WORKING PAPER

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Digital Age

Autonomous transport devices: Implications of game-changing technologies in the services sector in Europe

Game-changing technologies: Transforming production and employment in Europe

Author: Rebecca Ioppolo, Advait Deshpande, Stijn Hoorens, and Salil Gunashekar (RAND Europe)
Research Managers: Ricardo Rodríguez Contreras, Eleonora Peruffo

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This working paper on advanced robotics is one in a series of five presenting the findings of a study that examined the socioeconomic implications and applicability of game-changing technologies to the services sector in Europe. The other working papers in the series refer to the following technologies: blockchain, wearables, advanced robotics and virtual reality and augmented reality.

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European Foundation for the Improvement of Living and Working Conditions

Telephone: (+353 1) 204 31 00

Email: information@eurofound.europa.eu

Web: www.eurofound.europa.eu

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1. Introduction

Recent technological developments, underpinned by the growth of the internet, have implications – both positive and negative – for a range of sectors and stakeholders. However, while the potential implications are wide-ranging, they are not necessarily predictable, linear or deterministic. Developing a better understanding of the implications of the complex issues associated with technologies is therefore of critical importance for governments, policymakers, businesses, academia and citizens.

Incremental progress in technology could be expected to result in various economic and societal changes. However, technologies termed ‘disruptive’ or ‘game-changing’ are those transformative technological innovations with the potential to significantly reshape the way society does things, whether these be business and organisational practices or more generally associated with everyday life. Some technologies – such as artificial intelligence (AI) or improvements in battery storage – may develop as the result of incremental progress in a field and used in new, game-changing ways. Others – such as autonomous vehicles or blockchain – may provide opportunities for a fundamental reshaping of existing business and market practices and social organisation. While the impacts on markets and national economies are the most prominent examples, the changes go beyond the economic sphere. Significant shifts in business and consumption patterns may have wider socioeconomic implications as a result of the changing economic and labour patterns caused by the technology – such as the loss or displacement of some jobs, the creation of others, or the demand for new skills.

While the role of new technologies in reshaping the manufacturing sector has received noteworthy attention (Eurofound, 2018), there are also key implications for the services sector. As noted in the previous section, as described in the following section, the services sector is taking on an increasingly important role in the EU economy. Understanding the implications of game-changing technologies on the services sector will be essential for realising their benefits to society and the economy in Europe, as well as for minimising and preparing for the likely threats presented by the wider adoption of these technologies. The ‘game-changing’ context here refers to the potential of such technologies to critically influence or significantly change outcomes related to existing markets, market actors, established value chains, prevailing legislative, regulatory paradigms, economic thinking, and socio-political order, amongst others. [1]

This working paper – one in a series of five working papers – presents the findings of a study that examined the socioeconomic implications and applicability of autonomous transport devices to the services sector in Europe. This chapter presents the key objectives of the study, articulates the research approach adopted by the study team to meet the study objectives, and outlines the structure of the working paper.

1.1 Objectives of the study

The overarching objective of the study is to assess the potential applicability of the following five emerging and potentially ‘game-changing’ technology areas to the European services sector and the wider socioeconomic implications (Figure 1):

- **advanced robotics**;
- **autonomous transport devices**;

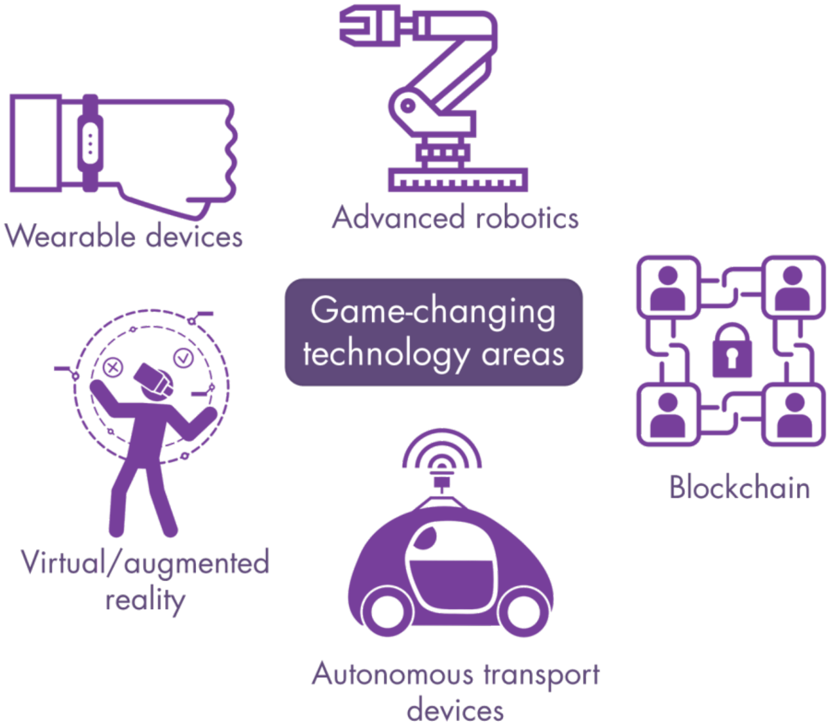
1 Since there is no canonical definition of ‘game-changing’ technologies, as described here, game-changing technologies correlate to the concept of disruptive innovation which is often used to describe innovation that results in the creation of new markets and in some cases displaces existing market mechanisms including businesses, value networks, products and services. See Bower and Christensen (1995).

- **blockchain**;
- **virtual and augmented reality (VR/AR)**;
- **wearable devices.**

The study has the following four specific objectives:

- **Objective 1:** to assess the scope of applicability of the five technology areas to the services sector (and relevant subindustries where possible) in Europe;
- **Objective 2:** to examine the potential implications of these technology areas on productivity and output and on work organisation;
- **Objective 3:** to analyse the potential implications of the technology areas on employment and on skill levels;
- **Objective 4:** to assess the potential implications on working conditions (including implications for and interaction with individual and collective employment relations systems).

Figure 1: The five 'game-changing' technology areas covered by this study



Source: RAND Europe.

The five technology areas identified in the study are, to varying degrees, still in their infancy, in terms of (potential) widespread commercial applications and wider implications, yet they may have significant implications for the future of the services sector in Europe. The technology areas are listed in Table 1, along with brief high-level descriptions. The descriptions are not intended to be prescriptive or comprehensive; they serve as a general guide to the manner in which each technology area has been interpreted in the context of this study. In chapter 2, the working paper goes into more depth about the descriptions and characteristics of the specific technology area that is the focus of this working paper, namely, autonomous transport devices.

Table 1: Brief high-level descriptions of the five technology areas

Technology area	Brief description
Advanced robotics	Advanced robotics refers to the improvements in machine dexterity and the machine's ability to interact with its environment, as a result of which robots can be engaged in tasks that go beyond repetitive, discrete motions (Grant, 2012).
Autonomous transport devices	Autonomous transport devices are a field of technology that will allow vehicles to sense their environment and navigate without human input (Rohr et al, 2016).
Blockchain	Blockchain technology is one of the most well-known uses of distributed ledger[2] technologies (DLT), in which the 'ledger' comprises 'blocks' of transactions, and it is the technology that underlies a cryptocurrency such as Bitcoin (Deshpande et al, 2017).
Virtual/augmented reality (VR/AR)	VR is a computer-generated scenario that simulates a real-world experience (Steuer, 1992). AR combines real-world experience with computer-generated content (Azuma, 1997).
Wearable devices	'Wearables' are technology devices comprised of an ensemble of electronics, software and sensors, which are designed to be worn on the body (Billinghurst and Starner, 1999).

Sources: Azuma, 1997; Billinghurst and Starner, 1999; Deshpande et al, 2017; Grant, 2012; Rohr et al, 2012

The five technology areas cover a wide spectrum of potential uses and outcomes associated with the underlying technologies. These vary from more artefact-based use cases related to autonomous transport devices, wearable devices, and virtual/augmented reality, to blockchain, which could be considered an underlying (back-end) technology that provides the basis for the application of the technology in relation to specific uses. Furthermore, there are overlaps and commonalities between the technology areas themselves depending on the manner in which they are interpreted and characterised, for example, advanced robotics and autonomous transport devices (in the context of drones) or virtual/augmented reality and wearable devices (in the context of the way in which 'devices' are interpreted).

Recognising that the technology areas are in different stages of development and adoption, the study team adopted the following timelines (with 2018 as the baseline year) as a reference when discussing the trends and implications of the technologies:

- 'Near or immediate term' refers to the developments likely to take place within the next 1–3 years
- 'Medium term' refers to developments likely to take place within the next 4–7 years
- 'Long term' refers to developments likely to take place in 8 years and beyond

These timelines were informed by an initial scan of the available evidence and in consultation with expert advisors (see the annexes for more details).

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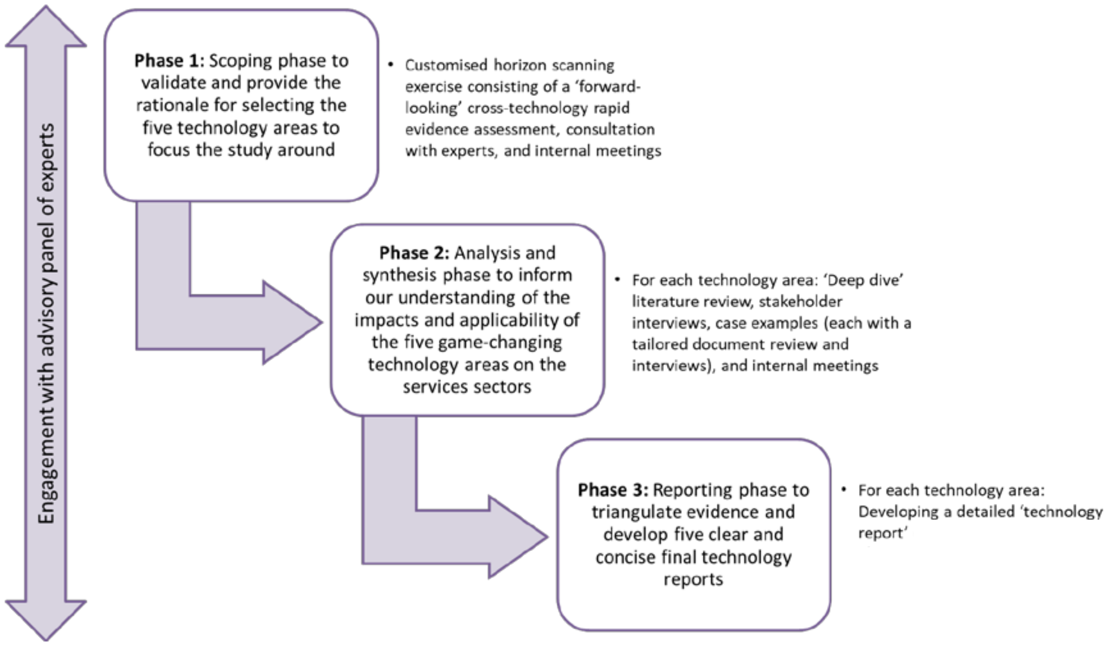
[2] A distributed ledger is a digital ledger (a computer file used for recording and tracking transactions) that stores cryptographically authenticated information on a network of machines, whereby changes to the ledger are reflected simultaneously for all holders of the ledger.

1.2 Research approach

The study was conducted from November 2017 to November 2018, and organised in three discrete but overlapping phases, as illustrated in Figure 2. Each of these phases is discussed in turn in the sections below.

The study team adopted a mixed-methods approach to design the study, relying on a set of carefully selected methodologies within each phase that were tailored to the study requirements. Throughout the study, the study team regularly consulted members of its advisory panel of experts (for example, to identify additional articles to review, to validate search terms, to suggest potential case examples and interviewee names, and to review the study team's analyses). Additional context on these phases is provided in the annex, which also discusses the the limitations of the findings presented in the working paper.

Figure 2: Overview of the main study phases



Source: RAND Europe.

1.2.1 Phase 1: Scoping phase

The aim of this initial phase was to validate and provide the rationale for selecting the five technology areas to focus the study around, namely:

- advanced robotics;
- autonomous transport devices;
- blockchain;
- virtual and augmented reality;
- wearable devices.

Following discussions with Eurofound during the kick-off meeting, this 'validation exercise' was primarily aimed at assessing the extent to which these five technology areas remained relevant to the goals of this study. In addition, the validation exercise was aimed at ensuring that other emerging technology areas and existing technologies with transversal impact on the five technology areas were also considered. To implement the work in this phase of the study, the study team conducted a quick scan of the available evidence in the literature, as well as three scoping consultations with stakeholders that included cross-sector technology and socioeconomic experts.

1.2.2 Phase 2: Analysis and synthesis phase

The study team aimed to collate and assimilate evidence related to the scope and relevance of the application of the technology areas to services sectors in Europe, their wider socioeconomic implications (for example, for employment, skills and working conditions, and work organisation and productivity), and specific case examples to provide illustrative snapshots of their applicability and implications. To this purpose, the study team used a bottom-up, evidence-based approach.

For each of the technology areas, the authors carried out a comprehensive document review, web searches and conducted at least three key informant interviews with different stakeholders.

1.2.3 Phase 3: Reporting phase

Finally, the study team triangulated the findings with respect to each technology area in a way to address the main objectives of the study.

1.2.4 Conceptual framework

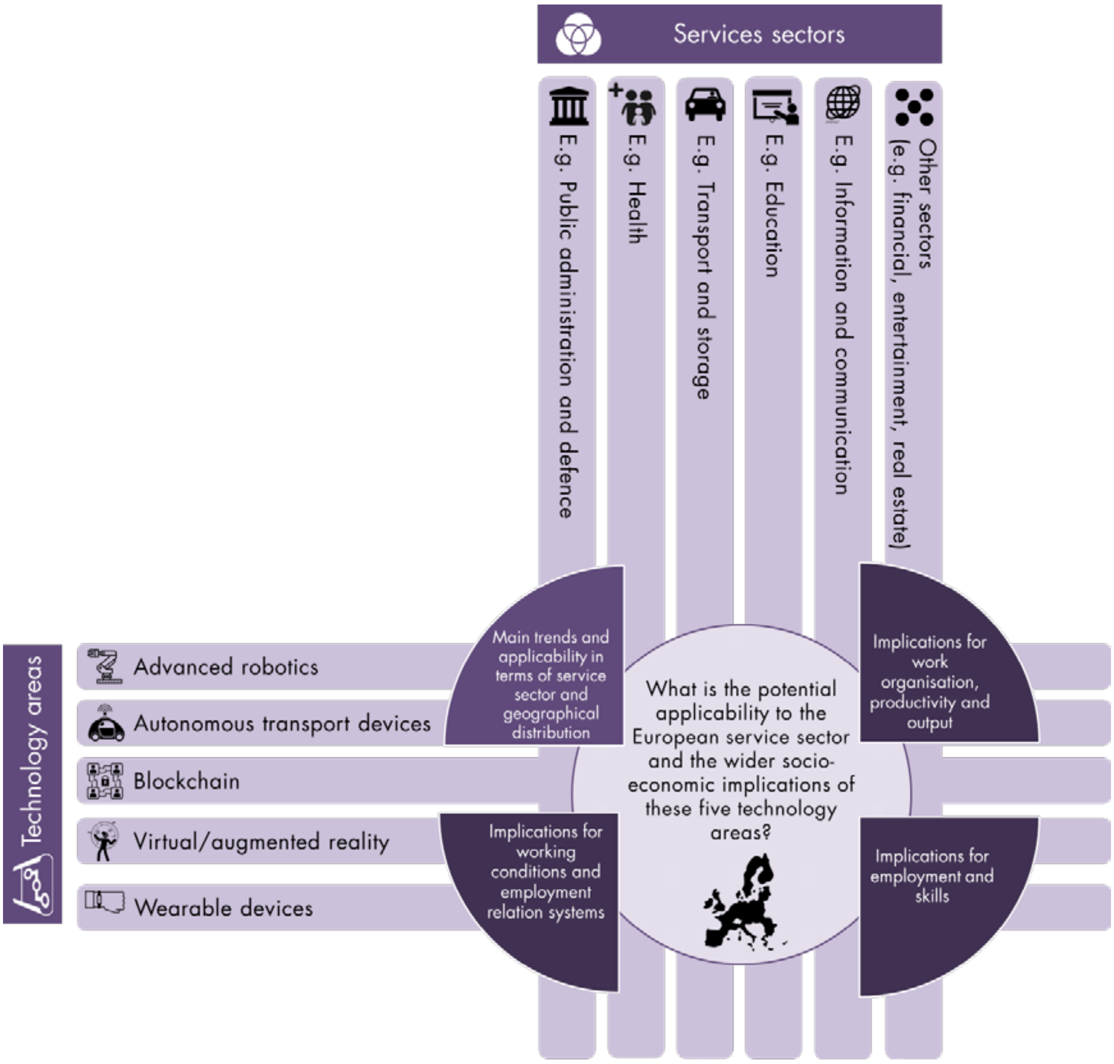
The conceptual framework for the study (Figure 3) provided an analytical instrument to assess the applicability and potential socioeconomic implications of the five selected technological areas to European services.

