, scientific or historical research purposes or statistical purposes shall, in accordance with Article 89(1), not be considered to be incompatible with the initial purposes ('**purpose limitation**');

(c)adequate, relevant and limited to what is necessary in relation to the purposes for which they are processed ('**data minimisation**');

(d)accurate and, where necessary, kept up to date; every reasonable step must be taken to ensure that personal data that are inaccurate, having regard to the purposes for which they are processed, are erased or rectified without delay ('**accuracy**');

(e)kept in a form which permits identification of data subjects for no longer than is necessary for the purposes for which the personal data are processed; personal data may be stored for longer periods insofar as the personal data will be processed solely for archiving purposes in the public interest, scientific or historical research purposes or statistical purposes in accordance with Article 89(1) subject to implementation of the appropriate technical and organisational measures required

by this Regulation in order to safeguard the rights and freedoms of the data subject ('**storage limitation**');

(f) processed in a manner that ensures appropriate security of the personal data, including protection against unauthorised or unlawful processing and against accidental loss, destruction or damage, using appropriate technical or organisational measures **('integrity and confidentiality')**.

2. The controller shall be responsible for, and be able to demonstrate compliance with, paragraph 1 ('**accountability**').

Article 6: Lawfulness of processing

Processing shall be lawful only if and to the extent that at least one of the following applies:

(a) **the data subject has given consent** to the processing of his or her personal data for one or more specific purposes;

(b) processing is **necessary for the performance of a contract** to which the data subject is party or in order to take steps at the request of the data subject prior to entering into a contract;

(c) processing is **necessary for compliance with a legal obligation** to which the controller is subject;

(d) processing is necessary in order to protect the vital interests of the data subject or of another natural person;

(e) processing is necessary for the performance of a task carried out in the public interest or in the exercise of official authority vested in the controller;

(f) processing is necessary for the purposes of the legitimate interests pursued by the controller or by a third party, except where such interests are overridden by the interests or fundamental rights and freedoms of the data subject which require protection of personal data, in particular where the data subject is a child.

Point (f) of the first subparagraph shall not apply to processing carried out by public authorities in the performance of their tasks.

Article 9: Processing of special categories of personal data

1. **Processing of personal data revealing racial or ethnic origin, political opinions, religious or philosophical beliefs, or trade union membership, and the processing of genetic data, biometric data for the purpose of uniquely identifying a natural person, data concerning health or data concerning a natural person's sex life or sexual orientation shall be prohibited**.

2. Paragraph 1 shall not apply if one of the following applies: [...]

Article 10: Processing of personal data relating to criminal convictions and offences

Processing of personal data relating to criminal convictions and offences or related security measures based on Article 6(1) **shall be carried out only under the control of official authority or when the processing is authorised by Union or Member State law providing for appropriate safeguards for the rights and freedoms of data subjects**. Any comprehensive register of criminal convictions shall be kept only under the control of official authority.

Article 20: Right to data portability

1. The data subject **shall have the right to receive the personal data concerning him or her, which he or she has provided to a controller, in a structured, commonly used and machine-readable format and have the right to transmit those data to another controller** without hindrance from the controller to which the personal data have been provided, where:

(a) the processing is based on consent pursuant to point (a) of Article 6(1) or point (a) of Article 9(2) or on a contract pursuant to point (b) of Article 6(1); and

(b) the processing is carried out by automated means.

2. In exercising his or her right to data portability pursuant to paragraph 1, the data subject shall have the **right to have the personal data transmitted directly from one controller to another, where technically feasible**.

Article 22: Automated individual decision-making, including profiling

1. The data subject **shall have the right not to be subject to a decision based solely on automated processing, including profiling, which produces legal effects concerning him or her or similarly significantly affects him or her**.

2. Paragraph 1 **shall not apply if the decision**:

(a) is necessary for entering into, or performance of, a contract between the data subject and a data controller;

(b) is **authorised by Union or Member State law** to which the controller is subject and which also lays down suitable measures to safeguard the data subject's rights and freedoms and legitimate interests; or

(c) is based on the data subject's **explicit consent**.

3. In the cases referred to in points (a) and (c) of paragraph 2, the data controller shall **implement suitable measures to safeguard the data subject's rights and freedoms and legitimate interests, at least the right to obtain human intervention on the part of the controller, to express his or her point of view and to contest the decision**.

4. Decisions referred to in paragraph 2 shall not be based on special categories of personal data referred to in Article 9(1), unless point (a) or (g) of Article 9(2) applies and suitable measures to safeguard the data subject's rights and freedoms and legitimate interests are in place.

Article 25: Data protection by design and by default

1. Taking into account the state of the art, the cost of implementation and the nature, scope, context and purposes of processing as well as the risks of varying likelihood and severity for rights and freedoms of natural persons posed by the processing, the **controller shall, both at the time of the determination of the means for processing and at the time of the processing itself, implement appropriate technical and organisational measures, such as pseudonymisation, which are designed to implement data-protection principles, such as data minimisation, in an effective manner and to integrate the necessary safeguards into the processing in order to meet the requirements of this Regulation and protect the rights of data subjects**.

2. The controller shall implement appropriate technical and organisational measures for ensuring that, **by default, only personal data which are necessary for each specific purpose of the**

processing are processed. That obligation applies to the amount of personal data collected, the extent of their processing, the period of their storage and their accessibility. In particular, such measures shall ensure that by default personal data are not made accessible without the individual's intervention to an indefinite number of natural persons.

Article 32: Security of processing

1. Taking into account the state of the art, the costs of implementation and the nature, scope, context and purposes of processing as well as the risk of varying likelihood and severity for the rights and freedoms of natural persons**, the controller and the processor shall implement appropriate technical and organisational measures to ensure a level of security appropriate to the risk, including inter alia as appropriate**:

> (a) the pseudonymisation and **encryption of personal data**
>
> (b) the ability to ensure the ongoing confidentiality, integrity, availability and resilience of processing systems and services;
>
> (c) the ability to restore the availability and access to personal data in a timely manner in the event of a physical or technical incident;
>
> (d) a process for regularly testing, assessing and evaluating the effectiveness of technical and organisational measures for ensuring the security of the processing.

2. In assessing the appropriate level of security account shall be taken in particular of the risks that are presented by processing, in particular from accidental or unlawful destruction, loss, alteration, unauthorised disclosure of, or access to personal data transmitted, stored or otherwise processed.

Article 35: Data protection impact assessment

1. **Where a type of processing in particular using new technologies, and taking into account the nature, scope, context and purposes of the processing, is likely to result in a high risk to the rights and freedoms of natural persons, the controller shall, prior to the processing, carry out an assessment of the impact of the envisaged processing operations on the protection of personal data.** A single assessment may address a set of similar processing operations that present similar high risks.

3. A data protection impact assessment referred to in paragraph 1 **shall in particular be required in the case of:**

> (a) a systematic and extensive evaluation of personal aspects relating to natural persons which is based on automated processing, including profiling, and on which decisions are based that produce legal effects concerning the natural person or similarly significantly affect the natural person; […]

Regulation 2018/1807 on a framework for the free flow of non-personal data in the European Union (Free flow of non-personal data Regulation)

Article 6: Porting of data

1. The Commission shall **encourage and facilitate the development of self-regulatory codes of conduct at Union level** ('codes of conduct'), in order **to contribute to a competitive data economy, based on the principles of transparency and interoperability and taking due account of open standards, covering, inter alia,** the following aspects:

(a)**best practices for facilitating the switching of service providers and the porting of data in a structured, commonly used and machine-readable format including open standard formats where required or requested by the service provider receiving the data**;

(b)**minimum information requirements to ensure that professional users are provided, before a contract for data processing is concluded, with sufficiently detailed, clear and transparent information** regarding the processes, technical requirements, timeframes and charges that apply in case a professional user wants to switch to another service provider or port data back to its own IT systems;

(c)**approaches to certification schemes that facilitate the comparison of data processing products and services for professional users**, taking into account established national or international norms, to facilitate the comparability of those products and services. Such approaches may include, inter alia, quality management, information security management, business continuity management and environmental management;

(d)communication roadmaps taking a multi-disciplinary approach to raise awareness of the codes of conduct among relevant stakeholders.

