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An analysis of possible socio-economic effects of a Cooperative, Connected and Automated Mobility (CCAM) in Europe

Effects of automated driving on the economy, employment and skills

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An analysis of possible socio-economic effects of a Cooperative, Connected and Automated Mobility (CCAM) in Europe - Effects of automated driving on the economy, employment and skills

A Cooperative, Connected and Automated Mobility (CCAM) is expected to have an overall positive impact on our economy and society. It is anticipated that sectors like automotive, electronics and software or freight transport will be positively affected while other sectors like insurance or maintenance and repair will face significant challenges. Important labour changes lie ahead for professional drivers, decreasing driving responsibilities towards new more technical roles. Some of these jobs will disappear in the long-term. This study feeds into the definition of an EU approach towards CCAM, strengthening the Commission's understanding of the societal aspects linked to it.

Contents

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The picture in the cover page is representing the *Hammering Man* sculpture designed by Jonathan Borofsky for the city of Frankfurt in 1990. In the words of the artist: "*The Hammering Man is a symbol for the worker in all of us*". Given the relevance of the automotive industry in Frankfurt (where the International Motor Show (IAA) takes place every two years next to the statue of the hammering man) and Europe, the picture symbolises future industries and users of a connected and automated mobility, and reflects the related socio-economic aspects dealt within the present study.

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Executive summary

A Cooperative, Connected and Automated Mobility (CCAM) is likely to have significant impacts on our economy and society. It is expected that CCAM will unveil new and unprecedented mobility opportunities that hold the potential to unlock a range of safety, environmental and mobility/energy efficiency benefits. At the same time, it is anticipated that it will bring deep changes in the labour market, progressively making some occupations and skills less relevant, while at the same time opening up new opportunities for different businesses and requiring new and more advanced skills. With Europe accounting for 23% of global motor vehicle production (1) and almost 72% of inland freight transported by road in Europe (2), the full deployment of Connected and Automated Vehicle (CAV) technologies is expected to have a substantial impact on the European economy. The economic impacts of CAVs will go far beyond the automotive industry, into sectors like insurance, logistics or health, among others. While it is clear that CAVs could offer unique opportunities for value creation, it is also essential to acknowledge that they might imply a substantial transformation of our economy and society.

Objective

The study analyses the value at stake for both economy and society as a result of a transition towards CCAM in Europe. It identifies the economic sectors that are most likely to be affected by CCAM as well as the factors driving future changes in each sector. The ultimate goal is to estimate ranges of potential impacts for the main affected sectors, with the support of a set of scenarios. The study also analyses the potential effects of CCAM on the workforce and skills that may be needed in the mobility transition. The focus of the study is exclusively on road transport for both passengers and freight.

Methodology and scenarios

A deployment scenarios matrix has been developed by considering projections of vehicle travel made with different levels of automation, for both passenger and commercial vehicles in 2025 and 2050 (3), on the basis of three levels of development in technology, policy and users' adoption (see Table 1). For passenger transport, our own assumptions of the amount of travel served by Mobility-as-a-Service (MaaS) versus Individual Ownership (IO) are given.

Table 1. Deployment scenarios matrix

SCENARIOS	**LEVELS OF DEVELOPMENT PER AREA**		
	TECHNOLOGY	**POLICY**	**USERS**
Baseline	*Eurostat (4) and EU Reference Scenario 2016 (5), without accounting for CAV technologies*		
Scenario 1. Low uptake	Slow	Little	Few
Scenario 2. Medium uptake	Moderate	Moderate	Moderate
Scenario 3. High uptake	Fast	Strong	Many

Source: Own elaborations.

These scenarios, together with a set of Key Performance Indicators (KPI), serve as a basis for the estimation of impacts per sector. To this aim, influencing factors like impacts of CAVs on traffic, accidents or the environment, each of which have implications on the economy, are studied. Besides a qualitative analysis based on literature, an attempt to provide some quantitative assessment is performed using the data available from existing sources (e.g.

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(1) According to 2016 data from ACEA World Motor Vehicle production Statistics (see footnote 54 for more details).

(2) European Commission (2017a).

(3) Passenger vehicle rates are extracted from Nieuwenhuijsen et al. (2018) and then taken as a basis for making assumptions on commercial vehicle rates.