First, for each technology area, the study team acquired a general understanding of the important *trends* that are taking place; this enabled the team to portray a picture of the current state of play of each technology, as well as its general direction of travel in the near to medium term. In parallel, the study team also analysed some of the notable driving forces (that is, enablers) for and barriers to the development and adoption of the technology areas.

Second, the study team examined the (potential) *implications* of these technologies on several areas broadly linked to *employment* (for example, the changing nature of employment and tasks) and *working conditions* (for example, contractual arrangements and health and safety), skills (for example, levels and types), *work organisation* (for example, task allocation, work schedules) and *productivity*.

The study team cross-analysed these factors in the context of different services sectors (and subindustries where possible) and geographical areas in Europe. Furthermore, where data are available, relevant snapshots on how the state of play varies in other parts of the world (for example, in the USA, China and Japan) have been provided. The study is largely qualitative in nature, but, where feasible, relevant quantitative data sources have been used to demonstrate the (potential) implications of the five technology areas.

Figure 3: Conceptual framework for the study



Source: RAND Europe

1.3 Structure of the working paper

The rest of this working paper is structured as follows:

- **Chapter 2** provides an in-depth discussion about the development and adoption of autonomous transport devices across the services sector. It highlights the main trends that characterise the development of autonomous transport devices, as well as the associated driving forces and barriers. Some examples of specific applications in the services sector are also discussed.
- **Chapter 3** presents a detailed analysis of the socioeconomic implications of autonomous transport devices on several key areas of the services sector, such as employment, skills and working conditions, and work organisation and productivity.
- **Chapter 4** brings together the key findings of the study against the primary objectives and the main elements of the conceptual framework.
- **Chapter 5** includes three 'real-world' case examples that demonstrate the applicability and implications of autonomous transport devices in the services sector in Europe.
- The **annex** contains additional details about the research approach, including the search strategy for literature reviews and the interview protocol, and discusses limitations of the analysis presented in this working paper.

2. Development and adoption of autonomous transport devices in European services

This section provides an overview of autonomous transport devices[3] as a technology area, in conjunction with the overall trends shaping the landscape, important drivers and barriers for the adoption of autonomous transport devices, and potential applications of the technology. In the following discussion, the study team has prioritised published literature with an emphasis on peer-reviewed articles, and has drawn additional material from interviews with external experts. Where available, interviewee opinion has been corroborated with published material.

2.1 Overview of autonomous transport devices

This section covers the broad range of autonomous transport devices, ranging from cars; to drones; to public transport devices, such as buses and trains; to sea-faring ships.

Autonomous transport devices are a field of technology that would allow vehicles to sense their environment and navigate without human input (Rohr et al, 2016). This study investigates a broad definition of autonomous transport devices, including, but not limited to, autonomous (road) vehicles, such as (passenger) cars and (freight) trucks; drones or unmanned aerial vehicles; automated guided vehicles (AGVs) used in controlled settings, such as ports or industrial settings; delivery bots; and any other technology-enabled device that travels between points without human intervention. The technology underpinning autonomous transport devices can be used for other purposes as well; however, this study focuses on the use of these devices for transport, in the transport sector specifically, but also in transport functions across the services sectors.

Before discussing these devices, it is important to understand different levels of automation, since these levels will have an important influence on the possible adoption and timelines of these devices.

2.1.1 Road vehicles and different levels of automation

There are different degrees of automation for road vehicles (for example, cars, trucks or pods[4]). Some technologists and researchers refer to four levels of automation (Anderson et al, 2016), while others refer to five levels of automation (Beede et al, 2017; Frisoni et al, 2016; Henry et al, 2017). This means that some reports refer to 'level 4/5' automation when referring to fully autonomous transport devices. Ultimately, both frameworks express the same core principle: there are degrees of automation, some of which are already supported in individual components of driving in today's vehicles; full automation of transport would be through the expansion of automation technology into more components of the driving process. The study team uses a similar classification in the following discussion and, unless otherwise stated, fully autonomous transport devices refer to level 4 or level 5 of automation. In Table 2, this information is combined with the forecasts by Beede et al (2016) and Frisoni

[3] The terminology regarding autonomous transport devices is varied in the available evidence and covers a number of different terms including driverless cars, pods, automated cars, and autonomous cars. As a result, throughout this working paper, the term autonomous transport devices is used as an all-encompassing term to cover the broad spectrum of devices including cars, trucks, drones, buses, ships and aeroplanes. Since the evidence is heavily focussed on cars and other road vehicles such as pods, trucks or buses, where applicable and supported by the underlying literature, the term autonomous road vehicles has been used to distinguish such devices from other devices such as drones, aeroplanes, or ships.

[4] Pods (also referred to as driverless or self-driving pods in relation to autonomous transport devices) are compact road vehicles often employed in public transport for short-duration transit between specific, pre-identified locations. The study team could not identify a canonical definition in the evidence reviewed and therefore refers to these vehicles as identified in the available literature. See Burgess (2018); Transport Systems Catapult (n.d.); and Vincent (2018).

et al (2016), which provide varying projections on the availability of autonomous road vehicles, and adopts a similar framework for the different levels of automation as that identified in Henry et al (2017). Frisoni et al (2016) do not offer any observations on the availability of devices with level 0 and level 1 of automation.

Table 2: Levels of automation for road vehicles and estimates of their availability

	Level 0	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
	No Automation	**Driver assistance**	**Partial automation**	**Conditional automation**	**High automation**	**Full automation**
Description of the level of automation	'A human driver is in control of all driving functions' (Henry et al, 2017).	'An **advanced driver assistance system** (ADAS) can assist the human driver in either steering or braking/accelerating but never at the same time' (Henry et al, 2017).	'ADAS can control both steering and braking/accelerating simultaneously but requires the human driver to continue to pay full attention at all times and assume control outside of those two functions' (Henry et al, 2017).	'All driving functions are performed by an **automated driving system** (ADS) in some circumstances, but the human driver must be able to respond when requested by the ADS. The driver assumes control in environments unmanageable by the ADS' (Henry et al, 2017).	'All driving functions are performed by an ADS in some circumstances, during which the driver does not need to pay attention. The driver assumes control in environments unmanageable by the ADS' (Henry et al, 2017).	'All driving functions are performed by an ADS in all circumstances. Human occupants are now passengers as opposed to drivers' (Henry et al, 2017).
Estimated timeline for availability	• Most cars in 2017 (Beede et al, 2017)	• In 2017 cars costing USD 20,000 (equivalent to €17,699 in 2017 average exchange rate) (Beede et al, 2017)	• In luxury cars in 2017 (Beede et al, 2017) • Between 2021 and 2036 (Frisoni et al, 2016)	• Perhaps in 2022 (Beede et al, 2017) • Between 2021 and 2036 (Frisoni et al, 2016)		• Perhaps in 2027 or later (Beede et al, 2017) • No sooner than 2036 (Frisoni et al, 2016)

Source: Henry et al, 2017; Beede et al, 2017; and Frisoni et al, 2016.

Full automation would require a number of different technologies working in tandem to fully understand the environment around the vehicles. Cameras using radar and lidar[5] would observe changes 360 degrees around the vehicle (Anderson et al, 2016; Frey and Osborne, 2013). Sensors embedded in infrastructure, such as road signs, traffic lights and travel lane markings, could help vehicles understand how to change their travel patterns when approaching intersections or other hazards (Henry et al, 2017). This kind of technology is referred to as vehicle-to-infrastructure, or v2i, technology. Vehicles would also need to be aware of changes in speed and position of other vehicles in their immediate surroundings. ‘Vehicle-to-vehicle’, or ‘v2v’, technology would allow autonomous transport devices to communicate with each other to avoid collisions and other hazards (Henry et al, 2017). The information from the sensors, when combined with the analytics of the algorithms, would enable the technology to distinguish between such scenarios as a pedestrian walking on a path parallel to the road and a child chasing after a ball bouncing into the road.[6]

Researchers differ on exactly when level 4/5 automation would be available in road transport vehicles (meaning cars and trucks). The earliest identified estimate of full automation refers to the year 2025 (Henderson and Spencer, 2016; Veryard et al, 2017), while others estimate that full automation would be available through mass production in the 2030s (Claus et al, 2017; Frisoni et al, 2016). Lee (2016) predicts that level 4/5 autonomous transport devices would not appear until the 2040s at the earliest because it could take many years to equip vehicles that can safely and autonomously travel in such varied environments. Chan (2017) makes the distinction between functional autonomous vehicles that could be available for affluent drivers or companies with shipping fleets, which could occur between 2020 and 2030, and wider availability of more affordable vehicles, in 2040 and 2060.

Despite long time horizons for the projections of level 4/5 vehicle automation, interviewees[7] agreed that the hype around autonomous transport is extremely high and out of proportion with the technology’s readiness. One interviewed expert from the European public sector said that it may not even be worth asking people what they think about autonomous vehicles, ‘because the technology is so far away [from reality] at the moment that their thoughts about it wouldn’t really be based in anything’.

An interviewed third sector expert reported that level 3 automation may not be attractive in the market. While level 3 autonomy has more capabilities than the lower levels, it may prove to be too difficult for users to safely supervise. The increased autonomy may make the human occupant feel more like a passenger than a driver and thereby fail to be alert enough to take control of the vehicle when necessary.

2.1.2 Drones

Drones, also known as unmanned aerial vehicles (UAVs), are another kind of autonomous transport device that is expected to be game-changing to the services sectors (Heutger and Kückelhaus, 2014). Similar to the situation with road vehicles, there are different levels of automation for drones, starting with remotely piloted vehicles (level 0) to fully autonomous vehicles (level 10) (Protti and Barzan, 2007). Although commercial use of drones is growing and forms the main basis of the discussion on drones in this report, the US military has deployed drones quite extensively in the last 10 years (LexInnova, 2016b). Most of these drones have been remotely piloted vehicles (level 0). In contrast, commercial drones are an emergent phenomenon, and the rules and regulation of their use are still under development in most of the countries. For example, there is some evidence that drones are being tested to

[5] Lidar is a remote sensing technology that measures the distance between objects.

[6] There are currently significant challenges with autonomous transport technology. While piloting of various kinds of autonomous transport devices has been ongoing for several years, the first fatality involving an autonomous vehicle occurred in March 2018, when an autonomous vehicle struck a pedestrian (Economist, 2018).

[7] Based on separate interviews with a European public sector expert and a third sector expert

meet various needs of the services sectors. In Rwanda, drones are launched from catapults to air-drop blood for transfusions to remote healthcare facilities that are poorly serviced by road infrastructure (Holtz, 2017). In the United Kingdom, the e-commerce company Amazon is conducting trials of drone delivery of small packages to local customers in rural areas where there is less risk of the drones causing any damage (Hern, 2015).

According to leaders at DHL, a German courier company operating internationally, drones will be game-changing because of their ability to reach poorly accessible areas in remote parts of the world without adequate road or rail infrastructure (Heutger and Kückelhaus, 2014). Drones can navigate through the sky either without human control or with a human remotely controlling the device (de Miguel Molina and Santamarina Campos, 2017). Some drone types can deliver and dispatch parcels, which is a relevant feature for the logistics sector. An estimated 42% of logistics services expect to use drones to operate parts of their business in the future (Marsh Ltd., 2015). Drones can be used in many other services sectors, as is described in more detail in chapter 2.4.

2.1.3 Other autonomous transport devices

Next to road transport vehicles (such as cars, trucks and pods) and drones also other kinds of existing transport devices, such as waterborne or rail transport, could become autonomous[8]. Far most of the development for autonomous ships has been in small devices that perform a few services in close proximity to a larger, traditional, human-operated ship (House of Lords, 2017). Some trains already operate without a human driver, such as those in London and Copenhagen. In the case of both ships and trains, the vehicles do not look starkly different from their traditional counterparts.

Autonomous transport technology could spur the creation of new kinds of devices altogether, such as delivery robots - like those being developed by Starship Technologies.[9] These robots are being used to deliver small quantities of food and other parcels by travelling on pedestrian paths.

2.2 Trends shaping the autonomous transport devices landscape

Box 1. Key trends shaping the autonomous transport devices landscape

- Automation in various degrees already exists in a variety of transport vehicles (such as cruise control and driver assistance), but fully autonomous vehicles are not expected to be deployed until the mid-2030s, although predictions vary.
- There is a wide array of transport devices that could use automation: road vehicles, such as cars and trucks; trains; delivery bots; airborne vehicles, such as planes and drones; and others (including waterborne devices).

In the next subsection, the regional and international trends in relation to autonomous transport devices are considered. This analysis is informed by patent-related activity for two specific types of autonomous transport devices - driverless cars and drones. Given that the autonomous transport devices technology area is still developing and the technologies have yet to see wider market adoption, the numbers of patent applications are used as signals of market interest and activity.[10] The following discussion is based on secondary analysis of patent data identified as part of the evidence review and is not based on primary analysis of

[8] Unmanned surface and sub-surface vessels have been extensively used in the defence sector, for mine-sweeping and disposal and possibly identifying enemy craft.

[9] Further information about Starship Technologies can be found at https://www.starship.xyz/.

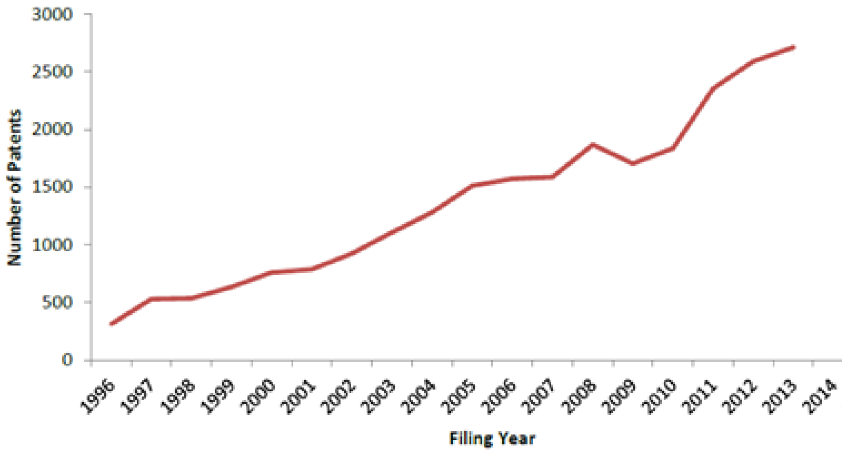
[10] This discussion draws on the patent landscape reports available via the World Intellectual Property Organization’s (WIPO) website. See for further discussion (including possible limitations of this approach).

the underlying patent data. This discussion is followed by specific trends related to road vehicles, drones and other autonomous transport devices.

2.2.1 Interest and activity in autonomous transport devices

The number of patents[11] for driverless car technology[12] has been increasing, notably since 2011.

Figure 4: Number of global patents for driverless car technology, 1996-2013



Source: Based on LexInnova (2016a). Original sourced with permission from LexInnova Inc.

A similar trend is seen when the patent activity[13] for drones[14] is considered. There is a sharp rise in patent filing from 2011 onwards. These data are for all types of drone-related patents, ranging from manually controlled drones to highly autonomous drones that may enable service delivery in the 'last mile'.[15]

[11] The key areas covered by the patents on driverless cars include control mechanisms (such as anti-collision systems), communication systems (such as radar/lidar systems), computer software powering the driverless cars, and various kinds of ancillary equipment (such as safety equipment, signalling systems) (LexInnova, 2016a).