2. The Commission shall ensure that the codes of conduct are developed in close cooperation with all relevant stakeholders, including associations of SMEs and start-ups, users and cloud service providers.

Directive 2019/1024 on open data and the re-use of public sector information (Open data Directive)

Article 1: Subject matter and scope

In order to promote the use of open data and stimulate innovation in products and services, this Directive establishes a set of minimum rules governing the re-use and the practical arrangements for facilitating the re-use of:

(a)existing documents held by public sector bodies of the Member States;

(b) existing documents held by public undertakings that are: […]

(ii) **acting as public service** operators pursuant to Article 2 of Regulation (EC) No 1370/2007;

Article 2: Definitions

'dynamic data' means documents in a digital form, subject to frequent or real-time updates, in particular because of their volatility or rapid obsolescence; data generated by sensors are typically considered to be dynamic data;

'high-value datasets' means documents the re-use of which is associated with important benefits for society, the environment and the economy, in particular because of their suitability for the creation of value-added services, applications and new, high-quality and decent jobs, and of the number of potential beneficiaries of the value-added services and applications based on those datasets;

Article 5: Available formats

8. The **high-value datasets**, as listed in accordance with Article 14(1) **shall be made available for re-use in machine-readable format, via suitable APIs and, where relevant, as a bulk download**.

Article 6: Principles governing charging

6.The re-use of the following **shall be free of charge for the user**:

> (a) subject to Article 14(3), (4) and (5), **the high-value datasets**, as listed in accordance with paragraph 1 of that Article

Article 9: Practical arrangements:

Member States shall **make practical arrangements facilitating the search for documents available for re-use, such as asset lists of main documents with relevant metadata, accessible where possible and appropriate online and in machine-readable format, and portal sites that are linked to the asset list**s. Where possible, Member States shall facilitate the cross-linguistic search for documents, in particular by enabling metadata aggregation at Union level.

Member States shall also encourage public sector bodies to make practical arrangements facilitating the preservation of documents available for re-use.

Article 14: Specific high-value datasets and arrangements for publication and re-use

1. The Commission shall adopt implementing acts laying down a list of specific high-value datasets belonging to the categories set out in Annex I and held by public sector bodies and public undertakings among the documents to which this Directive applies.

Such **specific high-value datasets shall be:**

> **(a)available free of charge,** subject to paragraphs 3, 4 and 5;
>
> (b)machine readable;
>
> (c)provided via APIs; and
>
> (d)provided as a bulk download, where relevant.

Those implementing acts may specify the arrangements for the publication and re-use of high-value datasets. Such arrangements shall be compatible with open standard licences.

The arrangements may include terms applicable to re-use, formats of data and metadata and technical arrangements for dissemination. Investments made by the Member States in open data approaches, such as investments into the development and roll-out of certain standards, shall be taken into account and balanced against the potential benefits from inclusion in the list.

Those implementing acts shall be adopted in accordance with the examination procedure referred to in Article 16(2).

2. **The identification of specific high-value datasets pursuant to paragraph 1 shall be based on the assessment of their potential to**:

> (a)generate significant socioeconomic or environmental benefits and innovative services;
>
> (b)benefit a high number of users, in particular SMEs;

(c)assist in generating revenues; and

(d)be combined with other datasets.

For the purpose of identifying such specific high-value datasets, the Commission shall carry out appropriate consultations, including at expert level, conduct an impact assessment and ensure complementarity with existing legal acts, such as Directive 2010/40/EU, with respect to the re-use of documents. That impact assessment shall include a cost-benefit analysis and an analysis of whether providing high-value datasets free of charge by public sector bodies that are required to generate revenue to cover a substantial part of their costs relating to the performance of their public tasks would lead to a substantial impact on the budget of such bodies. With regard to high-value datasets held by public undertakings, the impact assessment shall give special consideration to the role of public undertakings in a competitive economic environment.

3. By way of derogation from point (a) of the second subparagraph of paragraph 1, the implementing acts referred to in paragraph 1 shall provide that the availability of high-value datasets free of charge is not to apply to specific high-value datasets held by public undertakings where that would lead to a distortion of competition in the relevant markets.

4. The requirement to make high-value datasets available free of charge pursuant to point (a) of the second subparagraph of paragraph 1 shall not apply to libraries, including university libraries, museums and archives.

5. Where making high-value datasets available free of charge by public sector bodies that are required to generate revenue to cover a substantial part of their costs relating to the performance of their public tasks would lead to a substantial impact on the budget of the bodies involved, Member States may exempt those bodies from the requirement to make those high-value datasets available free of charge for a period of no more than two years following the entry into force of the relevant implementing act adopted in accordance with paragraph 1.

Annex I:

List of thematic categories of high-value datasets*, as referred to in Article 13(1) :*

[…] 6. Mobility

Directive 2000/31 on certain legal aspects of information society services, in particular electronic commerce, in the Internal Market (e-commerce Directive)

Article 14: Hosting

1.Where an **information society service is provided that consists of the storage of information** provided by a recipient of the service, Member States shall ensure **that the service provider is not liable for the information stored at the request of a recipient of the service, on condition that**:

(a) the provider does not have actual knowledge of illegal activity or information and, as regards claims for damages, is not aware of facts or circumstances from which the illegal activity or information is apparent; or

(b) the provider, upon obtaining such knowledge or awareness, acts expeditiously to remove or to disable access to the information.

or the control of the provider.

3. This Article shall **not affect the possibility for a court or administrative authority, in accordance with Member States' legal systems, of requiring the service provider to terminate**

or prevent an infringement, nor does it affect **the possibility for Member States of establishing procedures governing the removal or disabling of access** to information.

Article 15: No general obligation to monitor

1. Member States **shall not impose a general obligation on providers**, when providing the services covered by Articles 12, 13 and 14**, to monitor the information which they transmit or store, nor a general obligation actively to seek facts or circumstances indicating illegal activity**.

2. Member States **may establish obligations for information society service providers promptly to inform the competent public authorities of alleged illegal activities undertaken or information provided by recipients of their service or obligations to communicate to the competent authorities, at their request, information enabling the identification of recipients of their service** with whom they have storage agreements.

Regulation 2019/1150 on promoting fairness and transparency for business users of online intermediation services (P2B Regulation)

Article 2: Definitions

> **'online intermediation services'** means services which meet all of the following requirements:
>
> (a) they constitute information society services within the meaning of point (b) of Article 1(1) of Directive (EU) 2015/1535 of the European Parliament and of the Council (12);
>
> (b) they allow business users to offer goods or services to consumers, with a view to facilitating the initiating of direct transactions between those business users and consumers, irrespective of where those transactions are ultimately concluded;
>
> (c) they are provided to business users on the basis of contractual relationships between the provider of those services and business users which offer goods or services to consumers;

Article 3: Terms and conditions

The **notice period** set out in the second subparagraph of paragraph 2 **shall not apply where** a provider of online intermediation services: […]

> (b) **has exceptionally to change its terms and conditions to address an unforeseen and imminent danger related to defending** the online intermediation services, **consumers or business users from fraud, malware, spam, data breaches or other cybersecurity risks.**

Article 9: Access to data

1. **Providers of online intermediation services shall include in their terms and conditions a description of the technical and contractual access, or absence thereof, of business users to any personal data or other data, or both, which business users or consumers provide for the use of the online intermediation services concerned or which are generated through the provision of those services**.