(4) Data from 2015, from different Eurostat Databases, namely: Structural Business Statistics (SBS) and National Accounts (NA) (see footnotes 73 and 74 for further details), and according to the Nomenclature statistique des Activités économiques dans la Communauté Européenne (NACE) Rev. 2 classification (Eurostat, 2008).

(5) European Commission (2016a); precisely, taking the modified baseline of EU Reference Scenario 2016 from Hill et al. (forthcoming 2018) to see the evolution from 2015 up to 2050.

Eurostat Database), and relating it to the scenarios. To the extent possible, findings are described for the European context. Other trends like electrification of transport are only partially covered in this analysis, as the main focus is on automation and connectivity.

Along the study, some simplifying assumptions have been adopted given the uncertainty and complexity of the topic under study, as well as the lack of data (few studies exist on the topic). These should be revisited in the future, accounting for additional insights into CAVs behaviour and effects in different areas. Although it is implicitly considered in the narrative used to define the different scenarios, the study does not consider interactions between sectors. The estimations may therefore suffer from some double counting and from non-linear effects that cannot be properly addressed in the present work.

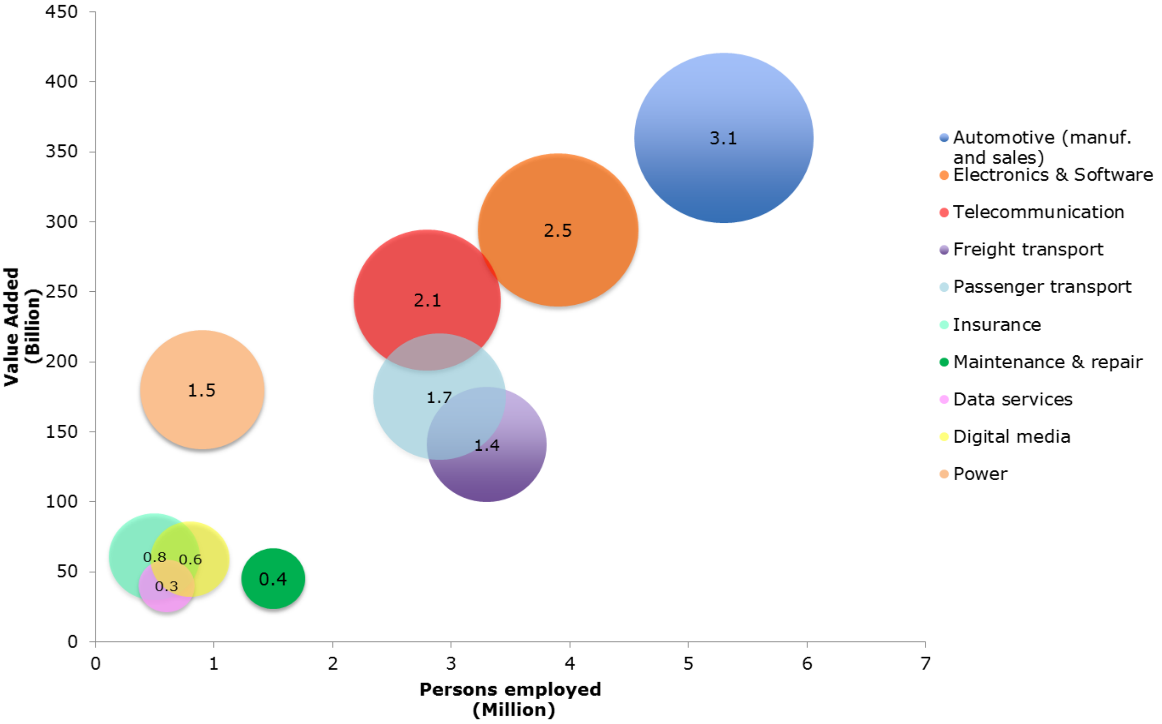
In addition, the economic impacts have to be seen as the global impacts of the introduction of CAVs to the European case. How much these impacts will contribute to the European economy has still to be seen. Much will depend on the capability of European businesses to stay competitive vis-à-vis new competitors, especially from the communication and Information Technology (IT) sectors, as well as on the ability of education and training systems to take anticipatory actions that address the skills needed in the future. It is also worth mentioning that the indicator to measure the economic impacts that has been adopted in this study is the potential revenues. The impact on the future European value added has not been considered at this stage.

The reader is invited to consider the estimations presented in this study as well-qualified indications of future trends and not in absolute terms.