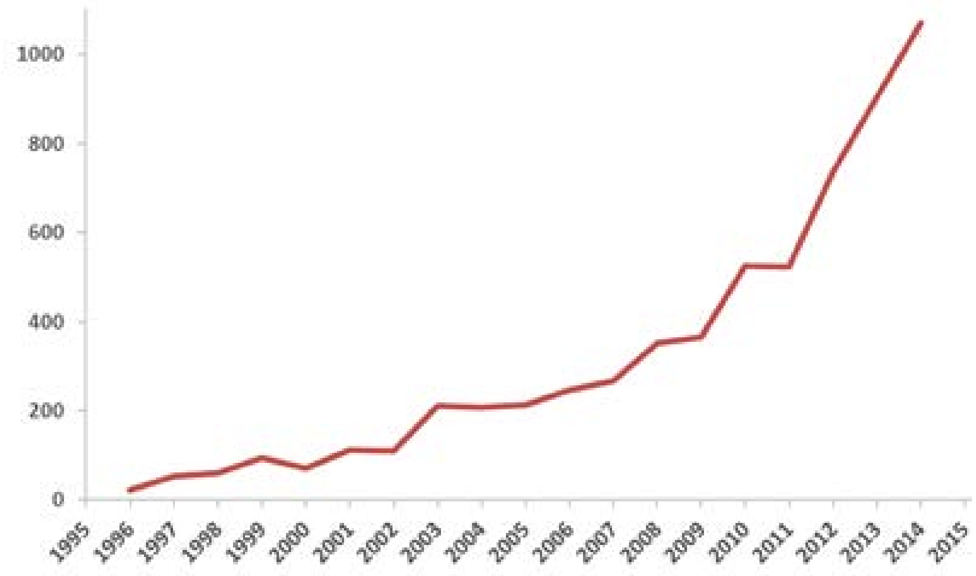
[12] This analysis is based on a LexInnova (2016a) report, in which driverless cars are identified as vehicles that can sense, navigate and communicate with their external surroundings without any human intervention.

[13] Key areas covered by the patents on drones include navigational control, aerial equipment, drone structures and equipment modifications (including battery life) (LexInnova, 2016b).

[14] This analysis is based on a LexInnova (2016b) report, which identifies drones as a broad range of unmanned aerial vehicles that are used for military, commercial and recreational (such as toys) purposes.

[15] The 'last mile' in transport planning and supply chain management refers to the movement of people and goods from a transport hub to the 'last mile to a final destination' in the home or a business premise. See Goodman (2005) and Zax (2011).

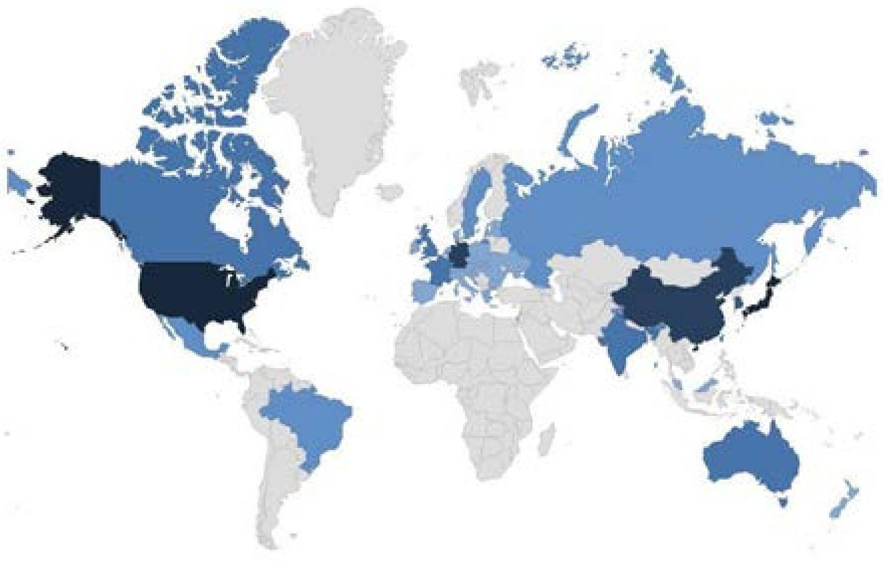
Figure 5: Number of global patents for drone technology, 1995-2014



Source: Based on LexInnova (2016b). Original sourced with permission from LexInnova Inc.

If the geographical coverage of the patents is considered, Japan emerges as the country with the highest number of patents on driverless car technology. The USA, China, Germany and South Korea also show high levels of patent activity. This is partly a reflection of Japan, the USA, Germany and South Korea being the home of car makers Toyota (Japan); Ford, General Motors (both the USA); BMW, Volkswagen (both Germany); and Kia (South Korea). The USA is also the home of Alphabet, Google's parent company, which has the driverless car Waymo currently undergoing testing. The map in Figure 7 depicts this activity based on the 2013 data, with deeper shades of blue colour indicating more numbers of patents filed.

Figure 6: Geographical distribution of global patents for driverless car technology, 2013

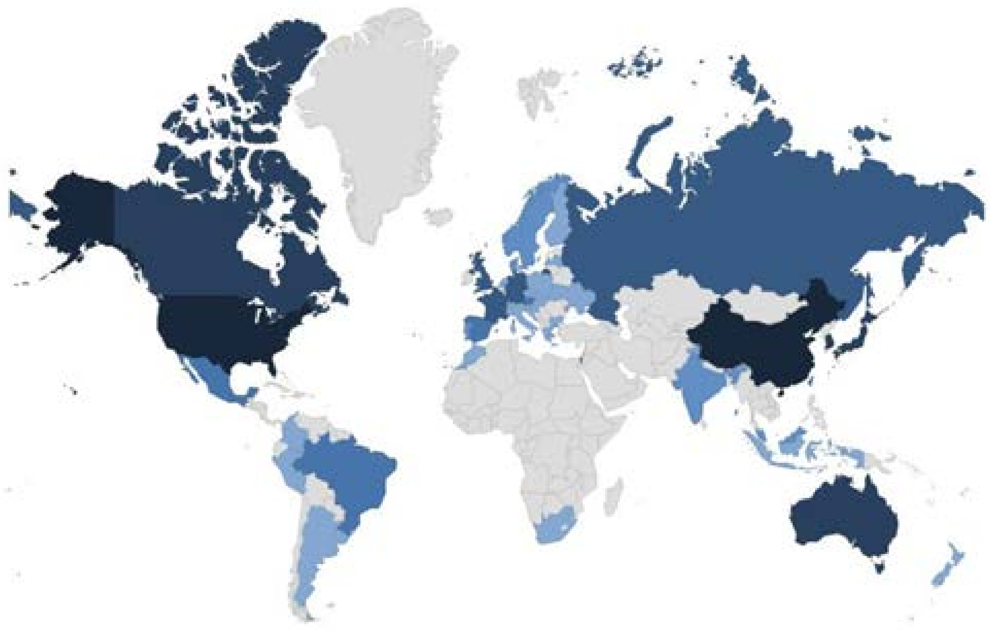


Source: LexInnova, 2016a. Reproduced with permission from LexInnova Inc. Darker shades of blue colour indicate more number of patents filed.

Within the EU, Germany appears to be a leader in driverless car-related patents, followed by the UK and France which are comparable to Canada, China, India and Australia in terms of number of patents filed.

If the geographical distribution of patent activity on drones and drone-related technology is considered, China appears to be a world leader, followed by the USA. Although Japan, South Korea and Canada are also among the top five countries, there is a large gap in the patent activity between China and the USA, on the one hand, and Japan, South Korea and Canada, on the other. Within Europe, France (where Airbus is headquartered), the UK and Germany appear to be the leaders in terms of drone technology-related patents, while Spain, Norway and Austria also indicate high levels of drone technology-related patent activity. The map in Figure 8 depicts this activity based on the 2014 data, with deeper shades of blue colour indicating more number of patents filed.

Figure 7: Geographical distribution of global patents for drone technology, 2014



Source: LexInnova, 2016b. Reproduced with permission from LexInnova Inc. Darker shades of blue colour indicate more number of patents filed.

The above analysis shows that investment in autonomous transport devices has been increasing across the world, with the USA, China, Japan, South Korea and parts of the EU being the forerunners in terms of patent activity in the area. Within the EU, Germany, the UK and France are the leaders if activity related to patents are considered.

2.2.2 Planned changes to transport infrastructure in some countries

In general, the USA, China, and Singapore are leaders in the development of autonomous transport devices (De Miguel Molina and Santamarina Campos 2017; Henry et al, 2017). In 2016, the US federal government updated its existing policies around level 4/5 vehicles with the aim of providing an appropriate amount of regulation to both ensure safety and foster innovation (Singh et al, 2017). The policy also dedicated almost USD 4 (€ 3.53) billion over 10 years to develop autonomous vehicles. This government investment would contribute to the autonomous vehicles market in the USA, which by one estimate could be worth as much as USD 42 (€ 37.12) billion by 2025 (Singh et al, 2017). US federal and state governments have also begun to legalise autonomous vehicles for testing and use (Singh et al, 2017).

Box 2. Adoption trends for autonomous transport devices (2018-2022)

Given the relatively early stage of adoption of autonomous transport devices, definitive sectoral data on their deployment are not yet readily available. However, a recent report on the future of jobs by the World Economic Forum (WEF) provides some indicative data on potential adoption of autonomous transport devices from 2018 to 2022. This is based on a survey of companies across the world done over a nine month period (November 2017 to July 2018) with a focus on large multinational companies and other companies which contribute significant revenue and employee size in a local context. The key findings of the report are briefly outlined below to enrich the broader context sketched by this working paper. The report used Occupational Information Network (O*NET) classifications of the sectors[16], which is retained in the next paragraph to ensure accurate representation of the findings.

Overall, 40% of the participating companies identified autonomous transport devices (referred to as autonomous transport in the survey and the report) as a technology they were likely to adopt between 2018 and 2022. When specific services sectors are considered, companies in the automotive, aerospace, supply chain and transport (74%), aviation, travel and tourism (58%), and information and communication technologies (44%) sectors reported a higher likelihood of adopting autonomous transport devices in comparison to the financial services and investors (16%), and global health and healthcare (20%) sectors. Of the companies surveyed, the share of companies identifying Eastern Europe and Western Europe as a market for the adoption of the technology from 2018 to 2022 was identical at 50%. Among the European countries for which national-level data are provided in the report, the share of companies identifying France, Germany, Switzerland, and the UK as potential markets for adopting the technology from 2018 to 2022 were 52%, 52%, 54%, and 49% respectively.

The report concludes that to achieve positive outcomes vis-a-vis jobs in the wake of rapid technological change would require an emphasis on lifelong learning, reskilling, and upgrading of individuals' skills across a number of occupational categories. In particular, technology skills as well as non-cognitive soft skills would become more important. Governments would need to upgrade education policies targeted at increasing education and skills levels for all ages; leverage public and private sector partnerships to stimulate job creation; and revise existing tax revenue approaches and social welfare programmes in line with the new economic and business models of work. Industries would need to support upskilling of current workforce to become more technologically skilled; contribute to building a sufficiently skilled talent pool; and adapt to the increasing influence of the platform economy. The report argues that much as the workers would need to take ownership of their own lifelong learning, the governments and industries would need to support transition and reskilling at work in equal measure.

Source: Mariani, 1999; National Research Council, 2009; World Economic Forum, 2018

Asian countries are also promoting the development of autonomous vehicles. There are three test sites operating in China for autonomous vehicles, and the Chinese Ministry of Industry and Information Technology expects to have long-distance corridors by 2020 and urban

[16] Occupational Information Network (O*NET) is a database of occupational definitions of work in the USA available online at https://www.onetonline.org/. It was developed under the sponsorship of the US Department of Labor/Employment and Training Administration (USDOL/ETA) in the 1990s. As of 2018, it is maintained by the US National Center for O*NET Development. See Mariani (1999) and National Research Council (2009) for more details.

infrastructure for autonomous vehicles by 2025 (Singh et al, 2017). Singapore has created a partnership that will manage the development and testing of autonomous vehicles on public roads. Another Singapore pilot programme offering on-demand software for autonomous mobility services is expected to be in operation by 2022 (Singh et al, 2017). Japan is developing road infrastructure that would underlie autonomous driving on public roads, which is meant to help the government achieve its goal of nearly zero traffic accidents by 2030 (Singh et al, 2017).

One interviewed European public sector expert sees the development of autonomous vehicles in other countries as being characterised by their specific environments. For example, according to the same interviewee, the USA 'lacks a comprehensive transport system in most areas with the exception of cities,' so a completely autonomous transport system would need to be able to cope with long distances in rural areas, across state boundaries. Passengers in Japan reportedly already use public transport for most needs, but the same interviewee suggested that autonomous vehicles could play an important role in supporting elderly populations in rural communities.

With regard to Europe, the European Commission has identified connected and automated mobility based on autonomous transport devices as a key part of its 'Vision Zero' aimed at ensuring no road fatalities on European roads by 2050 (DG MOVE, 2011). However, according to one interviewed third sector expert, vehicle manufacturers in Europe tend to be the main actors in the development of autonomous vehicles. The same expert suggested that since a significant portion of the transport sector (which is made up of small and medium-sized enterprises (SMEs)) may not have the capital to invest in autonomous driving technology, it is unclear how the industry's landscape may change. The same interviewee was also of the opinion that the developers of autonomous transport devices seem to be more motivated to test the limits of autonomous transport technology than to create practical devices for everyday use on European infrastructure. Anecdotally, an expert from the third sector mentioned that EU Member States seem to be interested in autonomous vehicles but are not willing to make necessary infrastructure investments that could help make an autonomous driving network a reality. In recognition of such challenges, the European Commission (2018) has identified the need for significant investments across the EU to build transport infrastructure capable of supporting automated mobility and ensuring adequate social acceptance for the changes. This has included a budget allocation of €443 million to help digitise road transport infrastructure across the EU as part of the Connecting Europe facility and €300 million as part of the Horizon 2020 programme to support research on autonomous road vehicles (European Commission, 2018).

2.3 Driving forces and barriers

Box 3. Summary of potential drivers and barriers

- The factors driving the development of autonomous vehicles include the potential gains for safety, spatial reallocation, fuel efficiency, and commuter productivity.
- Some barriers to the development of autonomous vehicles include risks around cybersecurity, privacy, environmental degradation, the potential for job losses, regulatory constraints and costs of infrastructural changes.

2.3.1 Potential drivers for the development and adoption of autonomous transport devices

Improved safety

The main driving force for the development of autonomous transport devices is the expected positive impact on safety (Anderson et al, 2016; Beede et al, 2017; Chan, 2017, Claus, 2017; Frisoni et al, 2016; Henry et al, 2017; Heutger and Kücklehaus, 2014; House of Lords, 2017).

Many estimates suggest that about 90% of roadway accidents occur because of an error in human judgement, distraction or drowsiness (Chan, 2017; Claus et al, 2017; Veryard et al, 2017). Because autonomous road vehicles would have a wide array of sensors and cameras, level 4/5 autonomous road vehicles would be better equipped to make safer adaptations to driving patterns more quickly than a human driver could, which might help limit injuries and fatalities among drivers, passengers, pedestrians and others in or near public spaces (Claus et al, 2017). The prospect of increased safety for drivers of road vehicles is likely to be an important driving force for a number of services sectors such as transport, aviation, tourism, healthcare, and emergency services which routinely employ professional drivers. In particular, in the long-term, professional drivers are likely to be expected to manage vehicles of varying levels of autonomy leading up to the adoption of level 4/5 autonomous road vehicles. In such scenarios, the potential for improved safety on road transport through autonomous road vehicles could become a key consideration.

Better land allocation

With the introduction of autonomous transport devices, the land area currently dedicated to wide driving lanes and parking spaces could be reallocated to other purposes (Anderson et al, 2016; Cohen, 2016; Henderson and Spencer, 2016). Autonomous vehicles could drive themselves to a remote parking location or deliver other passengers, rather than being left unused in valuable real estate near a passenger's destination (Cohen, 2016; Henderson and Spencer, 2016). As of 2014, nearly 72% of European population lived in urban areas with this expected to rise to 75% by 2020.[17] In such a scenario, the prospect of reallocating such oft-unused land in urban areas could become a key driver for the deployment of autonomous transport devices. For example, this land could be repurposed to build new retail spaces or small green spaces or for other services sectors such as hospitality or education for which availability of land is important. In the long-term, experts[18] believe that autonomous transport devices would not need to be owned by individuals or families and would not need to spend the majority of the day in a parking garage; they could pick up and drop off passengers or parcels at all hours of the day.