2. Through the description referred to in paragraph 1, providers of online intermediation services shall adequately inform business users in particular of the following:

(a)whether **the provider of online intermediation services has access** to personal data or other data, or both, which business users or consumers provide for the use of those services or which are generated through the provision of those services**, and if so, to which categories of such data and under what conditions**;

(b)whether **a business user has acces**s to personal data or other data, or both, provided by that business user in connection to the business user's use of the online intermediation services concerned or generated through the provision of those services to that business user and the consumers of the business user's goods or services, **and if so, to which categories of such data and under what conditions**;

(c) in addition to point (b), whether **a business user has access to personal data or other data, or both, including in aggregated form, provided by or generated through the provision of the online intermediation services to all of the business users and consumers thereof, and if so, to which categories of such data and under what conditions**; and

(d) whether any data under point (a) **is provided to third parties, along with, where the provision of such data to third parties is not necessary for the proper functioning of the online intermediation services, information specifying the purpose of such data sharing, as well as possibilities for business users to opt out from that data sharing**.

3. This Article shall be without prejudice to the application of Regulation (EU) 2016/679, Directive (EU) 2016/680 and Directive 2002/58/EC.

Directive 96/9 on the legal protection of databases (Database Directive)

Article 1: Scope

2. **'database'** shall mean a **collection of independent works, data or other materials arranged in a systematic or methodical way and individually accessible by electronic or other means**.

Article 7: Object of protection

1. Member States shall provide for a **right for the maker of a database which shows that there has been qualitatively and/or quantitatively a substantial investment in either the obtaining, verification or presentation of the contents to prevent extraction and/or re-utilisation of the whole or of a substantial part, evaluated qualitatively and/or quantitatively, of the contents of that database**.

2. For the purposes of this Chapter:

(a)**'extraction'** shall mean the permanent or temporary transfer of all or a substantial part of the contents of a database to another medium by any means or in any form;

(b)**'re-utilisation'** shall mean any form of making available to the public all or a substantial part of the contents of a database by the distribution of copies, by renting, by on-line or other forms of transmission. The first sale of a copy of a database within the Community by the rightholder or with his consent shall exhaust the right to control resale of that copy within the Community;

5. The repeated and systematic extraction and/or re-utilisation of insubstantial parts of the contents of the database implying acts which conflict with a normal exploitation of that database or which unreasonably prejudice the legitimate interests of the maker of the database shall not be permitted.

Directive 2001/29 on the harmonisation of certain aspects of copyright and related rights in the information society (Infosoc Directive)

Article 2: Reproduction right
Member States shall provide for the **exclusive right to authorise or prohibit direct or indirect, temporary or permanent reproduction by any means and in any form, in whole or in part**:

(a) for authors, of their works […].

Article 3: Right of communication to the public of works and right of making available to the public other subject-matter

Member States shall provide authors with the **exclusive right to authorise or prohibit any communication to the public of their works, by wire or wireless means, including the making available to the public of their works in such a way that members of the public may access them from a place and at a time individually chosen by them**.

Directive 2009/24 on the legal protection of computer programs (Computer programs Directive)

Article 1: Object of protection

2. Protection in accordance with this Directive **shall apply to the expression in any form of a computer program**. Ideas and principles which underlie any element of a computer program, including those which underlie its interfaces, are not protected by copyright under this Directive.

3. A **computer program shall be protected if it is original in the sense that it is the author's own intellectual creation.** No other criteria shall be applied to determine its eligibility for protection.

Article 4: Restricted acts
1. Subject to the provisions of Articles 5 and 6, **the exclusive rights of the rightholder** within the meaning of Article 2 shall **include the right to do or to authorise:**

(a)the permanent or temporary reproduction of a computer program by any means and in any form, in part or in whole; in so far as loading, displaying, running, transmission or storage of the computer program necessitate such reproduction, such acts shall be subject to authorisation by the rightholder;

(b)the translation, adaptation, arrangement and any other alteration of a computer program and the reproduction of the results thereof, without prejudice to the rights of the person who alters the program;

(c)**any form of distribution to the public**, including the rental, of the original computer program or of copies thereof.

Article 5: Exceptions to the restricted acts
3. The **person having a right to use a copy of a computer program shall be entitled, without the authorisation of the rightholder, to observe, study or test the functioning of the program in order to determine the ideas and principles which underlie any element of the program** if

he does so while performing any of the acts of loading, displaying, running, transmitting or storing the program which he is entitled to do.

Directive 2019/790 on copyright and related rights in the Digital Single Market (DSM Directive)

Article 2: Definitions

'text and data mining' mean any automated analytical technique aimed at analysing text and data in digital form in order to generate information which includes but is not limited to patterns, trends and correlations;

Article 4: Exception or limitation for text and data mining

1. Member States shall provide for an **exception or limitation to the rights provided for in Article 5(a) and Article 7(1) of Directive 96/9/EC, Article 2 of Directive 2001/29/EC, Article 4(1)(a) and (b) of Directive 2009/24/EC** and Article 15(1) of this Directive **for reproductions and extractions of lawfully accessible works and other subject matter for the purposes of text and data mining**.

2. Reproductions and extractions made pursuant to paragraph 1 may be retained for as long as is necessary for the purposes of text and data mining.

3. The exception or limitation provided for in paragraph 1 **shall apply on condition that the use of works and other subject matter referred to in that paragraph has not been expressly reserved by their rightholders in an appropriate manner, such as machine-readable means** in the case of content made publicly available online

Annex III Macroeconomic modelling

This annex provides an overview of the structure of the quantitative model employed for the quantification of cost of Non-Europe. The impact of various scenarios is estimated using a computable general equilibrium model (CGE). The model was enhanced with dynamic equations that allow the computation of the impact of a set of shocks over a specified time horizon. The model structure features an open economy with a sectoral breakdown that is tailored to the specific analytical requirements at hand. The model also includes a government sector. It is calibrated on recent data for the EU economy.

The theoretical structure of the model follows the one described in EC(2016).[421] It is assumed that the economy is divided in sectors, each producing a specific product.[422] We present the main model components below. In order to use suggestive notation, whenever possible we use the subscript i to refer to products, the subscript j to refer to sectors and t denotes time. Time in the model is discrete and the time step is assumed to be one year.

Household

The household in the model consumes a bundle of the products in the economy and supplies two types of labour (skilled and unskilled). It is described by the following per-period utility function:

$$U_t = \sum_{i=1}^{n} \theta_i \ln C_{it} - \sum_{j=1}^{n} \xi_j \frac{N_{jt}^{\rho+1}}{\rho+1} - \sum_{j=1}^{n} \pi_j \frac{H_{jt}^{\rho+1}}{\rho+1} + \kappa \ln S_t$$

Here C_{it} is the consumption of a product i in period t, N_{jt} is unskilled labour supplied in a sector j, H_{jt} is skilled labour supplied in a sector j and S_t is household savings.