Main economic figures in the 2015-2050 period

Figure 1 shows the current state of the sectors that are most likely to be affected by CCAM, including their relative size within the present EU-28 economy.

Figure 1. Current state of the main sectors affected by CCAM, showing 2015 figures on Value Added (VA), persons employed and share of Gross Value Added (GVA) in the total EU-28



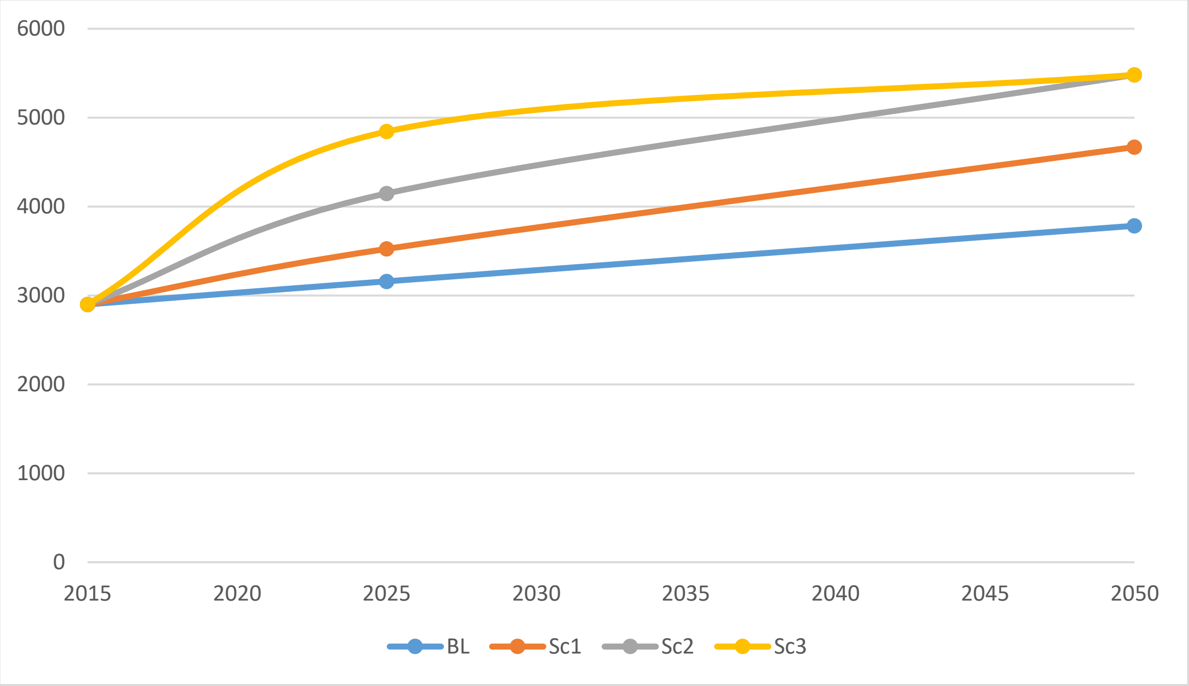
Source: Own elaborations (based on 2015 data from Eurostat SBS and NA databases) (⁶).

(⁶) The share of GVA is indicated at the centre of each bubble as % and is represented by the size of each respective bubble.

Some potential impacts for some of these sectors are indicated below.

As far as the **automotive** sector is concerned, CAVs may reinforce vehicle sales in line with travel activity increases. The higher the level of automation, the stronger the effect on Vehicle Kilometres Travelled (VKT), mostly as a result of a reduction in driving costs (including changes in the value of travel time) and new users like young people, elderly or disabled ([7]). Even though new mobility service models (MaaS) may increase vehicle usage intensity ([8]), the resulting decreased vehicle ownership may considerably impact vehicle sales. Our scenario estimations provide ranges of passenger vehicle sales increases from 18% to 39% during the period 2015-2025 and from 33% to 51% in the period 2015-2050. Figure 2 and Figure 3 show VKT and vehicle sales projections respectively. In Figure 3, it is possible to observe long-term lower vehicle sales on scenario 3 as a result of a dominant MaaS-based travel regime. Using current average car prices ([9]), total revenues from passenger car sales could exceed 550 billion euros by 2050. It is also expected that the sales of heavy commercial vehicles will increase in response to a more intense road travel activity in the future, which could be further reinforced by a more efficient operation of automated trucks. In this case, a growth of 19-29% could be expected in the period 2015-2025 and 38-68% in the 2015-2050 period. Total revenues from commercial vehicle sales could almost reach 150 billion euros in 2050 ([10]).