Fuel and energy efficiency benefits

Fuel efficiency benefits could be derived from autonomous transport devices' ability to travel closer together than human drivers can safely travel or brake and to change gears at precisely the right moment. Additionally, energy consumption by autonomous transport devices operating as battery electric vehicles or hybrid electric vehicles in mass transit modes is expected to result in greater fuel and energy efficiency in the long-term subject to significant government investment in the necessary infrastructure (US Energy Information Administration, 2018). For carbon fossil-based fuel devices, the ability to drive reliably close together without hazardous outcomes could result in improved fuel efficiency, since this would help reduce air resistance (or drag) on each individual vehicle (Anderson et al, 2016; Veryard et al, 2017; Voege et al, 2017). Freight vehicles could travel closer together in a formation known as platooning, which is considered to be the primary use for autonomous transport in the early stages of development (also interviews[19]; DG MOVE, 2011). Moreover, autonomous transport devices could be able to pick up and drop off passengers without needing to find a parking space, which could reduce congestion and fuel usage, since urban

[17] See the discussion in https://ec.europa.eu/regional_policy/sources/conferences/urban2014/doc/issues_paper_annex.pdf (accessed 23 January 2019)

[18] Based on separate interviews with a transport sector expert and an European public sector expert.

[19] Separate interviews with a third sector expert and a trade union representative

drivers currently spend a lot of time on the roads simply looking for a place to park. For example, in Germany, drivers spend 41 hours per year on average looking for parking, and UK drivers spend 90.5 hours, or four days, per year on average looking for parking (Sawer, 2017; Simmons, 2017). Despite the potential for autonomous transport devices to lower fuel and energy usage in the long-term, experts highlight that cheaper travel could increase congestion and waste time and fuel consumed (Wadud et al, 2016). In the case of electric or hybrid electric transport devices, their potential for achieving energy efficiency would depend on the available recharging infrastructure and costs of recharging the batteries (US Energy Information Administration, 2018).

Increased productivity or free time

Another positive implication of autonomous transport devices could be the possibility for increased productivity or time for individuals' personal pursuits (Chan, 2017; Claus et al, 2017; Frisoni et al, 2016). All the time professional drivers or other workers spend driving during working hours, commuting to and from their jobs, could be spent on other tasks. From an employer's perspective, companies and industries that rely on fleet vehicles and long supply chains could also see productivity and efficiency gains. Aided by autonomous transport technology, more miles could be travelled by fewer vehicles since the vehicles would not need to rely on drivers who need to take breaks to eat and rest. One estimate suggests that freight fleets could be reduced by as much as 50% if vehicles can run at all hours (Veryard et al, 2017).

2.3.2 Potential barriers to the development and adoption of autonomous transport devices

Low consumer trust

An interviewed third sector expert suggests that one barrier to the deployment of autonomous transport devices may be low levels of consumer trust. Travelling inside a vehicle at high speed with no control over the vehicle at all requires a certain kind of trust in machinery over human reaction that (with the exception of aeroplanes) has not previously been required with human-driven forms of transport.[20] The first fatality involving an autonomous vehicle, which occurred in the USA in March 2018, generated a lot of media attention (Economist, 2018). While it may be understandable for the first fatality stemming from a new technology to cause a lot of media attention, the coverage may have caused decision makers and members of the public to proceed more cautiously with the development of autonomous vehicles.

Autonomous transport devices could represent a paradigm shift in the way people travel across cities or even countries. The same interviewee suggested that the sophistication of the cameras, sensors, and the data processing capabilities that make autonomous transport possible may be difficult for non-experts to understand. At this stage of the technology's deployment, however, whether the lack of technical understanding would hinder consumers' acceptance is not known. As Table 2 suggests, the introduction and deployment of fully autonomous transport devices is likely to take place over a long duration (between 2027 to 2036), so it is also likely that consumers' understanding of the technology and trust in the technology would evolve as autonomous vehicles see widespread deployment.

[20] Although airplanes with autopilot capability exist, the autopilot functionality is about automated motion and is not autonomous (that is, the plane cannot fly itself); a human pilot is required on the aircraft. Additionally, air traffic is a very highly controlled environment and differs significantly from road traffic. See Goodwin (2018), Stewart (2017), and Moskvitch (2016).

Perceived risk of privacy invasion

While the possibility of improved safety in transport is widely recognised as a potential impact of autonomous transport devices, some authors argue that these vehicles could create new risks to safety via malicious actors hacking into a vehicle's controls (Henry et al, 2017; Rohr et al, 2016; Scoitsch, 2016). There would likely be a vast amount of data collected by vehicles about the locations passengers travel between. Additionally, the vehicles could capture images of pedestrians as they travel. Although such image capture (and the privacy risk) is not unique to autonomous vehicles, the use of cameras, sensors and scanners is essential to effective functioning of such vehicles. This could heighten the perceived loss of privacy in the event of potential ubiquity of autonomous vehicles. Both of these data types could compromise people's privacy if the information were accessed by unauthorised persons (Henry et al, 2017).[21] People may not feel comfortable about the use of autonomous transport devices (either by themselves or by others) because of the fear of physical or cyber harm. In such a scenario, autonomous transport may struggle to find demand and may not see extensive adoption.

Increased urban congestion

Some city planners may be concerned that autonomous transport could degrade the quality of urban transport networks by increasing congestion and pollution from increased use of private transport over public transport. Although the challenge of pollution could be alleviated by the use of electric or hybrid electric-powered autonomous transport, the challenges of increased travel time and congestion are likely (Wadud et al, 2016). Some researchers expect vehicle miles travelled to increase if autonomous transport devices make it easier for anyone and everyone to travel in one vehicle from their origin directly to their final destination (Anderson et al, 2016; Claus et al, 2017; Rohr et al, 2016). According to an interview with a third sector expert, the convenience provided by autonomous vehicles could mean that people would choose to travel by autonomous vehicles rather than by walking, cycling or taking public transport. One estimate suggests that distances travelled by road vehicles could increase by 12% by 2050 (Marsh Ltd., 2015). This increase in travellers could put a significant strain on the existing road transport infrastructure, and the efficiencies gained by having fewer vehicles driving around looking for a parking space may be countered by slower transport times. With more road vehicles engaged and stalled at various traffic points, they may continue to release greenhouse gasses and other pollutants as long as they continue to use combustion engines running on fossil fuels (Rohr et al, 2016). These pollutants can be particularly harmful to people living in or around areas of high traffic.

Potential for job losses

A frequently cited barrier to the wider roll-out of autonomous transport devices is their potential to put many professional drivers out of a job (Beede et al, 2017; Frey and Osborne, 2013; Heard et al, 2018; Kalra, 2017; Pedigo and Bendix, 2017; Pilli-Sihvola et al, 2016; Veryard et al, 2017; Wisskerchen et al, 2017). The socioeconomic costs resulting from these jobs losses may be deemed less favourable than the status quo by a number of stakeholders, including governments and trade unions. Therefore, trade unions may seek to delay the adoption of autonomous vehicles as they aim to keep human workers in their jobs as professional drivers. These concerns are discussed in more detail in the following section of this working paper, where arguments from researchers on the net impact of that autonomous

[21] This also has potential implications for the General Data Protection Regulation, in how it covers autonomous vehicle users' data and whether users would be made aware of what data are collected and how it would be used.

transport devices could have on jobs are explored: while some jobs may be lost, others are expected to be created.

Limitations of current infrastructure and regulatory approach

There are some other practical barriers to the rapid deployment of autonomous transport devices, including infrastructural and regulatory constraints. It seems likely that there could be a long transition period where conventional vehicles and autonomous transport devices share the same roadways. Owners of the conventional vehicles currently in operation may not likely abandon their vehicles until they reach the end of their useful life, which may slow deployment of autonomous vehicles (Lee, 2016). Moreover, there may be a relatively slow adoption of autonomous transport devices in their early stages because the costs may be prohibitive for many buyers (Chan, 2017; Lee, 2016). An interviewed third sector expert noted that during this transition time, safety may actually worsen because people may trust the vehicles' autonomy too much and higher-than-expected collisions could occur (see also Chan, 2017). Even if the physical and programmed aspects of autonomous transport devices are sufficiently managed, local, regional and national laws and regulation (for example, related to insurance costs, liability in the event of an accident, ownership of damages) may need to be updated to allow for vehicles to operate on public roads and in air spaces without having a human in control (De Miguel Molina and Santamarina Campos, 2017). As an example, the same interviewee mentioned that Finland's transport code has laid the groundwork for allowing automation and robotics on transport infrastructure with data sharing requirements. Ertico (2017) makes similar observations regarding Finland's transport system. As per the interviewed third sector expert, other European countries are looking at implementing similar legislation, but further legal changes would be needed in a number of countries to legally allow vehicles not operated by a human to travel in public spaces.

2.4 Potential applications in the services sector

Box 4. Summary of potential applications

- The transport and logistics sectors are likely to be the most impacted by the deployment of autonomous transport devices.
- Other impacted sectors are likely to include insurance, real estate, hospitality, emergency services, construction, public services and the arts.

2.4.1 Transport and logistics sectors

The services sector that may be the most directly impacted by the rise of autonomous transport devices is the transport sector, for both passenger and freight transport. Any business that employs drivers or manages a fleet or large supply chain could be impacted by autonomous transport devices. This includes professional drivers in dedicated transport systems for passengers or goods, such as drivers of trucks, taxis, busses and trains (Beede et al, 2017; Frisoni et al, 2016; Schoitsch, 2016). There are workers in other sectors for whom driving is a significant part of their job, such as ambulance drivers and sales persons (Beede et al, 2017; Schoitsch, 2016). In European road freight, 35% to 45% of operating costs are associated with human labour (Verhard et al, 2017). This suggests that employers who can use autonomous transport devices may do so to reduce these costs. Other jobs in a variety of sectors involve driving as a slightly less significant but still regular part of the job, including real estate agents, equipment installers and repairers, and home health care aides (Beede et al, 2017). Autonomous transport devices could eliminate the driving component of their current job and thereby change the skills required for the role. This could have knock-on effects for other jobs, such as eliminating the need for instructors teaching driving skills (EY Global, 2018).

The logistics sector and the postal service stand to be heavily impacted by autonomous transport devices, since such a large part of their service is the transport of goods between different destinations (De Miguel Molina and Santamarina Campos, 2017; Frey and Osborne, 2013; Henderson and Spencer, 2016; Heutger and Kükelhaus, 2014). For logistics and the postal service, particularly for smaller-volume and shorter-distance trips, drones are expected to play an important role in automating the 'first mile'[22] and 'last mile' of trips, which can be the most costly part of a delivery (Heutger and Kückelhaus, 2014). Other sectors that rely significantly on supply chains, such as food distribution, could also be impacted by autonomous transport devices (Heard et al, 2018).

2.4.2 Vehicle insurance, real estate, hospitality and emergency services sectors

Autonomous transport devices could change the way transport networks (such as roads and traffic management systems) operate, which could have consequences on how a number of other, non-transport-related sectors operate. For example, vehicle insurance makes up a large part of the insurance sector, especially because some countries mandate that drivers have vehicle insurance (Claus et al, 2017). However, vehicle insurance is predicated on the high probability that problems will occur due to human error. Autonomous transport devices are expected to be involved in fewer incidents than conventional vehicles, and the liability of fully autonomous devices may not rest with human owners. Therefore, forecasts by the Bank of England project that autonomous transport devices may shrink the UK motor insurance market by 21% between 2017 and 2040 (Claus et al, 2017). However, when accidents involving autonomous transport devices do occur, it may take more time and effort to resolve claims because the liability may be more difficult to ascertain, so there may still be a role for the insurance sector in the autonomous transport devices market (Claus et al, 2017). A study conducted for the European Parliament concluded that, while the legislative framework for civil liability and insurance could be amended to support business and consumer confidence in autonomous vehicles, there is no conclusive quantitative evidence that changing the framework would yield value for money at this time (Evas, 2018).

The real estate sector also stands to be transformed by autonomous transport devices (Cohen, 2016; Henderson and Spencer, 2016; Henry et al, 2017). If autonomous vehicles are not owned by individuals and are instead owned by leasing companies and shared among passengers, the vehicles could operate all day. This means that a significant portion of the current real estate dedicated to parking garages and on-street parking could be repurposed (Cohen, 2016; Henry et al, 2017). Some of this repurposed land could be used to create designated pick-up locations for autonomous vehicle passengers, which might look a bit like the bus stops of today, according to an interview with a third sector expert. Moreover, businesses in any sectors that own land dedicated to parked vehicles could benefit from monetising parking area for other purposes (Henderson and Spencer, 2016).

Other sectors, such as hospitality, healthcare and advertising, could be indirectly impacted by the changes brought about by autonomous transport devices. For example, if long-distance freight trucking does not require human drivers, businesses that support drivers, such as hotels and restaurants near roadways, may see a declining consumer base and could even be forced to close (Heard et al, 2018). Emergency responders and health care professionals may not need to spend as much time on tending to roadway accidents if there are fewer vehicle collisions, according to an interviewed transport sector expert. The increased use of drones for visual communications could allow new entrepreneurial entrants to the marketing and advertising industries and could change the way that hotels and realtors advertise properties (De Miguel Molina and Santamarina Campos, 2017).

[22] In contrast to the 'last mile', the 'first mile' in transportation planning and supply chain management refers to the first mile in the journey or movement of people and goods from their departure point in the home or their business premises to the transportation hub. See Goodman (2005) and Zax (2011).

Drones have different characteristics to road vehicles: they are airborne and are limited in the weight they can carry. These characteristics mean that drones could have a different set of applications in the services sectors. In the construction industry, drones equipped with cameras can be used to examine details of sites and structures from a variety of angles, heights and distances (De Miguel Molina and Santamarina Campos, 2017; Heutger and Kückelhaus, 2014; Howard et al, 2017). These images can be used to determine how a site could support a new construction project, how an ongoing construction project is progressing, or how a structure has been damaged after a natural disaster. Similarly, drones equipped with cameras and sensors can be used to support public services, in the examination of areas that may not be safe (for example, policing areas with high violence), or areas that are not easily accessible to human drivers or human pilots (for example, environmentally harzardous areas or remote areas targeted for the delivery of goods as part of development aid) (Hern, 2015; Heutger and Kückelhaus, 2014; Schoitsch, 2016). Drones equipped with cameras can also be used for photography and film arts to add aerial images of outdoor areas (Heutger and Kückelhaus, 2014; De Miguel Molina and Santamarina Campos, 2017).

Box 5. Drone use in service delivery (Amazon Prime Air) and in agriculture (NileWorks)

Drones are currently being tested to provide a number of services. In the UK, Amazon is piloting the use of drones for Prime Air, which aims to deliver small packages to consumers within 30 minutes of the placing of the order. Amazon believes that using drones instead of trucks will improve safety and efficiency of not just its operations but the transport system overall (Amazon, 2018).

Drones are also being used for a variety of other purposes beyond delivery. In Japan, a company called NileWorks is using drones to apply fertiliser to crops in areas where farmland lies on steep inclines (Loughran, 2018). Like many professional drivers, farmers in Japan tend to be older than the average worker, and drones are helping farmers continue working in older age by enabling them to focus on less physically demanding jobs.

In summary, the deployment of autonomous transport devices has implications for a wide array of services sectors. Table 3 displays the NACE services sectors and the ways in which the development of autonomous transport devices have implications for each sector. These are intended to be high-level descriptions of findings from the literature surveyed and insights from the interviewees. The following description is intended to be illustrative rather than exhaustive and thus does not cover some sectors where thedeployments are at a very early stage.