The household faces the following budget constraint:

$$\sum_{i=1}^{n} P_{it}\, C_{it} = (1-td) \sum_{j=1}^{n} (PN_{jt} N_{jt} + PH_{jt} H_{jt} + PKPR_{jt} KPR_{jt}) + ror \cdot A_t + tr_t - S_t,$$

where P_{it} is the price of product i, including indirect taxes, td is the (implicit) direct tax rate on income, and PN_{jt} and PH_{jt} are respectively the prices of unskilled and skilled labour in a sector j. It is assumed that the return on private capital KPR_{jt} in sector j is transferred to the household through the rental rate $PKPR_{jt}$. Additionally, the household receives interest ror on its assets A_t and transfers from the government tr_t.

The household's problem is to maximise utility U_t with respect to C_{it}, N_{jt}, H_{jt} and S_t subject to the above budget constraint.

Representative firm in sector

The representative firm in a sector j strives to maximise profit by employing skilled and unskilled labour, as well as renting public and private capital. Its profit function is

[421] WIK-Consult, Ecorys and VVA Consulting (2016). Support for the preparation of the impact assessment accompanying the review of the regulatory framework for e-communications. European Commission.

[422] Sometimes sectors are referred to as 'activities', while products are referred to as 'commodities', following established terminology in the CGE literature.

$$\Pi_{jt} = PVA_{jt}VA_{jt} - PN_{jt}N_{jt} - PH_{jt}H_{jt} - PKPR_{jt}KPR_{jt} - PKPU_{jt}KPU_{jt},$$

where PVA_{jt} is the price of value added, VA_{jt} is the real value added produced and $PKPU_{jt}$ is the rental rate of public capital KPU_{jt} in sector j.

The production technology available to the firm is a two-level one. First, skilled and unskilled labour are combined through a constant elasticity of substitution (CES) aggregator to produce the overall labour input L_{jt}:

$$L_{jt} = \sigma_{jt}^{L}\left(\beta_j^{L} N_{jt}^{\nu_j^{L}} + (1-\beta_j^{L}) H_{jt}^{\nu_j^{L}}\right)^{\frac{1}{\nu_j^{L}}}$$

Similarly, public and private capital stocks are combined though a CES-type aggregator to obtain the total capital input K_{jt} for the sector:

$$K_{jt} = \sigma_{jt}^{K}\left(\beta_j^{K} KPU_{jt}^{\nu_j^{K}} + (1-\beta_j^{K}) KPR_{jt}^{\nu_j^{K}}\right)^{\frac{1}{\nu_j^{K}}}$$

Second, value added is produced by means of a production function that in turn combines L_{jt} and K_{jt}. The specific form of the production function is given by

$$VA_{jt} = \sigma_{jt}^{VA}\left(\beta_j^{VA} L_{jt}^{\nu_j^{VA}} + (1-\beta_j^{VA}) K_{jt}^{\nu_j^{VA}}\right)^{\frac{1}{\nu_j^{VA}}}$$

The variable σ_{it}^{VA} is total factor productivity for sector j. Its evolution over time is described in the following sections.

Foreign trade aggregators

The supply Q_{it} of a product i on the domestic market is formed by combining imports of the product, denoted QM_{it}, and quantities QD_{it} produced locally for the domestic market (Armington assumption). Formally, the composite product aggregator is given by

$$Q_{it} = e_i\left(\beta_i QM_{it}^{-\sigma_i} + (1-\beta_i) QD_{it}^{-\sigma_i}\right)^{-\frac{1}{\sigma_i}}$$

The inputs to the above aggregator are determined through a cost minimisation problem that produces the optimal mix between domestically produced and imported products:

$$\frac{QM_{it}}{QD_{it}} = \left(\frac{PD_{it}}{pm_{it}\frac{\beta_i}{1-\beta_i}}\right)^{\frac{1}{1+\sigma_i}}$$

Here pm_{it} is the price of imports of commodity i and PD_{it} is the domestic price.

The domestically produced quantities of product i, denoted QP_{it}, are either exported or supplied locally. The allocation constraint between the domestic and export markets is

$$QP_{it} = f_i\left(\eta_i QE_{it}^{\gamma_i} + (1-\eta_i) QD_{it}^{\gamma_i}\right)^{\frac{1}{\gamma_i}}$$

where QE_{it} is the quantity for the export market.

The optimal allocation between domestic and exported products is again obtained through solving an appropriate cost minimisation problem, which results in the relationship

$$\frac{QE_{it}}{QD_{it}} = \left(\frac{pe_{it}}{PD_{it}}\frac{1-\eta_i}{\eta_i}\right)^{\frac{1}{\gamma_i - 1}},$$

with pe_{it} denoting the export price of product i.

Government

The government in the model collects revenues R_t from direct taxes, indirect taxes (at the implicit rate of τ_i per product i), the return on public capital and the return on net government assets AG_t:

$$R_t = td\sum_{j=1}^{n}(PN_{jt}N_{jt} + PH_{jt}H_{jt} + PKPR_{jt}KPR_{jt}) + \sum_{i=1}^{n}\tau_i\frac{P_{it}}{1+\tau_i}Q_{it} + \sum_{j=1}^{n}P\,KPU_{jt}KPU_{jt} + ror \cdot AG_t.$$

Government expenditures G_t are allocated between three spending categories: purchases of product i, transfers to households and capital expenditures KE_t. Formally, government expenditures are given by the equation

$$G_t = \sum_{i=1}^{n} P_{it}\,cg_{it} + tr_t + KE_t,$$

where cg_{it} denotes the volume of purchases of product i.

The budget balance BB_t is given by

$$BB_t = R_t - G_t.$$

The budget balance is accrued to net government assets AG_t to ensure intertemporal consistency, as explained in the section on model dynamics.

Model closure and equilibrium

Foreign savings in the model are defined from the standpoint of the external sector. Thus, revenues for the external sector comprise the domestic economy imports and interest on the net foreign assets AF_t (again vis-a-vis the domestic economy). Expenditures are computed as the sum of nominal domestic exports by product. Foreign savings FS_t are given by the equation

$$FS_t = \sum_{i=1}^{n} p\,m_{it}QM_{it} + ror \cdot AF_t - \sum_{i=1}^{n} p\,e_{it}QE_{it}.$$

We also impose the typical requirement that the total supply of each product is equal to its uses. This is implemented by means of the supply-use balancing equation

$$Q_{it} = \sum_{j=1}^{n} I\,C_{ijt} + C_{it} + cg_{it} + ID_{it} + QE_{it} + QT_{it}.$$

where IC_{ijt} is intermediate consumption of product i by sector j, ID_{it} is investments demand and QT_{it} is use of product i to cover trade and transport margins.

It is assumed that savings and investment are balanced at the sectoral level, with nominal investment for sector taken as part of total saving, using the share of sectoral capital in the total capital stock as the proportionality coefficient. The savings-investment balancing equation takes the form

$$\overline{PK}_t II_{jt} = \frac{K_{jt}}{\sum_{j=1}^{n} K_{jt}} (S_t + KE_t + BB_t + FS_t - ror(A_t + AF_t + AG_t) - \sum_{i=1}^{n} P_{it} Z_{it} - DUMMY_t),$$

where II_{jt} denotes sectoral investment in real terms, Z_{it} is the change in inventories of product i and the variable $DUMMY_t$ plays a technical role and should be zero in equilibrium.

$$\text{plevel}_t = \sum_{i=1}^{n} w_i P_{it}$$

Dynamics

Agents in the model optimise intratemporally. However, the model contains a set of dynamic equations that ensure consistent evolution of variables over the specified time horizon. These include stock-flow relationships and the dynamics of total factor productivity.