Figure 2. Passenger transport (in billion vehicle kilometres) for Baseline scenario (BL) and scenarios 1, 2 and 3 (Sc1, Sc2 and Sc3)



Source: Own elaborations.

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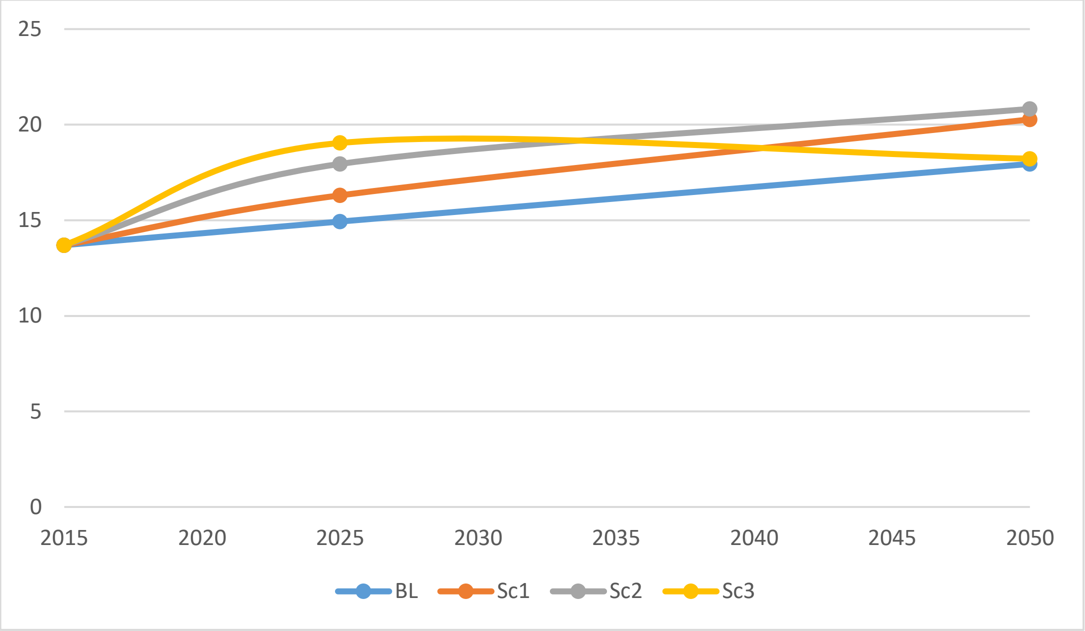
[7] As cited in e.g. Wadud et al. (2016).

[8] A 75% usage increase is stated in Schoettle and Sivak (2015) or a 10 times increase in Arbib and Seba (2017).

[9] An average passenger car sales price of 27,496 euros is used (Hill et al., forthcoming 2018). Please note that automated driving technologies are not included in this price, but counted separately in the electronics and software sector.

[10] Using the following three average vehicle prices for Light, Medium and Heavy Duty Vehicles: 30,238 euros (Hill et al., forthcoming 2018), 60,233 euros (average of 7.5, 12 and 18 Tonne vehicle prices from Lastauto Omnibus-Katalog, 2017) and 100,000 euros (average price of 4*2 and 6*2 HDVs considering Lastauto Omnibus-Katalog, 2017) and their relative shares in 2025 (according to 2015 data from ACEA Consolidated registrations by country Statistics, further explained in footnote 84) and 2050 (baseline of DIONE fleet impact model, Thiel et al., 2016).

Figure 3. Estimated vehicle sales for passenger transport (in million cars)



Source: Own elaborations.

The **electronics and software** sector would clearly benefit from the production and sale of new components and systems needed for automated driving (including hardware and software components). Whereas software will gain a more dominant role (in terms of monetary value proportion) with regard to today ([11]), the market for CAVs' hardware components like cameras, lidar, etc. will also grow ([12]). With the previously mentioned vehicle sales projections, total revenues from the sector could almost reach 180 billion euros by 2025 for both passenger and freight automated vehicles ([13]).

The **telecommunication, data services and digital media** sectors are also expected to experience significant growth, as in-vehicle connectivity increases and becomes pervasive. 5G networks will support the exchange of massive amounts of data generated by a future CAV. The monetization of car data holds a great potential (McKinsey&Company states it could generate from $450 to $750 billion globally in revenues by 2030 ([14])) and users are already demonstrating willingness to pay for services built around this data ([15]).