Table 3: Services sectors for which the deployment of autonomous transport devices have implications

NACE Sector	**Potential implications of autonomous transport devices to the services sector**
G: Wholesale and retail trade; repair of motor vehicles and motorcycles	• Retail and leasing inventory among vehicle types may change as conventional and autonomous vehicles (with various levels of automation) are simultaneously marketed. • The pattern of vehicle ownership and leasing may change away from personal/household vehicle ownership to a business model where commuters subscribe to transport services. • Vehicle maintenance may require more technical skills to repair data processing components built into autonomous vehicles, and other embedded equipment, such as cameras and sensors.
H: Transportation and storage	• Human drivers may not be needed to transport freight goods or passengers. • Vehicles may be able to travel during all hours, with less concern for human drivers' needs for breaks.
I: Accommodation and food service activities	• Restaurants and hotels along motorways may see a change in service if passenger vehicles can be slept in/driven all night.
K: Financial and insurance activities	• Vehicle insurance may not be held by individuals but instead by transport services. Auto insurance currently makes up a large portion of the insurance sector overall.
L: Real estate activities	• Use of land currently allocated to on-street parking and parking garages may change since vehicles may be shared between individuals. Stores could also be housed in autonomous road vehicles that visit customer's homes instead of being in a fixed bricks and mortar location.
O: Public administration and defence; compulsory social security	• The availability of public services to patrol wider geographic areas could change with drones.
Q: Human health and social work activities	• The frequency of emergency responders being called to action for victims of automobile accidents may reduce if vehicle safety is improved.

NACE Sector	Potential implications of autonomous transport devices to the services sector
R: Arts, entertainment and recreation	• Drones can make new forms of aerial photography and videography possible. • Autonomous vehicles could result in newer forms of in-vehicle entertainment to be delivered, since a human will be a passenger than a driver.
T: Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	• Autonomous vehicles could give passengers more flexibility to work as part of their commute and thus result in changes to their productivity patterns. • Autonomous vehicles could also enable passengers to pursue personal/household tasks remotely if they do not need to dedicate attention to driving.

Source: RAND Europe.

Box 6. Autonomous transport devices, Internet of Things (IoT), Artificial Intelligence, big data, and robotics: A cross-technology perspective

A number of existing and emerging technologies combine to enable autonomous transport devices to behave autonomously. These technologies include legacy automotive technologies, robotics, electronic display and recording devices, visual imaging, Internet of Things-enabled devices and sensors, Artificial Intelligence and machine learning, and big data driven analytics. In this box, some these key technologies are discussed to provide a cross-technology perspective on the development of autonomous transport devices.

In order to constantly adapt to dynamic traffic environments, collecting data through multiple IoT-enabled sensors and then analysing the data is critical to the continued functioning of autonomous transport devices. These data, in turn, form part of the analytics functions on-board the autonomous transport devices and are also provided to the embedded software platform that enables these devices to be continually updated (Rusitschka and Curry, 2016). IoT-enabled interfaces also facilitate the interaction of the devices with other devices in the near vicinity (referred to as Internet of vehicles, see Gerla et al, 2014) and contribute to the capability of the autonomous transport devices to provide emergency roadside assistance or change travel plans according to real-time traffic data (Krasniqi and Hajrizi, 2016). Given the importance of real-time data transmission and seamless communication, near-distance and long-distance wireless connectivity in the form of 4G LTE, Low-Power Wide-Area Networks (LPWAN), and the availability of 5G in the medium-term would also be crucial to autonomous transport devices (Simsek et al, 2016; Usman et al, 2018).

In imparting autonomy and ability to learn navigational behaviours in a variety of scenarios to the autonomous transport devices, Artificial Intelligence and machine learning techniques play a key role. Machine learning enables autonomous transport devices to understand the sensor data for specific aspects of navigation such as lane navigation, determining road curvature, human or non-human objects in the pathway, and functioning aerially, underwater, or on unstructured roadways (Carreras Pérez et al, 2005; Menze and Geiger, 2015; Pomerleau and Jochem, 1996; Shalev-Shwartz et al, 2016). Robotics platforms also perform data-specific functions and enable autonomous transport devices to deal with the inaccuracies and uncertainties of global positioning system (GPS) tracking, odometry[23], and computer vision (Kerner et al, 2015). Robotics platforms thus allow the autonomous transport device to be situated correctly in a local setting and plan its route including in conjunction with other devices or as part of dynamic traffic flows (Kerner et al, 2015; Wurman et al, 2008).

The integration of multiple disruptive technologies in autonomous transport devices is likely to result in complex and expensive hardware in early stages of deployment. A number of the component disruptive technologies such as IoT, big data analytics, and robotics are also undergoing similar transition towards broader market acceptance. The role of autonomous transport devices in shaping workplace practices in the services sector is likely to become clearer as these devices move beyond early trial stages.

Sources: Carreras Pérez et al, 2005; Gerla et al, 2014; Kerner et al, 2015; Krasniqi and Hajrizi, 2016; Menze and Geiger, 2015; Pomerleau and Jochem, 1996; Rusitschka and Curry, 2016; Shalev-Shwartz et al, 2016; Simsek et al, 2016; Usman et al, 2018; Wurman et al, 2008.

[23] Odometry is the use of data from motion sensors to understand changes in the position of the device.

3. Potential socioeconomic implications of autonomous transport devices

Autonomous transport devices could have many impacts on living, planning and working in modern society, as illustrated by the wide array of drivers, barriers and sector-specific applications previously described. This section aims to discuss the specific implications of this technology on workers, employment and other workplace and employer considerations across the services sectors.

3.1 Implications for productivity and outputs

Box 7. Summary of implications for productivity and outputs

- Some reports suggest that autonomous transport devices could help professional drivers and workers who commute make better use of their personal time. However, evidence to demonstrate this is less clear.
- Both technical and natural challenges could prevent passengers from being productive when travelling in an autonomous transport device.

3.1.1 Reduction in time spent driving

A commonly hypothesised impact of autonomous transport devices is that they may allow workers to be more productive (Anderson et al, 2016; Chan, 2017; Henderson and Spencer, 2016; Kær, 2016; Rohr et al, 2016; Sivak and Schoettle, 2016). Conventional driving requires the driver's complete and undivided attention, and beyond this drivers can do little more than listen to the radio, chat with a companion in the vehicle or make a phone call. As an example, in the UK, commuters spend 235 hours per year on average behind the wheel (Rohr et al, 2016). If these commuters were to use autonomous vehicles, this time could be used for work activities, adding to the total hours worked in a day. Alternatively, this time in the vehicle could be used for work-related activities without expanding the work day, meaning that workers could spend less time at their place of work and more time not working or, in the absence of a fixed place of work, not commuting.[24] Another possibility could be that the travel time could be spent doing personal activities - such as personal administrative tasks, consuming media, eating or sleeping - which could reduce stress and improve personal well-being.

3.1.2 Changes to productivity

One Danish study has attempted to quantify the productivity gains that autonomous transport devices could introduce for passengers. Selected food inspectors from the Danish Veterinary and Food Administration were given a simulated autonomous road vehicle experience (a conventional car driven by an 'invisible' human driver) and were asked to record how they spent their time in the vehicle. Food inspectors used these vehicles for the entire day: from their homes to various sites to conduct food safety inspections. Approximately 87% of the time used riding in the 'autonomous' vehicles was used for work-related purposes, such as reviewing notes, completing paperwork and making phone calls. However, some of the food inspectors were able to conduct phone calls while driving conventional cars themselves, so 87% does not represent a complete time savings. The researchers suggested that a 50% productivity gain could be a more conservative estimate. Given that these food inspectors typically spent 111 hours over the course of 2015 travelling, autonomous transport devices

[24] In 2015, the European Court of Justice (2015) ruled that journeys made by workers with a fixed or habitual place of work between their homes and the first and last customer of the day constitute working time.

could increase time available for working by 5.3%. Extending this average across all 300 food inspectors at the Danish Veterinary and Food Administration, this level of increased efficiency is 'equivalent [to] having an additional 10-17 full-time equivalent food inspectors' (Kær, 2016). The programme only observed the actions of one food inspector for one day and repeated this with other food inspectors for five days (Kær, 2016). The novelty of the exercise and participants' knowledge about the experiment's intention could have influenced their actions while they were being observed. Further research is needed to understand the decision making of autonomous vehicle passengers and how they spend their time.

However, some evidence suggests that many of these saved hours may not result in more productivity. A study conducted in the USA found that underlying factors - such as the desire to ride in an autonomous vehicle or a propensity to feeling motion sickness - could inhibit the maximisation of productivity for people travelling in autonomous transport devices (Sivak and Schoettle, 2016). The researchers of that study analysed 3,255 survey responses from respondents in the USA, Australia, China, India, Japan and the UK (Sivak and Schoettle, 2016).While the results of this particular survey would need to be investigated further to be confidently extrapolated, a significant number of the respondents to this survey indicated that they would either never ride in an autonomous transport device or might choose to partake in leisure activities instead of work-related activities. The responses are broken down by country in table 4.

Table 4: Survey responses on using extra time in a self-driving vehicle

Response	USA	Australia	China	India	Japan	UK
I would not ride in a self-driving vehicle	23.0	21.2	3.1	7.8	33.0	23.0
Watch the road even though I would not be driving	35.5	43.4	36.1	30.7	33.2	44.0
Read	10.8	6.5	10.5	10.2	5.6	7.6
Text or talk with friends/family	9.8	7.9	20.8	15.0	7.4	5.5
Sleep	6.8	7.1	10.8	4.7	12.6	7.2
Watch movies/TV	6.0	5.7	11.3	12.3	6.3	4.2
Work	4.8	5.1	5.4	16.3	0.7	4.9
Play games	2.0	2.0	1.3	2.1	1.2	1.9
Other	1.4	1.0	0.7	0.8	0.2	1.7

Source: Sivak and Schoettle, 2016.

The results suggest that between 38.5% and 67.0% of respondents[25] from these countries would not receive any productivity or leisure benefits from riding in an autonomous transport device.

Although these numbers are based on a survey and thus indicative only of the sample of respondents, these are nonetheless useful indicators for the perceptions regarding autonomous

[25] These values are the combined values of the first and second responses – 'I would not ride in a self-driving vehicle' and 'Watch the road even though I would not be driving' – for which the sum of these responses ranges from 38.5% (India) to 67.0% (UK).

transport devices in a global context. In particular, the above numbers suggest an unclear picture in terms of acceptance of autonomous transport devices and whether these would result in productivity gains. The transport infrastructure and conditions in these countries differ significantly, so these numbers may not be comparable. For example, India, where 16% of respondents indicated they would work while travelling in an autonomous transport device, is an outlier when compared to other countries, in which only 5% respondents indicate so. India and China are outliers when the willingness to travel in an autonomous transport device is considered. Only 7.8% and 3.1%, respectively, of the respondents in these countries would not prefer to travel in an autonomous transport device. In contrast, in Japan, 33% respondents indicate unwillingness to travel in an autonomous vehicle.

Kær (2016) notes that there are other concerns that could prevent time spent riding in an autonomous vehicle from being used productively. Without a solution to motion sickness, commuters may not be able to be completely productive with the attention they gain by not needing to drive themselves. Sivak and Schoettle (2016) note that new design considerations would need to be taken into account for travellers to be productive in an autonomous transport device. Specific work postures, including when using laptops or smartphones, or even when doing manual tasks, such as writing or drawing, could be hazardous in the event of a vehicle crash, and devices such as laptops may need to be strapped to vehicles' surfaces to reduce hazard potential in the event of a crash. Finally, the authors question the amount of productivity that could occur in the average commute: if the average commute to work is shorter than 20 minutes, then a commuter perfectly equipped to conduct work while travelling still may not have enough time to produce something meaningful in an autonomous transport device (Sivak and Schoettle, 2016).

Box 8. Autonomous transport devices and the trolley problem

An interviewed third sector expert discussed a possible ethical issue that arises from autonomous transport devices is how the vehicles would cope with competing hazards such as those identified in the ethical experiment known as the 'trolley problem' (see also Nyholm and Smids, 2016). Ethicists debate about the correct course of action to take in a hypothetical scenario where a trolley car is travelling down the track at full speed. In the scenario, a family of multiple people is standing on the track ahead oblivious to the oncoming trolley and would not move off the track in time. The trolley is moving so fast that it cannot brake in time to prevent a collision. Instead, the trolley driver could pull a lever and continue full speed on an alternate track where a man is slowly making his way across the track. In the scenario, the trolley would collide with him before being able to brake. Ethicists have argued what course of action would the most ethical.

Some people believe the trolley problem is relevant to autonomous transport devices, wondering how machines would be programmed to make decisions between two hazardous situations. However, one interviewee insisted that the 'trolley problem' is not a problem since the likelihood that there would be two such competing hazards in the same moment that the vehicle could not also safely avoid either of them is so rare as to be considered impossible. However, according to an interview with an European public sector expert, the trolley problem does help illustrate issues faced by software developers, legal decision makers, and the public about what other kinds of 'preferences' should be coded into an autonomous vehicle's operations: for example, under which circumstances it is 'acceptable' for an autonomous vehicle to sacrifice human life.

Source: Separate interviews with experts; Nyholm and Smids (2016)

3.2 Implications for work and employment

Box 9. Summary of potential implications for work and employment

- The potential for job losses is a common fear surrounding the deployment of autonomous transport devices.
- Professional drivers already perform other tasks beyond driving, suggesting that their entire job may not be completely automatable and that fears of extreme and sudden job losses may be unfounded.
- Autonomous transport devices could provide an opportunity for professional drivers to obtain better paid jobs.
- Workers would likely need training to develop new skills for tasks that are not fully pre-defined and that may require the worker to routinely improvise at work, by relying on more creative skills and social intelligence.
- Autonomous road vehicles promise better safety for professional drivers of freight or passenger vehicles and for commuters and passengers generally, but new security risks may emerge, such as those relating to cybersecurity and privacy.
- Fears about physical safety of drones may be at odds with some evidence which suggests that drones may improve workers’ safety in some sectors.

3.2.1 Potential for job losses

One of the most cited consequences of the rise of autonomous transport devices is the potential for job losses (Beede et al, 2017; Frey and Osborne, 2013; Heard et al, 2018; Kalra, 2017; Pedigo and Bendix, 2017; Pilli-Sihvola et al, 2016; Veryard et al, 2017; Wisskerchen et al, 2017). However, it is unclear exactly how many jobs could be lost and when this transition will occur.

There are many professional drivers in Europe (Veryard et al, 2017), so job losses for professional drivers could have a big impact on the economy as a whole. In the EU27 (as of 2013-2014), Norway and Iceland combined, heavy truck drivers alone represented 1.5% of the employed population in 2015, that is, 3.2 million people (Veryard et al, 2017). With the introduction of autonomous trucks, improvements in network connectivity for tracking these vehicles in remote regions, and the highly organised, planning-driven nature of the heavy truck industry, some of the heavy truck drivers face the prospect of having to re-skill or upskill as autonomous trucks see increased adoption. For example, estimates suggest that the number of heavy truck drivers employed in 2030 could be as few as 1.2 million to 1.7 million, which would represent a 46%-62% decrease in comparison to 2017 (Veryard et al, 2017). However, there are some countries in Europe, such as Germany, for which there are not enough professional truck drivers (Veryard et al, 2017).[26] For these countries, the transition to autonomous vehicles may provide some relief for a part of the economy that has been under resourced, as an interviewed European public sector expert reports. However, Veryard et al (2017) found that autonomous trucks would diminish the demand for drivers to well below the current number of European truck drivers, thereby likely causing two million European truck drivers to lose their job. These figures do not include other professional drivers, such as bus drivers, taxi drivers or chauffeurs for which similar projections about job losses may be valid (Kalra, 2017). Notably, the platform economy and ‘non-standard employment’ have been most present in the transport sector in particular (Australia Institute, 2018). According to interviewees[27], autonomous vehicles could, therefore, reduce the participation of professional drivers in the platform economy (for example, in services such as Uber or Lyft) overall.

[26] This was also the opinion of two separate interviewees, an European public sector expert and a trade union representative.

[27] Based on separate interviews with a third sector expert and an European public sector expert

Professional motor vehicle operators typically have similar characteristics in terms of age, education and occupation levels, which may help policymakers understand which populations are most at risk of losing their job due to autonomous transport devices. According to 2017 data from Eurofound, workers in road transport enterprises were 78% male (Eurofound, 2017). A study reporting similar demographic trends in the transport workforce in the USA suggested that 45.6% of motor vehicle operators in the USA were educated only through secondary school. This is much higher compared to the overall workforce with tertiary education, which stood at 24.7% in 2015 (Beede et al, 2017). Moreover, an interviewed trade union representative (see case example 1) noted that many drivers in Europe are older than the average workforce. For example, only 4% of professional drivers in Belgium are under the age of 45.