Public capital by sector is taken to evolve over time according to a standard capital accumulation equation:

$$KKPU_{j\,t+1} = (1 - \delta) KKPU_{jt} + IPU_{jt}$$

Here stands for the annual depreciation rate and is public investment in sector .

Private capital follows the same type of law of motion:

$$KKPR_{j\,t+1} = (1 - \delta) KKPR_{jt} + IPR_{jt}$$

with IPR_{jt} denoting private investment in the sector j.

The change in private sector assets reflects savings. The accounting identity is

$$A_{t+1} = A_t + S_t.$$

Similar accounting identities hold true for foreign assets and government assets:

$$AF_{t+1} = AF_t + FS_t,$$

$$AG_{t+1} = AG_t + BB_t.$$

Finally, total factor productivity changes in the basis of an exogenously specified growth rate γ_t^A:

$$\sigma_{j\,t+1}^{VA} = (1 + \gamma_t^A) \sigma_{jt}^{VA}$$

Model calibration

Most of the model coefficients are calibrated using public data from Eurostat, with a limited number of coefficients calibrated on theoretical grounds with values taken from the relevant literature. The bulk of the calibration is implemented by constructing a social accounting matrix (SAM) that measures the flows between the different institutional sectors of the economy for a selected base year. Additional data-based calibrations outside the SAM framework were carried out again using Eurostat data.

In order to ensure reproducibility of the computations and facilitate future updates of the model, the calibration process was implemented through a system of R language scripts.[423] These scripts sequentially carry out the following steps:

- Automatic retrieval of the necessary data tables from the Eurostat website;
- Sectoral aggregation according to a predefined grouping and temporal aggregation for a selected set of years;
- Aggregation of country-level data to the EU level or to another predefined regional grouping;
- SAM balancing and coefficient computation.

Specifically, the following tables are downloaded from the Eurostat database for use in the calibration exercise:

- `naio_10_cp15;`
- `naio_10_cp16;`
- `gov_10a_main;`
- `gov_10a_exp;`
- `lfsa_eisn2;`
- `earn_ses14_49.`[424]

The modelled sectors are based on the NACE codes provided in Table 32.

Table 32: Modelled sectors and their corresponding NACE Rev. 2 code

Modelled sector	NACE Rev. 2 section	NACE Rev. 2 Title
Agriculture	A	Agriculture, forestry and fishing
Construction	F	Construction
Finance and insurance	K	Financial and insurance activities
Industry	B, D, E	Mining and quarrying; Electricity, gas, steam and air conditioning supply; Water supply; sewerage, waste management and remediation activities
Land transport	H49	Land transport and transport via pipelines
Manufacturing (other)	C10-28, C30-33	Manufacturing other than Manufacture of motor vehicles, trailers and semi-trailers

[423] The R Project for Statistical Computing (n.d.). Official website.

[424] The following data was downloaded: Supply table at basic prices incl. transformation into purchasers' prices, Use table at purchasers' prices, Gorvement revenue, expenditure and main aggregates, Central government expenditure by function, Employment by occupation and economic activity, Mean annual earnings by sex, economic activity and occupation respectively. The tables were last accessed in June 2020.

Transport (other)	H50-53	Transportation and storage other than Land transport and transport via pipelines
Manufacturing of vehicles	C29	Manufacture of motor vehicles, trailers and semi-trailers
Other services	G, I, J, L-U	Wholesale and retail trade; repair of motor vehicles and motorcycles; Accommodation and food service activities; Information and communication; Real estate activities; Professional, scientific and technical activities; Administrative and support service activities; Public administration and defence; compulsory social security; Education; Human health and social work activities; Arts, entertainment and recreation; Other service activities; Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use; Activities of extraterritorial organisations and bodies

Source: Eurostat (2008)[425].

The inputs required for the model calibration have been constructed for an approximation of the EU economy. This is done by aggregating data on 24 EU countries (Croatia, Estonia and Sweden are excluded due to data constraints, and the UK is not considered). As the model exploits the structure of the data rather than the absolute numbers, this level of coverage is considered satisfactory.

The calibration year is taken to be 2016, which is deemed to be an acceptable compromise between recency and coverage. Notably, while a single year was used in this case to give prominence to the most recent period of acceptable coverage, the system in principle allows for the use of average values over several years.

The SAM, as directly constructed from the statistical data sources, is unsuitable for CGE modelling, since the presence of statistical discrepancies will violate accounting identities in the model. It is therefore necessary to distribute these discrepancies so that the SAM is balanced (row sums are equal to column sums). There exist different balancing procedures and for this modelling exercise the procedure recommended by Hosoe et al., Ch. 4, is used.[426] This procedure is readily implementable by optimisation software and helps ensure consistency in the balancing approach across datasets and calibration updates. More specifically, the procedure for balancing the SAM involves the following problem:

$$\min_{x_{kl}} \sum_k \sum_l \left(\frac{x_{kl} - x_{kl}^0}{x_{kl}^0} \right)^2$$

subject to

$$\sum_l x_{kl} = \sum_l x_{lk}, \forall k,$$

[425] Statistical Classification of Economic Activities in the European Community, Rev. 2 (2008) (NACE Rev. 2) Eurostat, Methodologies and Working papers.

[426] Hosoe, N., Gasawa, K. and Hashimoto, H. (2010). Textbook of Computable General Equilibrium Modelling: Programming and Simulations. Palgrave Macmillan.

where x_{kl} denotes the entry in the k-th row and l-th column of the adjusted matrix, while x_{kl}^{0} is the corresponding entry in the unadjusted SAM, taken as a parameter. The procedure is applied to the non-zero entries of the original SAM.

At the end of the calibration procedures, a balanced SAM and an additional set of model parameters are available to be provided as input for the main model code.

Baseline calibration

Policy Option 1 (baseline) is specifically calibrated for the purposes of this study. The baseline refers to keeping the status quo, where the term 'status quo' should be understood in a dynamic sense. It includes the key policy measures that have been approved for implementation over the simulation horizon, regardless of whether they are already in force or will become effective at a future date. This implies that the changes due to the Policy Option 1 reflect the changes induced by the known policy measures, depending on when they become effective and how their implementation propagates through the economy.

Since incorporating the various pieces of legislation into the baseline on a case-by-case basis requires the development of a large number of sub-scenarios, which is impractical, our baseline takes the existing policies on board in an integrated fashion. To calibrate the baseline for the simulations in this report, we adapted the baseline calibration of a version of the CGE model that uses a similar sectoral breakdown. The source model is calibrated on the basis of a comprehensive set of responses to a Delphi method exercise that covers the main sectors of the EU economy. The questions from the Delphi method that are used to calibrate the baseline cover the key channels of impact of extant policies, such as consumer demand, investment, labour supply and demand, production efficiency and innovation. The expert assessments from the Delphi method cover a medium-term horizon of five years, which is deemed sufficient to reach the full impact of the measures considered.

The advantage of this approach is that the baseline calibration of the source model incorporates sector-specific expert assessments and expectations. This ensures both consistency of the baselines between the different model versions and efficient use of available information by economic sectors. The time horizon of the Delphi method survey is sufficiently long to capture effects from delayed implementation of certain policy measures, as well as lags in the adaptation of the economy to the measures. Thus, the calibration of the baseline using the Delphi method responses allows the inclusion of the effects of both upcoming and recently implemented policy measures in an integrated manner via the sector-specific expert responses.

Quantification of the impacts in absolute values

The computation of the effects of the policy options under consideration in absolute terms requires the values of the respective variables in the baseline scenario. The country coverage of the CGE model, while sufficient for the purpose of approximating the structure of the EU-27 economy, precludes the direct use of the baseline from the model. Moreover, the baseline scenario from the CGE model does not take into account cyclical fluctuations in the variables induced by shocks such as the COVID-19 pandemic. Therefore, the values of the variables of interest in the baseline need to be obtained through additional computations.