Vehicle automation will act as a transformational technology in the **freight transport** sector by diminishing operating costs and allowing more efficient logistics ([16]). These benefits would justify the idea that this sector becomes one of the early adopters of CAV technologies ([17]). The two most costly elements in commercial vehicles operation are fuel and drivers, both of which can be reduced through truck automation ([18]). When it comes

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([11]) From a 10%-90%-0% to a 40%-40%-20% for software, hardware and contents (including the apps that connect and integrate software and hardware) respectively, as stated in Römer et al. (2016).

([12]) Asselin-Miller et al. (2017).

([13]) It is important to note that the cost of automation is too uncertain at present and therefore subject to significant changes. Our calculations are based on an assumed cost of full automation (level 4/5) for passenger vehicles of around $10,000 by 2025 (from Mosquet et al., 2015), which is also used in Wadud's Total Cost of Ownership (TCO) analysis (2017). Though it could represent a lower bound estimate when compared to other sources (e.g. Bansal and Kockelman, 2017). For trucks, £15,000 is used (average of the estimated prices for different types of trucks indicated in Wadud, 2017). It could also represent a lower bound estimate. Thus, in euros, the cost of full automation is 8,091 and 16,870 for passenger vehicles and heavy duty vehicles respectively. Other estimations are made for lower levels of automation (see details in 3.2.2).

([14]) Bertoncello et al. (2016).

([15]) Dungs et al. (2016).

([16]) World Economic Forum (2016a).

([17]) Wadud (2017).

([18]) Gundermann et al. (2015).

to fuel savings, truck platooning could decrease fuel consumption by 2-8% for the leading vehicle and 8-13% for the following vehicle (19). The role of a professional driver can be radically transformed in the future (starting with early platooning applications), gradually undertaking other duties than driving and possibly turning into a more technical role (20). To which extent this will lead to a reduction in the number of drivers needed still remains an unanswered question that deserves careful attention. It is also important to stress that CAV technologies could help to compensate the shortage of long-haul drivers (21), as e.g. Germany is expecting to lose around 250,000 drivers who will retire in the next 10 to 15 years (22). Effects of CCAM on truck driver jobs are further discussed in the employment section below.

The **insurance** sector could be disrupted by the expected drastic reduction in the number of road accidents. The improved road safety conditions might imply significant discounts in motor vehicle premiums. On the basis of discounts currently applied to vehicles equipped with collision avoidance systems (23), our estimations indicate potential decreases in insurance premiums of 10-30% in 2025 and 15-40% in 2050 compared to today. These reductions could represent up to 53 billion euros in 2050 (24).

A lower crash rate would also drive a large part of the changes expected in the **maintenance and repair** sector, with revenues decreasing as a result of a lower demand for crash-related repairs (25). Although a lower acceleration/deceleration could also lead to reductions in maintenance, this potential decrease could be offset by higher labour and equipment costs of repair (26). Telematics will enable predictive maintenance applications that would also lead to lowering repair frequency and overall maintenance costs (27). The Original Equipment Manufacturers' (OEM) privileged access to car sensor data would make them well-positioned in this type of offerings (28). Competition in car maintenance would be higher, thereby creating downward price pressure and reduced VA in these services. One potential factor leading to a growth in revenues in this sector could be linked to the cleaning and repair activities that could be needed for shared vehicles (29).

An overview of the expected direction of change in each of the sectors is given in Table 2.

Table 2. Main economic effect per sector

Industries	Main effect prevailing in 2025 - 2050 scenarios
Automotive	↑
Electronics and software	↑
Telecommunication, data services and digital media	↑
Freight transport	↑
Insurance	↓
Maintenance and repair	↓

LEGEND: ↑ Positive effect, ↓ Negative effect

Source: Own elaborations.

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(19) SARTRE (2014), as cited in Janssen et al. (2015).
(20) Clements and Kockelman (2017).
(21) Lanctot (2017).
(22) Hollis (2016).
(23) Palmer (2015), as cited in Wadud (2017).
(24) Revenues from new insurance categories (e.g. cyber security, product liability for software and hardware) are not considered in these calculations.
(25) Thierer and Hagemann (2015).
(26) Wadud (2017).
(27) European Commission (2017b).
(28) Mohr et al. (2014).
(29) Bösch et al. (2018).