In Europe, according to the same interviewee, unattractive working conditions, including being away from home for many days and nights at a time, are one of the main reasons for the shortage of professional drivers. In some cases, professional drivers may be migrants from other European countries or elsewhere and thus susceptible to exploitation in terms of salary and working terms, as noted by an interviewed third sector expert. To limit illegal practices in the road transport sector, the European Commission's Transport Committee updated its rules in 2018 aimed at ensuring fair competition, providing equal pay for drivers regardless of the EU country from which they operated or worked, and improving the allocation of rest periods available to drivers (European Parliament Press Office, 2018). The non-EU drivers in the EU in particular reportedly face several challenges in terms of working conditions, including insufficient rest times, and falsified documents on salaries (Boros, 2018).[28] However, not all subgroups of professional drivers have the same demographic characteristics: bus drivers are more likely than other professional drivers to be older, female and unionised, and to have lower educational attainment (Beede et al, 2017). One paper notes that professional drivers generally tend to earn a decent wage especially compared with people in other jobs that do not require a tertiary education (Pedigo and Bendix, 2017). If professional drivers lose their jobs because of autonomous transport devices, the socioeconomic outcomes gap between those who have received higher education and those who have not may expand further (Frey and Osborne, 2013; Pedigo and Bendix, 2017). Other sectors where the transport sector has large indirect effects, such as hospitality, insurance, health services and police, could also experience job losses (Heard et al, 2018; Heutger and Kückelhaus, 2014; interview with a transport sector expert).

3.2.2 Potential job creation

The development and deployment of autonomous transport devices could also create new jobs. Autonomous transport devices are expected to have different development, design, testing and maintenance needs than conventional transport systems, as noted by different interviewees[29]. Road vehicles could have multiple forms of sensors and cameras that might each need different kinds of upkeep, which could have a positive impact on the technology and telecommunications industries (Frisoni et al, 2016; Kalra, 2017). There may also be a need for new kinds of roles, such as autonomous transport planners, analysts, fleet managers and supply chain managers (Autor, 2015; Kalra, 2017; Veryard et al, 2017). According to an interview with an European public sector expert, taxis, buses and trains might be autonomous but might still require 'hosts' or 'conductors' in lieu of drivers to act as neutral parties in the shared, enclosed environment of the vehicle. Kalra (2017) suggests there are similarities in the deployment of autonomous transport devices and the advent of the internet. She observes that 'the internet reduced or eliminated jobs that were once routine like travel agents and bank tellers, but it created new jobs that were hard to conceive of just a few decades ago like app

[28] According to Boros (2018), some of the non-EU drivers are reportedly paid as low as €0.79 per hour.

[29] Based on separate interviews with a third sector expert and an European public sector expert

developers, bloggers, and social media managers' (Kalra, 2017).[30] In a similar way, autonomous transport devices may create jobs that cannot currently be foreseen. For example, autonomous transport devices could usher in jobs involving providing technical training on the underlying algorithms as part of upskilling employees, explaining how algorithms work to business leaders and policymakers, and maintaining the proper function of the algorithms that make autonomous vehicles function (Wilson et al, 2017). New jobs created to support the development of autonomous transport devices could require a unique set of skills, such as software development, sensor installation and an understanding of the industry's supply chain. Increased demand for such unique skills, in combination with good compensation packages, is likely to enable the autonomous transport industry to attract and maintain a high-quality workforce. This diversity of skills could also help attract the next generation into the transport industry, where younger employees may be more willing and able to work with more advanced technology and be responsible for a wider variety of tasks.

3.2.3 Task allocation

Driving may be the primary task for professional drivers, but they may also be responsible for other tasks, such as loading and unloading cargo in the vehicle at its origin and destination and providing safety checks of the vehicle (Lee, 2016; Veryard et al, 2017). An interviewed European public sector expert noted that in public transport systems, the driver implicitly acts as a neutral arbiter and authority figure when there are disputes on the vehicle. The same expert noted that these roles may still need to be fulfilled, because it may be quite a long time before a vehicle can load and unload itself autonomously or before passengers feel safe in a vehicle without a human authority figure. Two interviewees[31] described a possible future scenario whereby a driver of an autonomous truck could do paperwork or other administrative tasks in the vehicle while travelling in clearly marked, straight corridors in a platooning formation, that is in a situation where the autonomous functions of the vehicle can most reliably take control. As per the interviewed third sector expert, the vehicle could alert the driver that in a few minutes it would approach a section of roadworks where navigation would be difficult for the autonomous technology and human driving would be safer. The same interviewees emphasised that having a human driver on board is likely to be essential for many years through the various transition phases of autonomous driving development.

Because of these other, varied tasks, Wisskerchen et al (2017) believe that not all professional drivers would be completely displaced by autonomous transport devices. Moreover, in some cases it may take some amount of time to completely discern all of the tasks associated in a job and then determine exactly which can be done better by humans and which can be better left to the new technologies (Veryard et al, 2017). In addition to driving, professional drivers often undertake additional duties including selling tickets, baggage handling, cleaning the vehicles, and assisting passenger on formal (such as travel times, traffic conditions) and informal (such as local attractions, places to stay) queries (ETF, 2018). At the very least, the paperwork and administrative activities done by professional drivers as of 2018 may need to be automated before the adoption of autonomous transport devices, and this could slow the rate at which job losses may occur. Transport workers may fear that their jobs could disappear completely and immediately, even if researchers do not believe the changes would be so quick and dramatic. However, some authors report that intermediate changes around task allocation could still happen more quickly than expected (Pedigo and Bendix, 2017). As a result, where jobs losses are likely, companies will need to institute buyouts for union

[30] The prospect of existing jobs being displaced and new jobs being created is not unique to autonomous transport devices and has also been observed in relation to other disruptive innovations such as steam engines, advent of electricity, and personal computing introduced by previous industrial revolutions. See Block (2018) for a related discussion.

[31] Based on separate interviews two separate interviewees, a third sector expert and a trade union representative.

workers or set aside yearly contributions for their non-union transport employees in the near term (Pedigo and Bendix, 2017).

3.2.4 Training needs

Given the reallocation of roles within existing jobs and the creation of new jobs, different skills may be needed to perform new tasks. The new tasks and jobs described may require more creative skills and social intelligence (Frey and Osborne, 2013; Wisskerchen et al, 2017), which are not skills that professional drivers need to use currently (Beede et al, 2017). Research has found that professional drivers tend to have fewer skills that could be applied to cognitive tasks (Beede et al, 2017). It may be difficult for professional drivers of freight vehicles to find new work in a new employment landscape if the creative and social skills required for the new jobs vary dramatically from the skills they have previously used (Beede et al, 2017). This could increase the socioeconomic gap between those with education and innate creative and social skills and those who do not have them (Frey and Osborne, 2013; Pedigo and Bendix, 2017). This suggests that workers who can retrain in new skill areas, such as creative or social skills, may be able to find other employment prospects. Having been retrained, the workers could potentially be engaged in tasks that go beyond pre-defined routines and may require the workers to regularly improvise at work by using such skills. However, the extent to which full-time professional drivers can transition to other jobs and whether they can be retrained for jobs that require creative skills and social intelligence is not clear based on available evidence.[32]

3.2.5 Improved safety

As noted previously, one of the motivations to develop autonomous transport devices is improving safety in transport (Anderson et al, 2016; Beede et al, 2017; Chan, 2017; Claus et al, 2017; Frisoni et al, 2016; Henry et al, 2017 Heutger and Kückelhaus, 2014;interview with an European public sector expert). In both Europe and the USA, 90% of road accidents and fatalities are due to human error (Frisoni et al, 2016; Veryard et al, 2017). The US Office of the Chief Economist analysed data from the 2011-2015 Census of Fatal Occupational Injuries and the 2011-2015 Survey of Occupational Injuries and Illnesses to calculate the rates of fatalities and injuries for motor vehicle operators workers in other non-driving occupations per every 100,000 full-time equivalents (FTEs), as shown in table 5.

Table 5: On-the-job injuries and fatalities involving roadway vehicles

	Motor vehicle operators	**Other on-the-job drivers**	**All occupations**
Risk of driving fatalities	16.1 per 100,000 full-time equivalents (FTEs)	2.2 per 100,000 FTEs	1.6 per 100,000 FTEs
Risk of driving injuries	479.5 per 100,000 FTEs	125.5 per 100,000 FTEs	55.5 per 100,000 FTEs

Source: Beede et al, 2017.

Table 5 demonstrates that motor vehicle operators were almost four times more likely to be injured by a roadway vehicle as other on-the-job drivers and more than eight times more likely to be injured than non-driving workers. Similarly, motor vehicle operators were more than eight times more likely to die from an incident involving a motor vehicle as other on-the-

[32] See Blake et al (2018) for a more detailed discussion on broader loss of jobs beyond traditional working class occupations.

job drivers and more than 10 times more likely to die than non-driving workers. Additionally, professional drivers are exposed to other occupational health and safety hazards, such as prolonged sitting, insufficient breaks or sleeping time, late-night shift working, and exposure to carbon monoxide among other pollutants (Eurofound, 2017; European Agency for Health and Safety at Work, n.d.). In the medium term, with increased automation in transport, the safety of workers who are professional drivers and of other workers who travel as some component of their job could improve.

In the absence of widespread deployment of autonomous transport devices, the new safety risks posed by these devices remain unknown. A small handful of autonomous transport devices in operation may not likely cause noticeable improvements in the number of injuries and fatalities (Frisoni et al, 2016). Moreover, during the transition period, wherein a significant minority of vehicles are autonomous and need to navigate around traditional vehicles driven by humans, the number of injuries and fatalities may increase (Chan, 2017). An interviewed third sector expert suggested that especially if human drivers believe that the autonomous transport devices around them are more autonomous than they actually are, safety could actually decline. For example, vehicles that have some degree of autonomy but still require human intervention during difficult-to-navigate areas of road works could prove dangerous for human drivers who do not remain alert enough to take over in situations that are problematic for the autonomous technology to decipher.

Drones have been shown to improve safety in the construction industry by making inspections that would be dangerous for a human to undertake (Howard et al, 2017).

Box 10. Autonomous transport devices and the implications for security and privacy

The security and privacy risks posed by autonomous transport devices include physical as well as digital challenges. As identified in the discussion on the trolley problem (see Box 8), autonomous transport devices may pose a physical hazard and are arguably unproven when complex traffic scenarios involving human-driven vehicles and other autonomous devices are considered. Taeihagh and Lim (2019), for example, suggest that additional physical safety requirements for autonomous road vehicles and possible strategies for regulation of crash algorithms can be better understood only after the devices reach wider deployment. As Glancy (2012) identifies, individual privacy and freedom will be affected by autonomous transport devices and such devices would need to be designed to enable privacy by default. Autonomous transport devices are also expected to include a blackbox which would continually collect data about the operating environment, the people using the devices or interacting with it externally (Lindsay, 2014).

As devices that rely extensively on sensors to collect and transmit data wirelessly and which are powered by software platforms, autonomous transport devices are also susceptible to cybersecurity failures (Yağdereli et al, 2015). In this context, privacy laws, security standards, and liability requirements are not yet fully defined and remain untested in the court of law (Calo, 2018; Fagnant and Kockelman, 2015). Since awareness of the capabilities of autonomous transport devices and varying degrees of autonomy is at an early stage, when such devices are introduced in practice, humans may not fully understand that they are interacting with a partially autonomous (level 2/3) device and erroneously cede control to the perceived accuracy and reliability of the device, according to the interviewed European public sector expert. Such a scenario also has implications for working in sectors such as transport, tourism, hospitality, and healthcare in the event of accidents or hazardous circumstances. For example, early tests of Alphabet’s autonomous taxi service Waymo have revealed that the vehicle would often get confused by rainstorms or crowded parking areas, and take unexpected left turns (Hawkins, 2019).

With regard to the privacy challenges of digital technologies such as autonomous transport devices, the EU’s GDPR is intended to improve the legal framework and protection for personal data from technologies and platforms that collect and transmit data continually. The introduction of GDPR makes collecting and processing these data without explicit user consent illegal. It also enables EU Member States to enact national legislation related to workers' rights and privileges when using digital technologies and tools in a workplace. A relevant example of this kind of legislation is the Organic Law on Data Protection and Digital Rights Guarantee (LOPDGDD) enacted by the Spanish parliament in 2018 (Jefatura del Estado, 2018).

Source: Calo, 2018; Fagnant and Kockelman, 2015; Glancy, 2012; Hawkins, 2019; Jefatura del Estado, 2018; Lindsay, 2014; Taeihagh and Lim, 2019; and Yağdereli et al, 2015.

In summary, for all kinds of autonomous transport devices, the safety factor could be monitored very closely throughout the vehicles' development and deployment. As one interviewed European public sector expert stated, 'autonomous transport devices will improve safety, and if they do not improve safety they would never be deployed'. However, a third sector expert argued that gains to safety are not obvious with autonomous transport, particularly if they completely eliminate all forms of conventional driving. While autonomous transport could prove much safer on clearly marked, straight freight corridors, it may be a very long time before autonomous vehicles are as good at managing dense urban environments, according to the same expert.

3.2.6 Working patterns and accessibility

Other aspects of working conditions are likely to change as a consequence of the deployment of autonomous transport devices, including worker compensation, physical access to jobs (via commuting distance) and increasing professional drivers' access to regular working hours that allow them to spend more time at home. Autonomous transport devices could reduce the commute time for workers (who drive to work but are not professional drivers) between their place of employment and their homes. Professional drivers - particularly those driving freight vehicles - spend many hours and days on the road away from home, as the interviewed third secotr expert pointed out. But with a new set of tasks, as described above, workers who tend to the vehicles and unload the vehicles' contents could have more consistent work schedules, improving not only their experience at work but also their quality of life (Veryard et al, 2017).[33]

According to the interview with an European public sector expert, in the long-term, workers, whether they are professional drivers or not, who live in poorly connected neighbourhoods may see their ability to commute to and from work improve with the wider deployment of autonomous transport devices. Workers who are not professional drivers and live in an urban area not well connected by public transport can have long and arduous commutes. Autonomous transport devices shared across an urban community could lower costs by 30% to 90% per mile (about 1.6 kilometres) compared with traditional transport options that require paying wages to a human driver (Kalra, 2017).[34] One interviewed transport sector expert suggested that this could help people who are looking for work increase the geographic range of their job search because they could be supported by reliable door-to-door transport. This reliability can also make a big impact for people with physical disabilities who - without autonomous transport devices - may be excluded from work opportunities (Kalra, 2017, also echoed by some interviewees).

[33] This view was also echoed by two of the interviewees.

[34] Kalra (2017) does not specifically identify the cost of the driver as part of the assumptions, and thus the stated benefits of autonomous shared mobility (for example, Uber with an autonomous vehicle) may not be entirely comparable with shared mobility solutions with human drivers (for example, existing car sharing schemes).

3.2.7 Labour relations and social dialogue

As workers' jobs could be at risk with the increased use of autonomous transport devices over the coming years, trade unions may continue to play an important role in advocating for the benefit of workers (Henry et al, 2017; Pedigo and Bendix, 2017). Faced with the prospect of job losses, non-standard contractual relationships at work, loss of tacit knowledge and human skill, and lower job security, DG EMPL (2018) has highlighted the need for ongoing social dialogue between the organisations, public sector authorities, workers and trade unions. One report suggests that from the organisations' perspective the financial implications of introducing autonomous transport and the resultant non-unionised working in a highly unionised transport sector are not entirely clear (Pedigo and Bendix, 2017). One interviewed European public sector expert posited that loss of jobs among unionised transport workers could decrease the size of the workers' unions. On the other hand, employers that do not engage with trade unions to coordinate the introduction of autonomous transport devices into a workplace, and that provide insufficient support to workers at risk of losing their job, may face industrial action (Pedigo and Bendix, 2017). Faced with redundancies and loss of membership, the unions would have reduced negotiating influence. However, there is insufficient evidence about the extent of actual loss of jobs and loss of union influence at this stage of development of autonomous transport devices to offer any definitive assessment. A possible counterexample to such an outcome was offered by the interviewed European public sector expert, who stated that the biggest transport workers' union in Sweden has an official policy of welcoming the automation of trucks and buses. The same interviewee reported that the union 'sees [automation] as a natural evolution' to the sector and aims to help workers develop new skills to potentially enable their transition to other jobs.