The values throughout 2020 and 2030 in the baseline for total employment, nominal and real GDP were calculated in the following way, as presented in Table 33. We use the respective values for 2019 from Eurostat as a starting point (specifically datasets nama_10_gdp and lfsa_eisn2 for the latest available data). The nominal GDP values for 2020 and 2021 are computed using the real GDP growth and GDP deflator projections from the Spring 2020 Economic Forecast of the European

Commission.[427] The nominal GDP values for 2022-2030 are computed by applying the average annual nominal GDP growth for the period 2000-2019. The real GDP and total employment are calculated in the same way.

Table 33: Applied calculation of the values of economic indicators throughout 2019-2030 for the construction of the baseline in absolute values

Economic indicator	Value in 2019	Value in 2020-2021	Value in 2022-2030
Total employment Nominal and real GDP	Eurostat value for 2019	Projections calculated in the Spring 2020 Economic Forecast of the EC[427]	Value in the preceding year is multiplied by the average growth rate for the period 2000-2019
Employment per sector Nominal and real GDP per sector	Eurostat value for 2019 per sector	Calculated indicator for the whole economy multiplied by the sector share of 2019	Calculated indicator for the whole economy multiplied by the sector share of 2019

Source: Authors.

In the absence of projections for nominal value added, real value added and employment by sector, the respective baseline paths are constructed using the computed baseline values of nominal GDP, real GDP and employment and applying the assumption of constant structure over time, using the respective sector shares from 2019. This enables the use of the most recent data available to account for the sectoral structure of the economy. A limitation of this approach is that it cannot capture sectoral differences in cyclical or structural developments in the baseline. This limitation is partially mitigated by the fact that such structures are relatively slow changing.

The computation of the absolute deviations for the respective variables is carried out by applying the percentage deviations from baseline of real GDP, real value added and employment as obtained from the CGE model to the baseline paths described above and rescaling appropriately to ensure additivity of the sectoral results to the total. In the case of nominal variables, the absolute deviations are computed by applying the percentage deviations for the respective real variables.

Sensitivity analysis

There are various estimates on the sizes of increases in intermediate consumption available in the literature. We have assumed, that the intermediate consumption of insurance services increases by 10 % due to the introduction of the Policy Option 2 while other assumptions are the same. To test the sensitivity of it, we also assumed that the increase in intermediate consumption is 5 % and 15 %. These are commensurate with the estimates in EPRS on additional insurance costs associated with a stricter liability regime. [428] The respective policy options are refered to as Policy Option 2.1 and Policy Option 2.3.

[427] European Commission (2020) Spring 2020 Economic Forecast, available at https://ec.europa.eu/commission/presscorner/detail/en/ip_20_799.

[428] EPRS (2019). Cost of non-Europe in robotics and artificial intelligence: Liability, insurance and risk management, p.54.

Table 34: Assumptions for Policy Option 2

	Demand for vehicles	Demand for transportation services	Intermediate consumption of insurance services	Value of time savings
Policy option 2.1	0 %	30 %	5 %	10 %
Policy option 2	0 %	30 %	10 %	10 %
Policy option 2.3	0 %	30 %	15 %	10 %

Source : Authors.

The results are presented in Table 35 – 37. They suggest that there are negligible differences between these different assumptions.

Table 35: Impact of implementing Policy Option 2 on selected macroeconomic variables, in percentage deviations from baseline

Year	GDP			Private consumption			Employment			Capital stock		
	PO2.1	PO2	PO2.3	PO2.1	PO2	PO2.3	PO2.1	PO2	PO2.3	PO2.1	PO2	PO2.3
2020	0.06	0.06	0.06	0.07	0.07	0.07	0.13	0.13	0.13	0.00	0.00	0.00
2021	0.14	0.13	0.13	0.16	0.16	0.15	0.27	0.27	0.27	0.01	0.01	0.01
2022	0.22	0.22	0.22	0.26	0.26	0.26	0.44	0.43	0.43	0.02	0.02	0.02
2023	0.32	0.32	0.32	0.38	0.38	0.37	0.62	0.62	0.62	0.04	0.04	0.04
2024	0.44	0.44	0.43	0.51	0.51	0.50	0.82	0.82	0.82	0.07	0.07	0.07
2025	0.57	0.57	0.56	0.66	0.65	0.65	1.04	1.04	1.04	0.10	0.10	0.10
2026	0.73	0.73	0.73	0.83	0.82	0.82	1.32	1.32	1.32	0.15	0.15	0.15
2027	0.91	0.91	0.90	1.00	1.00	0.99	1.60	1.60	1.60	0.21	0.21	0.21
2028	1.10	1.09	1.09	1.19	1.19	1.18	1.89	1.89	1.89	0.29	0.29	0.29
2029	1.29	1.29	1.28	1.39	1.38	1.38	2.18	2.18	2.18	0.38	0.38	0.38
2030	1.49	1.49	1.48	1.59	1.58	1.58	2.48	2.48	2.48	0.49	0.49	0.49

Note: PO refers to Policy option.
Source : Authors.

Table 36: Impact of implementing Policy Option 2.1 on employment by sector, in percentage deviations from baseline

Sector	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.10	0.22	0.37	0.54	0.73	0.95	1.28	1.61	1.94	2.27	2.60
Construction	0.14	0.31	0.51	0.75	1.03	1.35	1.84	2.33	2.82	3.32	3.81
Finance and insurance	0.06	0.14	0.26	0.41	0.59	0.81	1.14	1.48	1.82	2.17	2.52
Industry	0.14	0.30	0.48	0.67	0.88	1.11	1.40	1.69	1.98	2.28	2.57
Land transport	-0.29	-0.28	0.01	0.53	1.25	2.15	3.43	4.69	5.93	7.16	8.38
Manufacturing (other)	0.20	0.40	0.60	0.80	1.00	1.21	1.42	1.64	1.86	2.09	2.33
Other services	0.12	0.25	0.40	0.56	0.73	0.92	1.15	1.39	1.64	1.89	2.14
Transport (other)	0.17	0.35	0.55	0.76	0.99	1.22	1.48	1.74	2.01	2.27	2.54
Manufacturing of vehicles	0.23	0.45	0.68	0.90	1.13	1.36	1.61	1.86	2.11	2.37	2.63

Source : Authors.

Table 37: Impact of implementing Policy Option 2.1 on real value added by sector, in percentage deviations from baseline

Sector	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.02	0.05	0.09	0.15	0.21	0.29	0.40	0.52	0.65	0.79	0.95
Construction	0.07	0.15	0.25	0.37	0.51	0.68	0.94	1.20	1.46	1.74	2.02
Finance and insurance	0.02	0.06	0.12	0.20	0.29	0.41	0.58	0.76	0.95	1.15	1.36
Industry	0.04	0.09	0.15	0.22	0.30	0.40	0.52	0.65	0.79	0.94	1.10
Land transport	-0.12	-0.11	0.01	0.23	0.54	0.92	1.46	1.99	2.52	3.05	3.58
Manufacturing (other)	0.11	0.22	0.33	0.45	0.57	0.70	0.83	0.98	1.13	1.30	1.47
Other services	0.07	0.14	0.23	0.32	0.43	0.55	0.70	0.86	1.03	1.21	1.39
Transport (other)	0.07	0.16	0.25	0.35	0.46	0.59	0.73	0.87	1.03	1.20	1.38
Manufacturing of vehicles	0.09	0.18	0.27	0.37	0.47	0.58	0.70	0.84	0.98	1.14	1.30

Source : Authors.