Main findings on employment and skills

The concerns on job destruction by machines can be dated back to the first industrial revolution. The short run effects of effective technologies implementation negatively impacted workers (30) but on the long run, technology advancements eventually led to higher job creation (31). In general, estimating the **number of jobs at risk of automation** has been proved difficult and can lead to completely different results depending on minor changes applied in the approach used. Frey and Osborne find for example that 47% of US jobs are at risk of computerisation (32) but Arntz et al. find that only 9% of jobs in OECD countries is at risk instead (33). The former study estimates the share of jobs threatened by automation based on experts opinion over specific occupations while the latter uses the same methodology but with a task-based approach, so based on the same experts predictions but estimating the degree of their automation-risk predictions on the proportion of automatable task within each occupation.

At the present state of art, Automated Vehicles (AVs) cannot perform all the tasks required in most driving-related jobs and there is much uncertainty if they will ever do (34). However, a partial tasks substitution (e.g. platooning substitutes the tasks that now strictly require a second driver to perform) will increase competition in the lower-skills labour market. Firstly, because the tasks substitution by AVs will make the job appealing for more people that previously had a dislike for driving (35). Secondly, because lower demand for drivers will make the transport sector less accessible. The competition effect will not only be restricted to the transport sector but to all the other lower-skilled occupations where displaced drivers will apply (36).

According to our estimations, workers endangered of technological substitution (drivers and mobile plant operators, ISCO 83) working in land transport (NACE 49 sector) amount to approximately 1.5% of total EU-15 employment in 2012 and those who require new training to keep performing the job (metal, machinery and related trades, ISCO 72) in wholesale, retail and repair of motor vehicles (NACE 45 sector) amount to 0.7% of total EU-15 employment in 2012 (37). It also seems evident that employment effects will not only be restricted to the land transport sector but will impact all sectors that employ drivers such as warehousing and support, wholesale trade or postal and courier activities. ITF estimates that the current 3.2 million truck-driving jobs in Europe may decrease to 2.3 or even up to 0.5 million by 2040 according to different scenarios (38). A slow CAV uptake or an informative awareness campaign can lead workers to qualify on time and mitigate the transition costs for them (39). Retraining or income assistance programs are mechanisms that can support the transition (40).

It is relevant to note that both occupations under study (ISCO 72 and 83) have low levels of Information and Communication Technologies (ICT) use, whereas **ICT skills** will be increasingly demanded in the future. CEDEFOP highlights the increasing land transport sector dependency on ICT-based and specialized equipment and products (41). Thierer and Hagemann also emphasize the need for ICT skills in addition to the traditional vehicle repair skills (42). In this context, a shortage of ICT professionals has been identified for 2020 (43). If the demanded skills can be matched in the future, there could be opportunities for

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(30) The White House (2016).

(31) ITF (2017).

(32) Frey and Osborne (2017).

(33) Arntz et al. (2016).

(34) Litman (2018).

(35) Miller, J. (2015).

(36) The White House (2016).

(37) The selected occupations come from the International Labour Organization ISCO-08 International standard classification of occupations.

(38) ITF (2017).

(39) Ibid.

(40) Rea et al. (2017).

(41) CEDEFOP (2016).

(42) Thierer and Hagemann (2015).

(43) European Commission (2016b).

reallocation of employees. For instance, Thierer and Hagemann claim that in the future some highly qualified mechanics might move over to higher-paying jobs in the information sector (44). The ITF also postulates that skilled and experienced drivers could be demanded in the case that remote control rooms are installed for CAVs monitoring (45).

Inequality between low-skilled and high-skilled workers will widen. AVs can make some sectors more profitable but most of the benefits will be reaped by those highly skilled workers who can either produce and repair the new vehicles or those who get more productive with the additional time previously spent in transport activities. This has been proven to be the case in other non-transport-related sectors (46). The European Commission highlights that by 2025, about 50% of EU's jobs offerings will target highly qualified people (47). However, another aspect to consider is the easier geographical connectivity facilitated by CAV technologies, which could enable workers to accept jobs from firms previously rejected due to distance to the workplace or because less accessible in general (48). This effect is likely to be positive on labour market participation and on skills match between employers-employees.

Another challenge is predicting what kind of **new occupations** will be created in the future. Even though recent labour market experiences suggest that those will be mostly skewed on the higher part of the skill distribution (49), it is very difficult to determine the qualifications and characteristics of the future jobs demanded by the economy.