4. Conclusions

This study aimed to understand the implications of autonomous transport devices as a potential game-changing technology area to the services sector in Europe. The findings suggest that autonomous transport devices are at a relatively early stage of adoption in the services sector. Although the outcomes related to jobs, required skills, working conditions and workplace practices in the services sector are still emerging and vary significantly depending on the needs of the different sectors, early adoption trends and high-level implications can be discerned, as has been outlined in chapters 2 and 3 of this working paper. This chapter summarises the key findings in relation to the primary objectives and the main elements of the conceptual framework outlined in chapter 1.

4.1 Applicability of autonomous transport technologies in the services sector

Most of the testing and deployment of autonomous transport devices as of 2018 has been in the transport sector. With drones being increasingly trialled for delivery of goods in the last mile, the logistics sector is the services sector in which autonomous transport devices are likely to see adoption in the near to medium term. The timelines for the introduction and widespread adoption of fully autonomous vehicles (with level 4/5 autonomy) vary according to expert opinion, with suggestions ranging from 2027 to 2036 as the earliest timelines for their commercial availability. Subject to the extent to which fully autonomous transport devices see widespread adoption, services sectors such as insurance and real estate may undergo structural changes due to the changing patterns of vehicle use and commutes to work, respectively. Based on available evidence, non-transport sectors, such as hospitality and emergency services, where transport of goods and people play an important role are also likely to be sectors which will be impacted by autonomous transport devices.

4.2 Potential implications of autonomous transport technologies on productivity, output and work organisation

Although there is some initial evidence to suggest that autonomous transport devices could help workers and commuters make better use of their personal time, such findings remain untested over longer durations of the use of autonomous transport devices. Available evidence suggests that both technical (related to the use of devices, such as computers and smartphones) and natural (including motion sickness) challenges could prevent passengers from being productive when travelling in an autonomous transport device. The available evidence on the extent to which autonomous transport devices could influence productivity in workplaces is limited. Globally, the attitudes about the use of autonomous transport devices appear to vary significantly across countries; with respondents from countries such as China and India indicating a higher acceptance of autonomous transport devices in contrast to the UK, the USA, and Japan. In the absence of specific data or long-term trends on the changes to working practices, working conditions owing to autonomous transport devices, as of 2018, further research would be necessary to identify the implications of autonomous transport devices on output and productivity. A key question relates to the average length of the commute for most workers and whether the use of autonomous transport could make the working lives of those using it easier. This suggests an unclear picture in terms of acceptance of autonomous transport devices and whether these would result in productivity gains.

4.3 Potential implications of autonomous transport technologies on employment and skill levels

One of the most discussed potential impacts of autonomous vehicles is the potential for job losses among professional drivers of taxis, buses and trucks. However, available evidence suggests that although some jobs may be lost, the emergence of autonomous transport devices may result in the creation of new jobs. These new jobs may require different - and often more advanced - skills than the jobs lost, such as creative, social intelligence and technical skills. This may pose challenges to the individuals at risk of losing their job without sufficient opportunities or resources for re-skilling to adapt to the changing work environment. The extent to which professional drivers would be able to successfully adapt to the changed paradigm of jobs in the transport and logistics sector remains an unknown at this stage of the technology's development. Workers who do manage to develop the necessary new skillset may find that they have jobs with better wages, benefits and safety standards. However, such an outcome would require investment in re-skilling of workers at risk of job losses by employers, government, charities or other relevant stakeholders. In such a scenario, continued engagement with trade unions, and their participation in re-skilling and redeployment of existing workers, would be crucial to minimise disruption to existing economic activity and ensure that any productivity gains from autonomous transport devices do not occur at a heavy cost to workers.

4.4 Potential implications of autonomous transport technologies on working conditions

Autonomous transport devices operating on roads and in the air could have numerous implications for the way work happens in the services sectors in Europe. One of the biggest impacts may be improvements to safety in workplaces or working conditions where road vehicles are currently in use. Current expert views on the future of autonomous transport suggests that taking the human driver out of the transport equation will lower the frequency of injuries and fatalities that occur as a result of collisions caused by human error. However, it is unclear whether the introduction of autonomous vehicles could result in new safety risks. Such risks may be especially evident in the early stages of autonomous vehicle deployment if (or quite possibly when) autonomous vehicles share the same infrastructure as conventional, non-autonomous vehicles. Individuals may not fully understand how to supervise autonomous vehicles they are travelling in or how to interact with autonomous vehicles while they are in conventional vehicles in public spaces. The extent to which this contributes to safety risks in such environments is not clear at this stage of the deployment of autonomous transport devices.

Overall, interviewees cautioned that autonomous transport technology is still very nascent and that it is difficult to predict the potential impacts with any certainty or possible timelines for the outcomes. While the case examples demonstrate real use of autonomous transport devices in Europe, these examples do not yet indicate widespread or highly developed use of the technology. Most experts suggest that further research is necessary to understand how much and how quickly autonomous vehicles would change: while some job tasks could be eliminated, others will be created. The uncertain future of autonomous transport devices may make it difficult for policymakers, employers or workers to plan precisely. Creating a regulatory framework that can adapt to the changing technical and socioeconomic landscape to protect workers and citizens, while promoting technology that can enhance safety, productivity and well-being for workers in Europe would be crucial in the near future.

5. Real-world case examples illustrating the applicability and potential implications of autonomous transport devices

Three examples of ‘real-world’ applications of autonomous transport devices are presented below. The examples are intended to illustrate rather than assess the applicability and impacts of autonomous transport devices in the services sector. Instead of offering insights on a broad range of implications of autonomous transport devices (as has been presented in chapter 3), the case examples are meant to succinctly exemplify implications in one or two (or more, where information is available) NACE sectors. The examples are meant to enrich the overarching analysis presented in this working paper by offering a real-life illustration of how these applications have had or will have implications in practice.

Table 6 Case example 1: Automated guided vehicles in the Port of Rotterdam

Automated guided vehicles in the Port of Rotterdam
Location: Rotterdam, the Netherlands
Example service sector(s) the case example applies to: • Transportation and storage (NACE sector H)
Background and overview of the technology: The Port of Rotterdam has been Europe's largest port since 1966, and in 2018 it was the world's ninth-largest port. The port accounts for the direct or indirect employment of about 300,000 people and accounts for 3% of the Netherlands' gross domestic product (Rotterdam World Gateway, 2014). The Port of Rotterdam Authority is an unlisted public limited entity owned by the municipality of Rotterdam and the Dutch government (Port of Rotterdam, 2015a). The Port Authority leases the public land to about a dozen private terminal companies (Port of Rotterdam, 2016a). These terminal companies are responsible for transhipment of containers between waterborne transport and road or rail transport. The Port Authority itself employed 1,150 people in 2015, while all of the workers at the terminal companies and in the port environment totalled 180,000, which is about 19% of the total workforce in the greater Rotterdam region (Port of Rotterdam, 2015b, 2015c). In 1993, Rotterdam became the first port in the world to use automated guided vehicles (AGVs) (Stehouwer, 2015). AGVs are battery-powered devices that use magnetic and infrared technology to lift, drive, stack and sort shipping containers. A magnetic grid in the tarmac helps the AGVs understand where they need to go, and infrared sensors tell the vehicle which area of the port the container should be delivered to (Robot Workforce, 2013). AGVs allow the port to operate at all hours, which is useful given that the volume of cargo shipping keeps growing (Stehouwer, 2015; Veryard et al, 2017). In 2013, the port expanded by means of a human-made peninsula created specifically for adding new, fully automated terminals (Port of Rotterdam, 2016b). The terminal companies operating on Maasvlakte 2 do not use human workers to perform tasks directly at the terminal; there are no human workers driving containers around the terminal because AGVs are fully deployed there. The tracks for automated guided vehicles are pre-programmed so no humans are needed on-site, although humans do monitor the automated processes from a remote control centre (Veryard et al, 2017). These operators can monitor more activity than a single operator of a conventional crane machine (Economist, 2016).
Illustrations of potential socioeconomic implications: According to ITF Global, a trade union representing port workers, the expansion of the Port of Rotterdam with Maasvlakte 2 would result in investments requiring the port to operate at a greater capacity than might be expected with current economic growth projections (ITF Global, 2017). FNV Havens, the Dutch dockers' union, argued that investments in AGVs and other autonomous technology would not be in the port's interest as expensive investments may not be earned back in increased profits, as reported by a trade union representative. According to the same interviewee, it is difficult to defend jobs for workers in the face of innovative technological advancements in the port, so fears of job losses still exist around the port. In 2016, when the trade union's requests for limiting automation were not sufficiently addressed and attempts to negotiate a collective bargaining agreement for job protection failed, a strike was organised (ITF Global, 2017). On one side, crane drivers at the Port of Rotterdam had gone on strike to protest against what they saw as the inevitable job losses and forced layoffs that would result from the total reliance on AGVs at the port (Economist, 2016). On the other side, the terminals and the Port Authority felt that there were not enough drivers available to meet the employment demand, particularly when considering the rising demand on the port's capacity (Veryard et al, 2017). As a result of the strike, within 24 hours,

workers on strike managed to bring large portions of the port to a halt for the first time in 13 years (Economist, 2016). Eventually, a collective bargaining agreement was made between all of the terminals on Maasvlakte 2 and FNV Havens, as reported by a trade union representative. The same interviewee indicated that this agreement protected workers from job losses for four years.

It has been noted that the use of AGVs and other autonomous technology at the port could improve working conditions for workers who do continue to work there. One report emphasised that the use of AGVs at the port would not necessarily mean that there would be no jobs for crane drivers; some workers who would be able to retain their job but move into the remote control office would potentially have better working conditions. However, the report suggests that the net effect would likely be job losses (Veryard et al, 2017).

The interviewed trade union representative reported that the retirement age in the Netherlands was 65 in 2018 and will increase to 67 by 2021. He added that driving conventional vehicles is one of the ways workers can experience more suitable working conditions as they age. The same interviewee also argued that the driving jobs were ‘good’ for older workers who could no longer handle the physically intense jobs in the port that they may have had when they were younger. Autonomous driving technology could make these opportunities scarcer for workers approaching retirement, so there have been some agreements with the Port Authority that the roads connecting the terminals would not become automated so that there would still be a need for human drivers, according to the interviewed trade union representative.

A representative from the Port of Rotterdam highlighted that the Port Authority has partnered with Erasmus University and Delft University of Technology to understand the impact of AGVs on human capital. According to the same interviewee. public- and private-sector decision makers at the port have an understanding that workers in the port need technical and ICT skills, and a number of partners are working together to deliver this training. As per the interviewed Port of Rotterdam representative, workers hired into new vacancies will be trained by the Shipping and Transport College of Rotterdam, but retraining for existing employees will also be important in the coming decades. While working in the port traditionally used to be a very physical job, the same interviewee suggested that the workers of the future will need ‘more brains than brawn’.

Furthermore, the interviewed Port of Rotterdam representative observed that the changes in working conditions and the move towards more ‘intellectual’ tasks that autonomous vehicles may potentially result in might allow more women to work in the port.

Even though the Port of Rotterdam is growing, it may need fewer employees on the payroll at the port’s terminal companies. Instead, as suggested by the same interviewee, it may require more indirect employees from companies providing outsourced services, such as maintenance officers, data analysts and financial officers.

Despite the higher-skilled jobs that may be filled at the port, one expert claims it is unclear whether the automation of the port helps Rotterdam earn more tax revenue, fund pensions, increase demand for goods shipped from overseas, and/or make shareholders of businesses more profitable, according to the Port of Rotterdam representative. The Port of Rotterdam does appear to be leading the way globally to incorporating autonomous transport technology into its operations, and the outcomes of these changes and the extent to which autonomous technology is still in use may be better assessed in long-term.

Table 7 Case example 2: STIMULATE project at Charité hospital

STIMULATE project at Charité hospital
Location: Berlin, Germany
Example service sector(s) the case example applies to: • Human health and social work activities (NACE sector Q)
Background and overview of the technology: STIMULATE (which stands for sustainable urban mobility with automated electric vehicles) is a project to test autonomous shuttles in a real-world, multimodal environment. The autonomous shuttles are operating on the Charité – Universitätsmedizin Berlin campuses in Berlin, Germany. The project partners are Berliner Verkehrsbetriebe (BVG), the public transit authority in Berlin; Charité university hospital (one of the largest hospitals in Europe and one of the largest employers in Berlin); the Berlin Senate Department for the Environment, Transport and Climate Protection; and the German Federal Ministry for the Environment, Nature Conservation, Building, and Nuclear Safety (BVG, 2018a). The project aims to explore user take-up of autonomous vehicles, as well as improve the environmental capabilities of autonomous vehicle technology (BVG, 2018a). The autonomous shuttles have been operating on weekdays on two campuses of the Charité hospital, as reported by an Easy Mile representative[35]. Both routes are loops of up to 1.5 km. The project has been designed in three phases. Phase I, which began in May 2017, involved shuttles with no passengers running autonomously while being supervised by an onboard conductor (BVG, 2018a). Phase II, which began in June 2017, added passengers to the operation, as reported during an interview with an Easy Mile representative. The same interviewee indicated that Phase III of STIMULATE will not involve onboard supervision, and the only people inside the shuttles will be passengers; this phase is expected to begin in 2019. The project is scheduled to complete in April 2020 (BVG, 2018a). The autonomous shuttles are provided by two companies, EasyMile and NAVYA, which are both based in France. Like other autonomous road vehicles, these shuttles use three-dimensional lidar scanning to identify objects in their surroundings to determine a safe trajectory (BVG, 2018b). The shuttles are powered with electricity, which has the potential to reduce street-side emissions, as suggested by the Easy Mile representative. While the autonomous shuttles can reach speeds of 45 km/h, they are currently not operated at speeds greater than 12 km/h because the vehicles are still in testing. As the project progresses, the shuttles may operate at 20 km/h (BVG, 2018a). The autonomous shuttles are also equipped with an emergency ‘stop button’, and the doors can be opened manually at any time (BVG, 2018a).
Illustrations of potential socioeconomic implications: As STIMULATE began only recently, the impacts from the project are still emerging. Interviewees did not comment on any socioeconomic implications on employment or labour conditions. In the phases implemented thus far, the autonomous shuttles still operate in a supervised setting; a human is still overseeing the vehicles’ actions. Another interviewed Easy Mile representative, familiar with the project’s technology indicated that currently safety aspects are the foremost concern. According to the same interviewee, the project aims to maintain a high level of safety that is ‘at least as good’ as conventional, human-driven road transport, while also offering a service that is timely, smooth and useful to commuters. As indicated by an Easy Mile representative, the autonomous shuttles are being operated on the hospital campuses because the hospital provides a private setting, where it is legal to operate autonomous shuttles, while providing a

[35] The study team interviewed two members of the Easy Mile project

real-world (rather than simulated) environment. According to another Easy Mile representative, the shuttles operate in a narrow street environment which sees a lot of traffic from visitors' cars and ambulances, as well as students and hospital staff on foot and on bicycles.

Further deployment of autonomous shuttles - and by extension the breadth of their potential impacts on work and working conditions - may depend on whether they are viewed as an acceptably safe form of safe transport. It is worth noting that the STIMULATE project is also conducting research to understand the user experience and acceptance of autonomous transport, as indicated by one interviewed Easy Mile representative. According to the same interviewee, the Institute of Medical Sociology and Rehabilitation is interested in capturing the perspectives of both autonomous shuttle riders and pedestrians. Researchers will gather information from surveys, focus groups and observations (BVG, 2018c). The other interviewed Easy Mile representative indicated that initial findings indicate that most people are not afraid of autonomous vehicles and that those who begin with some fear appear to quickly lose it with a small amount of exposure to the technology.

According to the same informant, public transport workers and drivers are 'interested and willing to learn' about autonomous shuttles, as many understand that autonomous shuttles are designed to complement existing public transport options as a 'first mile/last mile' solution. For example, autonomous shuttles can help improve access to a train station that is too far away to walk to. He posited that while autonomous transport is sometimes associated with potential job losses for professional drivers, autonomous shuttles still require support from human workers to monitor the position of buses on various routes, respond to passengers when they want to speak to a remote operator, and repair shuttles that require maintenance. Interviewees did not comment on the net change in the number of jobs that could result from wider deployment of autonomous shuttles.