Table 38: Impact of implementing Policy Option 2.3 on employment by sector, in percentage deviations from baseline

Sector	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.10	0.22	0.37	0.53	0.73	0.95	1.28	1.61	1.93	2.26	2.59
Construction	0.14	0.31	0.51	0.75	1.02	1.35	1.84	2.33	2.82	3.31	3.80
Finance and insurance	0.06	0.16	0.28	0.44	0.63	0.85	1.19	1.54	1.89	2.24	2.61
Industry	0.14	0.30	0.48	0.67	0.88	1.10	1.39	1.69	1.98	2.27	2.57
Land transport	-0.29	-0.28	0.01	0.53	1.25	2.15	3.43	4.69	5.93	7.16	8.37
Manufacturing (other)	0.20	0.40	0.60	0.80	1.00	1.21	1.42	1.64	1.86	2.09	2.32
Other services	0.12	0.25	0.40	0.56	0.73	0.92	1.15	1.39	1.64	1.89	2.14
Transport (other)	0.17	0.35	0.55	0.76	0.98	1.22	1.48	1.74	2.00	2.27	2.54
Manufacturing of vehicles	0.22	0.44	0.66	0.87	1.09	1.32	1.56	1.81	2.06	2.31	2.57

Source : Authors.

Table 39: Impact of implementing Policy Option 2.3 on real value added by sector, in percentage deviations from baseline

Sector	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.02	0.05	0.09	0.15	0.21	0.29	0.40	0.52	0.65	0.79	0.94
Construction	0.07	0.15	0.25	0.37	0.51	0.68	0.93	1.19	1.46	1.74	2.02
Finance and insurance	0.03	0.07	0.13	0.21	0.31	0.43	0.60	0.78	0.98	1.18	1.40
Industry	0.04	0.09	0.15	0.22	0.30	0.40	0.51	0.64	0.78	0.93	1.09
Land transport	-0.12	-0.11	0.01	0.23	0.54	0.92	1.45	1.99	2.52	3.05	3.58
Manufacturing (other)	0.11	0.22	0.33	0.45	0.57	0.69	0.83	0.98	1.13	1.30	1.47
Other services	0.07	0.14	0.23	0.32	0.43	0.55	0.70	0.86	1.03	1.21	1.39
Transport (other)	0.07	0.16	0.25	0.35	0.46	0.59	0.72	0.87	1.03	1.20	1.37
Manufacturing of vehicles	0.08	0.17	0.26	0.36	0.46	0.56	0.69	0.82	0.96	1.11	1.28

Source : Authors.

Detailed results

The detailed results for Policy option 2 are presented in Table 40 - 42.

Table 40: Impact of implementing Policy Option 2 on selected macroeconomic variables, in percentage deviations from Policy Option 1

Sector	GDP	Private consumption	Employment	Capital stock
2020	0.06	0.07	0.13	0.00
2021	0.13	0.16	0.27	0.01
2022	0.22	0.26	0.43	0.02
2023	0.32	0.38	0.62	0.04
2024	0.44	0.51	0.82	0.07
2025	0.57	0.65	1.04	0.10
2026	0.73	0.82	1.32	0.15
2027	0.91	1.00	1.60	0.21
2028	1.09	1.19	1.89	0.29
2029	1.29	1.38	2.18	0.38
2030	1.49	1.58	2.48	0.49

Source : Authors.

Table 41: Impact of implementing Policy Option 2 on employment by sector, in percentage deviations from Policy Option 1

Sector	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.10	0.22	0.37	0.54	0.73	0.95	1.28	1.61	1.94	2.27	2.59
Construction	0.14	0.31	0.51	0.75	1.03	1.35	1.84	2.33	2.82	3.31	3.81
Finance and insurance	0.06	0.15	0.27	0.42	0.61	0.83	1.17	1.51	1.85	2.21	2.56
Industry	0.14	0.30	0.48	0.67	0.88	1.11	1.40	1.69	1.98	2.27	2.57
Land transport	-0.29	-0.28	0.01	0.53	1.25	2.15	3.43	4.69	5.93	7.16	8.37
Manufacturing (other)	0.20	0.40	0.60	0.80	1.00	1.21	1.42	1.64	1.86	2.09	2.33
Other services	0.12	0.25	0.40	0.56	0.73	0.92	1.15	1.39	1.64	1.89	2.14
Transport (other)	0.17	0.35	0.55	0.76	0.98	1.22	1.48	1.74	2.01	2.27	2.54
Manufacturing of vehicles	0.22	0.45	0.67	0.89	1.11	1.34	1.58	1.83	2.09	2.34	2.60

Source : Authors.

Table 42: Impact of implementing Policy Option 2 on real value added by sector, in percentage deviations from Policy Option 1

Sector	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.02	0.05	0.09	0.15	0.21	0.29	0.40	0.52	0.65	0.79	0.94
Construction	0.07	0.15	0.25	0.37	0.51	0.68	0.93	1.19	1.46	1.74	2.02
Finance and insurance	0.03	0.07	0.13	0.20	0.30	0.42	0.59	0.77	0.96	1.17	1.38
Industry	0.04	0.09	0.15	0.22	0.30	0.40	0.52	0.64	0.79	0.94	1.10
Land transport	-0.12	-0.11	0.01	0.23	0.54	0.92	1.46	1.99	2.52	3.05	3.58
Manufacturing (other)	0.11	0.22	0.33	0.45	0.57	0.69	0.83	0.98	1.13	1.30	1.47
Other services	0.07	0.14	0.23	0.32	0.43	0.55	0.70	0.86	1.03	1.21	1.39

Transport (other)	0.07	0.16	0.25	0.35	0.46	0.59	0.72	0.87	1.03	1.20	1.37
Manufacturing of vehicles	0.09	0.17	0.26	0.36	0.46	0.57	0.69	0.83	0.97	1.12	1.29

Source: Authors.

The detailed results of absolute impacts for Policy Option 2 are presented in Table 43 - 45.

Table 15: Impact of implementing Policy Option 2 on selected macroeconomic variables (absolute deviations from Policy Option 1 values)

Sector	GDP	Employment
2020	7 868	243
2021	18 430	537
2022	30 730	864
2023	45 286	1 233
2024	62 276	1 644
2025	81 906	2 101
2026	107 483	2 685
2027	135 144	3 285
2028	164 934	3 900
2029	196 901	4 532
2030	231 097	5 181

Note: GDP figures reported at constant 2019 prices in millions of euros. Employment figures reported in thousand persons. Source: Authors.

Table 16: Impact of implementing Policy Option 2 on employment by sector (deviations from Policy Option 1 values, thousand persons)

Sector	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	9	20	34	50	68	89	120	152	184	217	250
Construction	5	10	17	25	34	45	61	78	95	113	130
Finance and insurance	3	7	13	20	29	40	56	73	90	108	126
Industry	5	10	16	22	29	37	47	57	67	77	88
Land transport	- 17	- 16	0	31	74	127	204	281	357	434	511
Manufacturing (other)	54	111	166	221	277	334	396	460	526	594	665
Other services	171	367	577	806	1 059	1 337	1 690	2 054	2 430	2 818	3 218
Transport (other)	8	17	26	36	46	58	70	83	97	110	124
Manufacturing of vehicles	6	11	17	23	28	34	41	48	54	62	69

Source: Authors.