At the level of **skills required for driving a CAV**, the automation of the driving task will increasingly require supervision and selective intervention skills in opposition to manual control and manoeuvring skills (50). Understanding the automated driving systems functioning will also be essential for a safe operation of AVs, for which the highly heterogeneous vehicle systems could represent a challenge (51). As automation is gradually deployed, progressive and continuous training could become more relevant than the current one-off initial training (52).

The impacts of CCAM on employment are largely influenced by the speed of introduction of the new technologies and mobility changes. The more gradual the introduction will be the higher the probability that the negative implications on employment will be absorbed by the economic system of the European society.

Conclusions and way forward

The present study has highlighted some main challenges and opportunities linked to the transition towards CCAM, which will need to be faced in order to unlock the benefits that it could bring to our society and economy. Policymakers and industry players in Europe shall then seize the opportunity of capturing these benefits within the EU by adopting different measures. The findings presented in this study will contribute to the ongoing debate on the type and magnitude of potential impacts of CCAM on our economy and society.

Although the scenarios analysed do not represent a forecast of impacts, they help to illustrate a set of possible effects that could drive fundamental changes in different sectors of our economy and society. Results of this initial assessment, corroborated by additional data, will be used as input to a more thorough study where the different elements identified here will be integrated in a modelling framework able to handle the dynamics and the causal loops intrinsic to the European economic sector.

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(44) Thierer and Hagemann (2015).

(45) ITF (2017).

(46) As stated in e.g. ITF (2017), The White House (2016), Arnzt et al. (2016), Frey and Osborne (2017), OECD (2016).

(47) European Commission (2016c).

(48) Litman (2018).

(49) ITF (2017).

(50) Spulber and Wallace (2016).

(51) Ibid.

(52) Ibid.

1 Introduction

The development of automated driving technologies is gaining momentum at present and it has become no more a question of if but when autonomous vehicles will be a reality in our roads (Mosquet et al., 2015; DHL Trend Research, 2014). As their market deployment becomes closer, with some levels of autonomy already available in the market (up to SAE level 2 technologies, SAE International, 2016 ([53])), central questions are being raised, such as the economic and societal implications that these technologies will have. A Cooperative, Connected and Automated Mobility (CCAM) is likely to bring fundamental changes to our economy and society. It is expected that CCAM unveils new and unprecedented mobility opportunities that hold the potential to unlock a wide range of safety, environmental and efficiency benefits. At the same time, it is anticipated that it will bring profound changes in the labour market, progressively making some occupations and skills less relevant, while at the same time opening up new opportunities for different businesses and requiring new and more advanced skills. Given that Europe accounts for 23% of global motor vehicle production (being second after China ([54])) and almost 72% of inland freight is transported by road in Europe ([55]), the full deployment of Connected and Automated Vehicle (CAV) technologies is likely to have a substantial impact on the European economy. The different stakeholders along the automotive value chain will be affected, e.g. vehicle manufacturers and suppliers, dealers and aftermarket services providers, mobility services providers. But the economic impacts of CAVs will go far beyond the automotive sector, into sectors like insurance, logistics or health, among others. In a context of high global competitiveness, Europe must harness the opportunities brought by CAV technologies and strengthen its leadership position in innovative mobility (which is currently the largest economic sector in the world, European Commission, 2017c).

The analysis of socio-economic effects of CAVs is recently growing attention, given its significance for both businesses and the life and working conditions of citizens. Far-reaching socio-economic impacts can be already associated to these technologies, like an increase in safety (through reduced road accidents), an improved accessibility (for persons with limited transport access), a growth in productivity (with changes in the value of travel time) or a transformation of current transport and vehicle-related jobs (professional drivers, mechanics and engineers, to name a few). They could also give rise to inequality and social division, like in the case that it leads to different levels of services for different users or to a widening of the digital gap (POLIS, 2018). Besides, they could lead to traffic and emissions increases, as a consequence of safer travelling conditions, new users and new usage patterns (Fagnant and Kockelman, 2015). They can also raise important ethical considerations (Renda, 2018). They have the potential to create new highly qualified jobs while making others obsolete. However, the analysis of their socio-economic implications still remains a largely unexplored area, with a limited number of publications existing in the field. Further analysis is thus needed to cover the gap, and more especially within the European Union, so that anticipatory strategic actions can be made with extensive knowledge of the possible consequences of adopting different measures. For example, a new skills training program could be prepared to cover the changes in skills needed in the future. Industries can also prepare themselves by adapting their business models (e.g. as many are already doing through new partnerships or recruitments). Subsidies could be offered to displaced workers. While it is clear that CAVs could offer unique opportunities for value creation, it is also essential to acknowledge that they might raise important concerns and imply a substantial transformation of our economy and our social and living conditions. Wide European policy areas are thus affected by the introduction of CAVs, such as the ones on regional development, transport, energy, climate change and environment, ethics, growth and jobs and skills (European Commission, 2017d).