Table 8 Case example 3: Drive Me project in Sweden

Drive Me project in Sweden
Location: Gothenburg, Sweden
Example service sector(s) the case example applies to: • Transportation and storage (NACE sector H)
Background and overview of the technology: The Drive Me project was started in 2013 by the Volvo Car Group, in conjunction with the City of Gothenburg, Chalmers University of Technology, Lindholmen Science Park (a partnership group between academia and government), Autoliv (a vehicle safety features developer and manufacturer), and the Swedish Transport Authority. According to an interview with a Volvo car group representative, the project aims to develop solutions to societal transport issues through the development of autonomous vehicles to create a safer, more sustainable transport system. The same interviewee indicated that the project has a number of research questions around how consumers develop trust in the vehicle, what the infrastructure needs are for autonomous vehicles, and how to improve congestion in areas with growing populations (Lindholmen Science Park, 2013; Volvo Cars, 2018). Through the project, Volvo and its partners aim to improve the liveability of shared urban spaces; the environment; and road safety for drivers, passengers and other road users, such as cyclists and pedestrians (EntertainmentWOWtv, 2014). Vehicles can be used in both ‘supervised’ and ‘unsupervised’ forms. Supervised driving is the same as conventional driving, where the human driver is completely responsible for all of the vehicle’s movement. Unsupervised, or autonomous, driving is available on a 30 mile track of public roads around Gothenburg. According to the interviewed Volvo car group representative, these are roads that Volvo has tested rigorously; they have also gathered lots of data about the physical spaces and driving patterns of other vehicles. The Drive Me project aimed to give 100 cars to selected Gothenburg residents that could be used in ‘unsupervised’ mode on the defined track by 2017. It is, however, unclear how many cars are available as of 2017, or how many are operational in fully ‘unsupervised’ mode (Hawkins, 2017). There were also reports that Volvo would extend the project to cities abroad, although these plans have not yet been realised (Hawkins, 2017). The interviewed Volvo car group representative suggested that 2021 is the new timeframe aimed for wider deployment of fully autonomous vehicles. As reported by the same interviewee, the vehicles in the Drive Me project also have the capability to fit themselves into parking spaces without human intervention. Some governments are particularly interested in self-parking technology because it could allow for a reduction in the overall land area needed for parking. Therefore, governments could reallocate land to other public or industrial spaces. The same interviewee reports that Drive Me is also aware that self-parking technology produces benefits for consumers, who would need to dedicate less time to parking. While autonomous vehicles are not a completely novel technology, they require a different kind of trust from the passenger: instead of trusting in the training and reflexes of a human driver, passengers must trust the algorithm coded into the vehicle to transport them safely. The interviewed Volvo car group representative highlighted that it will take some time to develop trust in the vehicles (see also Volvo Cars, 2017). However, the same interviewee compared autonomous transport to the technology used to fly commercial aeroplanes: while there are often multiple human pilots onboard an aeroplane, autopilot technology is used to fly aeroplanes through the majority of the trip, with pilots being responsible for take-off and landing. Although there are arguably many more uncertainties and complexities associated with road traffic, people who feel safe in airplanes with technology ‘in control’ may be able to more readily understand the safety behind unsupervised driving.

Illustrations of potential socioeconomic implications: Interviewees did not comment on any notable socioeconomic impacts from the Drive Me project on employment or labour conditions. Drive Me is interested in understanding how users spend their time when not actively supervising driving activities. The first family recruited to use the Drive Me vehicles is the Hein family, who suggested that they could use the time in the vehicle to do professional tasks, such as taking calls and responding to emails, and conduct home tasks, such as helping children with homework (Best New Cars, n.d.). At the moment, as pointed out by the interviewed Volvo car group representative, the time spent in autonomous mode is quite short, so it is difficult to assess how time might be spent with longer periods in autonomous mode. However, results from other research about traffic accidents in conventional vehicles tells researchers that consumers are already interested in sending text messages while driving, which suggests that there is interest in using driving time to engage in alternative tasks, according to the same interviewee.

It was pointed out by the interviewee that the Drive Me project could also pave the way for changes in future jobs in the development of autonomous vehicles. As a result of more sophisticated technology inside the vehicles and the data they collect, Volvo may also need more employees with specific sets of skills and talent in (for example) software development, Artificial Intelligence, and behavioural research who better understand the user experience.

Drive Me researchers have not reported definitive answers yet about the impacts the vehicles will have on working conditions and productivity in relation to commuters travelling to desk-based or computer-based (office) jobs. The interviewed Volvo Car Group representative reported that the public-private partnership model that oversees Drive Me has been cited as a positive outcome of the initiative. It may become more common for public-private partnerships to emerge as autonomous transport (and indeed other new and emerging technologies) are adopted and deployed in cities and workplaces across Europe.

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Annex – Further details about the research approach

Phase 1: Scoping phase

As noted in Chapter 1, the main objective of this phase was to validate the five technology areas to focus the study around and to examine the extent to which the technology areas originally identified by Eurofound (that is, advanced robotics, autonomous transport devices, blockchain, virtual and augmented reality, and wearable devices) remained relevant to the goals of this study. In addition, the study team aimed to ensure that other technologies with potentially cross-cutting impact on the five technology areas – such as artificial intelligence and data analytics – were also considered.

As part of the validation exercise, the study team surveyed white and grey literature,[36] including journalistic and blog sources, as well as company reports and individuals' websites focused on horizon scanning of science and technology. Key sources of literature targeted by the study team included reports by international organisations (for example, OECD, World Economic Forum and World Bank), documents from European Commission sources (for example, European Political Strategy Centre), industry sources (for example, McKinsey, Deloitte, and Accenture), academic literature (for example, *Harvard Business Review* and *MIT Technology Review*), and sources from think tanks or third-sector organisations (for example, Pew Research Centre, Lisbon Council, and Nesta). Many of these sources report on the deployment of emerging technologies and applications and thus enabled the study team to assess the current and emerging landscape of game-changing technologies in relation to the objectives of the study.[37]

The study team initially scanned these sources to identify specific citations of current and emerging technologies that are having/are likely to have a disruptive impact. The study team also identified some additional sources from the reference lists in the original corpus of articles. In total, 72 sources were identified to be examined through this quick scan of the literature. As part of the quick scan, the study team coalesced the identified technologies into broad technology area 'buckets' and conducted a 'strength of evidence' analysis of appearance of the technologies across the set of articles. This analysis assessed the frequency of the number of appearances of the technologies across the set of articles. Additionally, the nature of the evidence available (for example, peer-reviewed or grey literature) was also considered when determining the strength of evidence.[38]

Finally, having identified the technology areas, the study team discussed and validated the findings of the analysis with three 'cross-technology' experts. These scoping consultations focussed on establishing a cross-sectoral overview of the technology areas and their influence on key study themes, such as working conditions, employment prospects and productivity.

[36] 'White literature' refers to the content produced by commercial publishers. 'Grey literature' refers to content produced by entities (individuals or organisations) which do not publish content as their main task. For more details, see https://www.lib.uwo.ca/tutorials/greyliterature/

[37] Key search strings included the following terms and their combinations: 'game-changing technolog*', 'emerging technolog*', 'disruptive innovation', 'future of jobs', 'future of employment', 'future of work', 'future of productivity', 'new job skills for the future', 'future of workforce', 'future of services', 'future of services sector'. Additionally search strings related to specific service sectors – for example, transport, financial services, health and healthcare, retail, hospitality, logistics, pharmaceuticals, and entertainment – were used to augment the search as necessary.

[38] It is important to note that in the event of a consultation conducted with a wider set of stakeholder groups and a systematic review of the literature, the emerging strength of evidence could differ significantly.

Phase 2: Analysis and synthesis phase

Literature review searches

The study team identified a bibliography list for each of the technology areas. When the search was conducted, the emphasis was on articles that discuss the (potential) implications of the (future) technology applications in the services sector on the following aspects: work and employment (for example, in terms of skills and competences, working conditions, job quality, and employment relations) and production processes (for example, in relation to productivity, outputs, business models, and value chains). Although articles published before 2013 were considered where relevant, articles published from 2013 onwards have been prioritised. The study team focussed on building a corpus of English-language articles to inform the technology deep dives, but, where appropriate, a limited number of articles in other languages (for example, Dutch, French, German and Italian) were examined. Additional relevant articles were also 'snowballed' from the reference lists of some of the originally identified articles.

The generic search strings used for informing the initial literature search were as follows:

Generic search strings
([technology area] AND service*) AND (work* OR employment OR skill* OR "productivity" OR "working conditions" OR "work* relation*")
([technology area] AND [specific service sector]) AND ("work*" OR "employment" OR skill* OR productivity OR working conditions OR work* relation*)

Exemplary search strings for the [technology areas] were as follows.

Technology area	**Search string**
Advanced robotics	(Advanced robotics OR mobile robotics OR robot*)
Autonomous transport devices	(Autonomous transport devices OR autonomous vehicles OR driverless cars OR drones OR autonomous transport*)
Blockchain	(Blockchain OR distributed ledger* OR dlt)
VR/AR	(Virtual reality OR augmented reality OR mixed reality OR immersive technolog*)
Wearables	(Wearables OR wearable* OR wearable technog* OR wearable device*)

Limitations of the analysis

There are some caveats that need to be borne in mind when reading and interpreting the analyses presented in this working paper. This working paper is part of a larger study that includes the five potentially game-changing technology areas: advanced robotics, autonomous transport devices, blockchain, virtual/augmented reality, and wearable devices. Where relevant and supported by the discussion in the underlying literature, the study team has considered cross-functional and cross-sectoral implications of these game-changing technologies on each other. However, this working paper is intended to be stand-alone, and thus the emphasis is on the trends and socioeconomic implications observed in relation to autonomous transport devices.

During the scoping phase, additional technology areas – notably artificial intelligence and big data analytics – also emerged as important areas for consideration. However, the available literature suggests that these technology areas cover a broad spectrum of changes that could have a significantly transformative effect on the wider society and the economy. As a result, the study team has regarded these technology areas as 'transversal', or 'cross-cutting', and therefore to be considered in conjunction with the five core technology areas as needed – that is, whenever pertinent information about these technology areas emerged when the study team was collecting evidence, this was included in the analysis. For example, artificial intelligence appeared as a significant cross-cutting technology area that has been considered in the analyses conducted in relation to advanced robotics and autonomous transport devices. Any such discussion is informed by the relevance of these technologies within the key themes of this study and where supported by available evidence.

To identify the most relevant literature for the analysis, the study team adopted a rapid evidence review approach. Rapid evidence review does not aim for systematic coverage of the literature and thus aims to strike a balance between the available time and achieving sufficient depth of coverage in selecting the material. In doing so, the study team prioritised peer-reviewed literature for analysis. Where relevant, grey literature was used to corroborate the findings. Since the literature searches predominantly identified English language sources, where feasible the study team looked out for non-English material. Although the study team aimed to ensure inclusion of relevant material, it recognises that the rapid evidence review approach may result in important material not being identified in some cases.

For the interviews, the study team identified a long-list of experts drawing on its own network and subject matter expertise, and with inputs from its advisory board. A short-list was identified based on a consultation with Eurofound to ensure geographical coverage across Europe. The interviews were done based on availability of the external experts and to ensure a broad coverage of the themes related to the study. The study team has primarily used the expert opinion to complement findings from the evidence review. In some cases, expert testimony has been used to identify possible outcomes in the absence of suitable peer-reviewed material. In such instances, the study team has endeavoured to identify these outcomes as expert opinions rather than corroborated facts.

These game-changing technologies are still in the early stages of development, and their implications are still emerging. Therefore the discussion in this working paper combines qualitative analysis with quantitative data where available. Since long-term data on the adoption of technologies is not yet readily available, the study team has considered the available data in the form of patents, research publications, and R&D expenditure as signals of market interest and activity. To understand the general trends across the EU and in key non-EU countries, such as the USA, Japan and China, the study team referred to the latest available Eurostat data on patent activity and R&D expenditure. The timelines for this Eurostat data vary: the latest data on R&D expenditure is dated 2016, and the latest patent data on high-tech sectors is dated 2013. The study team acknowledges that some of the trends observed in the study may change significantly once newer data sets on patents or R&D expenditure become available.

For analysing the trends specific to the technology areas, the study team used the patent landscape reports available via the World Intellectual Property Organization's (WIPO) website[39] and the data on patents and research publications published by the Tools for Innovation Monitoring (TIM),[40] created by the European Commission's Joint Research Centre (JRC). With both these sources, the study team did not have access to the underlying data, and thus the findings on patent data and research publications in relation to the technology areas presented in the study are a form of secondary analysis. Some patent landscape reports rely on the patent data available in public domain and thus do not incorporate the findings for the latest five years at the time of their publication. Although the

[39] See http://www.wipo.int/patentscope/en/programs/patent_landscapes/ for more details.

[40] See http://www.timanalytics.eu/ for more details.

study team endeavoured to ensure that latest patent landscape reports were referred to for each of the technology areas, as of 2018, some of the reports only cover the patent data until 2013. Additionally, the study team recognises that although the patents, publications and R&D expenditure data are useful to identify macro-level trends, these data do not provide the full picture of trends regarding the development and adoption of the technologies. This analysis is thus intended to inform the analysis of socioeconomic implications in relation to such themes as work, employment and productivity, rather than provide a definitive account of the potential outcomes of these technology areas on the services sectors in Europe.

Although the study team has, as far as possible, endeavoured to adopt a pan-European perspective in the analyses, it is important to acknowledge that the geographic scope within Europe in relation to data gathering for the study has been underpinned by the technologies themselves.

Protocol for stakeholder interviews

Part 1: Introductory Questions

1. What is your current role and background?
    - o For what areas do you have responsibility?
    - o Do you have any conflict of interest in relation to this study?

Part 2: General understanding of the developments in the [technology area] landscape

2. With regard to the current state of play of [technology area] (in Europe and beyond), what do you think are some of the main trends that we observe?
3. What are some of the important driving forces for these trends that are enabling the development and adoption of [technology area], and why are these important?
4. What are some of the potential barriers to the development and adoption of [technology area], and how are they hindering the progression?

Part 3: Perceptions of the different socioeconomic implications of [technology area]

5. In relation to its potential to be a 'game-changing' technology area, how are [technology area] likely to have implications for the services sector?
    - In your view, which service sectors (and subsectors or specific industries) do you think present the current (and future) opportunities for the application of [technology area], and why?
    - Can you provide examples of applications of [technology area] in these sectors?
    - Aligned with the earlier question, in your view, which service sectors are least likely to be influenced by the development and adoption of [technology area], and why?
6. We would like to discuss the qualitative implications (positive and negative, direct and indirect) of [technology area] in terms of the following broader themes:
    - o Work organisation, (workforce) productivity, and output/products
    - o Employment
    - o Skills
    - o Individual working conditions
    - o Collective employment relations
    - o Are there any other implications?

Part 4: Perceptions of potential applicability of [technology area] to services sectors in Europe and beyond

7. In relation to some of the points that that you have raised so far, could you offer any observations that are specific to EU countries, or particular "geographical areas" in Europe?
    - o How does the situation vary in / compare to different parts of the world?
8. More specifically, do you have any thoughts on potential 'real world' case examples to illustrate the application/implications of [technology area] in particular services sectors?
9. Could you recommend any relevant literature sources that we should consult as part of this study?
10. Do you have any thoughts on prospective quantitative data sources/indicators that we could draw upon?

Part 5: Additional insights – ethics and collective bargaining

11. Do you have any thoughts about the ethical implications concerning the deployment of [technology area]? Do you have any thoughts on the way increased use of [technology area] could change or influence the ethics of human-machine interaction at work would be welcome.

12. Do you have any thoughts about developments, if any, in collective bargaining with regard to changes in job descriptions or occupations?

Part 6: Wrap-up

13. Do you have any recommendations for other potential (technology/socioeconomic) experts and/or stakeholders that you think we should be speaking to?
14. Do you have any recommendations for potential case examples i.e. examples of [technology area] being used in practice and showcasing some of the implications we have covered as part of this discussion?
15. Based on your knowledge and experience of working in this field, is there anything else that you would like to add that we have not yet covered?

Interviewees

- Transport sector expert
- European public sector expert
- Third sector expert on transport.
- Trade union representative.

Case example interviewees

- Trade union representative.
- Port of Rotterdam representative.
- Two Easy Mile representatives
- Volvo car group representative.

The European Foundation for the Improvement of Living and Working Conditions (Eurofound) is a tripartite European Union Agency, whose role is to provide knowledge in the area of social, employment and work-related policies. Eurofound was established in 1975 by Council Regulation (EEC), No. 1365/75, to contribute to the planning and design of better living and working conditions in Europe.