Table 17: Impact of implementing Policy Option 2 on real value added by sector (deviations from Policy Option 1, constant 2019 prices, millions of euros)

Sector	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	39	103	190	303	447	625	880	1 171	1 497	1 858	2 254
Construction	366	889	1 537	2 345	3 339	4 544	6 374	8 313	10 364	12 532	14 821
Finance and insurance	134	382	735	1 213	1 828	2 595	3 748	5 008	6 376	7 853	9 440
Industry	137	328	555	831	1 160	1 548	2 058	2 629	3 260	3 953	4 707

Land transport	- 291	- 291	37	663	1 570	2 735	4 422	6 163	7 953	9 794	11 686
Manufacturing (other)	1 754	3 814	5 943	8 234	10 702	13 371	16 399	19 688	23 246	27 082	31 202
Other services	4 494	10 352	17 032	24 840	33 885	44 297	57 795	72 445	88 274	105 310	123 583
Transport (other)	215	495	810	1 172	1 582	2 044	2 592	3 189	3 836	4 535	5 286
Manufacturing of vehicles	189	414	651	911	1 196	1 512	1 882	2 291	2 738	3 226	3 754

Source: Authors.

The detailed results for Policy option 3 are presented in Table 46 - 48.

Table 18: Impact of implementing Policy Option 3 on selected macroeconomic variables, percentage deviations from Policy Option 1

Sector	GDP	Private consumption	Employment	Capital stock
2020	0.08	0.09	0.16	0.00
2021	0.17	0.19	0.35	0.01
2022	0.28	0.32	0.55	0.03
2023	0.41	0.46	0.77	0.05
2024	0.54	0.62	1.01	0.09
2025	0.70	0.79	1.27	0.14
2026	0.89	0.99	1.60	0.20
2027	1.10	1.20	1.92	0.28
2028	1.31	1.42	2.26	0.37
2029	1.54	1.65	2.60	0.48
2030	1.77	1.89	2.94	0.60

Source: Authors.

Table 19: Impact of implementing Policy Option 3 on employment by sector, in percentage deviations from Policy Option 1

Sector	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.14	0.31	0.50	0.71	0.95	1.21	1.59	1.97	2.35	2.73	3.11
Construction	0.21	0.45	0.71	1.01	1.35	1.74	2.29	2.84	3.40	3.95	4.52
Finance and insurance	0.10	0.23	0.40	0.59	0.82	1.09	1.47	1.86	2.26	2.66	3.07
Industry	0.18	0.39	0.60	0.84	1.09	1.36	1.70	2.03	2.38	2.72	3.07
Land transport	-0.19	-0.08	0.30	0.92	1.75	2.74	4.12	5.47	6.81	8.13	9.44
Manufacturing (other)	0.24	0.48	0.71	0.95	1.19	1.44	1.69	1.96	2.22	2.50	2.78
Other services	0.15	0.32	0.50	0.69	0.90	1.12	1.40	1.68	1.96	2.25	2.55
Transport (other)	0.21	0.43	0.67	0.92	1.18	1.46	1.76	2.07	2.38	2.69	3.01
Manufacturing of vehicles	0.26	0.53	0.79	1.05	1.32	1.59	1.88	2.17	2.47	2.77	3.08

Source: Authors.

Table 20: Impact of implementing Policy Option 3 on real value added by sector, in percentage deviations from Policy Option 1

Sector	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	0.03	0.07	0.13	0.20	0.28	0.37	0.50	0.64	0.80	0.97	1.15
Construction	0.10	0.21	0.35	0.50	0.68	0.88	1.17	1.46	1.77	2.08	2.41
Finance and insurance	0.04	0.11	0.19	0.29	0.41	0.55	0.75	0.96	1.18	1.42	1.67
Industry	0.05	0.12	0.20	0.28	0.38	0.50	0.64	0.79	0.96	1.13	1.32
Land transport	-0.08	-0.03	0.14	0.40	0.75	1.18	1.75	2.33	2.90	3.48	4.06
Manufacturing (other)	0.13	0.26	0.40	0.54	0.68	0.83	1.00	1.18	1.36	1.56	1.77
Other services	0.08	0.18	0.29	0.40	0.53	0.68	0.85	1.04	1.24	1.45	1.67
Transport (other)	0.09	0.19	0.30	0.43	0.56	0.71	0.87	1.05	1.24	1.43	1.64
Manufacturing of vehicles	0.10	0.21	0.32	0.43	0.56	0.69	0.83	0.99	1.16	1.35	1.54

Source: Authors.

The detailed results of absolute impacts for Policy Option 3 are presented in Table 49 - 51.

Table 21: Impact of implementing Policy Option 2 on selected macroeconomic variables (deviations from baseline scenario values)

Sector	GDP	Employment
2020	10 305	315
2021	23 796	687
2022	39 180	1 092
2023	57 094	1 540
2024	77 723	2 034
2025	101 286	2 577
2026	131 141	3 251
2027	163 408	3 944
2028	198 145	4 657
2029	235 416	5 391
2030	275 287	6 147

Note: GDP figures reported at constant 2019 prices in millions of euros. Employment figures reported in thousand persons. Source: Authors.

Table 50: Impact of implementing Policy Option 3 on employment by sector (deviations from Policy Option 1 values, thousand persons)

Sector	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	13	28	46	66	88	113	149	186	223	261	300
Construction	7	15	23	33	45	58	76	96	115	135	155
Finance and insurance	5	11	19	28	39	52	71	90	110	130	151
Industry	6	13	20	28	36	45	57	68	80	93	105
Land transport	- 11	- 5	18	54	103	163	245	328	411	494	577
Manufacturing (other)	64	131	196	262	329	398	472	549	628	710	794
Other services	216	461	719	1 000	1 305	1 638	2 048	2 473	2 912	3 366	3 836
Transport (other)	9	20	31	43	56	69	84	99	115	131	147

Manufacturing of vehicles	7	13	20	27	34	41	48	56	65	73	82

Source: Authors.

Table 51: Impact of implementing Policy Option 3 on real value added by sector (deviations from Policy Option 1 values, constant 2019 prices, EUR mln.)

Sector	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Agriculture	57	146	260	407	588	808	1 112	1 456	1 840	2 265	2 730
Construction	558	1 300	2 163	3 197	4 425	5 875	7 966	10 178	12 517	14 988	17 599
Finance and insurance	231	598	1 080	1 700	2 471	3 409	4 750	6 213	7 800	9 512	11 352
Industry	180	425	714	1 058	1 465	1 938	2 544	3 219	3 964	4 779	5 666
Land transport	- 197	- 76	380	1 143	2 191	3 500	5 330	7 215	9 156	11 153	13 208
Manufacturing (other)	2 103	4 576	7 135	9 892	12 866	16 080	19 700	23 627	27 871	32 441	37 343
Other services	5 792	13 211	21 540	31 149	42 156	54 699	70 529	87 699	106 244	126 199	147 601
Transport (other)	268	611	995	1 432	1 925	2 477	3 122	3 825	4 586	5 407	6 289
Manufacturing of vehicles	227	498	783	1 097	1 442	1 822	2 262	2 747	3 277	3 853	4 476

Source: Authors.

Artificial intelligence is a key enabler for autonomous vehicles that potentially provides European citizens with economic, environmental and social benefits. However, at the absence of a relevant European framework around liability, data protection, cybersecurity and protection of users creates costs of non-Europe in terms of economic output and employment. It also generates other costs, in particular around data protection and privacy, which can influence fundamental rights for European citizens.

This study is annexed to the Cost of non-Europe report entitled 'Artificial intelligence in road transport', published by EPRS.

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