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[53] For more details on the SAE levels of autonomy, see 2.1.

[54] ACEA World Motor Vehicle production Statistics, available at: http://www.acea.be/statistics/tag/category/world-production (last accessed 9 April 2018).

[55] With nearly half of the total freight transport activity and more than 80% of the total passenger transport activity done by road (European Commission, 2017a).

With increasing market penetration, automation will likely act as a transformational factor in mobility, closely interwoven with on-demand mobility services and electro-mobility. The higher the level of automation, the larger the socio-economic effects (up to the so called Passenger Economy (56) linked to full automation). Urbanization, the shifting global population dynamics and the rapid expansion in global connectivity will also disrupt the current mobility paradigms. In terms of readiness for the deployment of fully automated vehicles, a myriad of challenges still remain to be addressed, ranging from the development of CAV technologies (mostly the training of algorithms) to users' acceptance and adoption of CAV systems, and the enabling legal and regulatory aspects. But hype in the media may lead to inflated expectations about CAVs, currently showing their strong disruption potential (Panetta, 2017). These challenges need to be faced in order to unlock the unprecedented benefits that CAV technologies could bring, keeping social fairness and improved competitiveness as crucial targets to be pursued.

In order to understand and anticipate some of the likely economic and employment changes brought about by CAVs, a comprehensive analysis of recent studies has been conducted. In this analysis, the main economic sectors affected by these technologies have been studied: automotive manufacturing and supply chain, electronics and software, telecommunication, data services, digital media, freight transport, passenger transport, insurance, maintenance and repair and other sectors. On the basis of Key Performance Indicators (KPIs) for each sector and on different assumptions on the rate of penetration of the new technologies, different scenarios have been designed and analysed in a qualitative manner. Different societal implications such as the impacts on traffic, accidents or environment, each of which have implications on the economy, are also studied. Finally, the analysis is specifically covering the potential effects of CAVs on the workforce and is drawing conclusions on skill gaps that may emerge in the mobility transition.

1.1 Policy context

The EU must undertake a leading role in shaping the global change in order to stay competitive in the automotive sector, which represents more than 3% of EU's Gross Value Added (GVA), provides jobs for over 5 million people (57) and stands as the largest private Research and Development (R&D) investor in the EU (European Commission, 2017c). To this aim, the European Commission is actively supporting the coordinated rollout of CAVs by 2020 through a wide range of measures and initiatives in cooperation with stakeholders from the industry and Member States (European Commission, 2017c). Since the Declaration of Amsterdam (European Union, 2016), different advances have occurred in the field, such as the signature of the Letter of Intent in Rome on March 2017 by EU ministers, plus Norway and Switzerland, on testing and large scale demonstrations of Connected and Automated Driving (CAD) (European Commission, 2017e), and the establishment of High Level Structural Dialogues (two have occurred to date, and an Action Plan on Connected and Automated Driving (CAD) has been produced, German Federal Ministry of Transport and Digital Infrastructure, 2017a). The Cooperative Intelligent Transport Systems (C-ITS) Platform initiated in 2014 was successfully concluded with the publication of a second report that further develops a shared vision on the interoperable deployment of C-ITS towards CCAM in the EU (European Commission, 2017f). Linked to it, the C-ROADS Platform was initiated in 2016 by European Member States and road operators for cross-border testing and implementation of harmonised and interoperable C-ITS services. Besides, the GEAR 2030 initiative was established at the beginning of 2016 as a High Level Group (HLG) on the Automotive Industry in order to agree on a roadmap to follow over the next 15 years, which was delivered by the end of 2017 (European Commission, 2017d). Several Roundtables on CAD have been held since 2015 (European

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(56) The Passenger Economy is a term coined by Intel that can be defined as the economic and societal value generated by fully automated vehicles (SAE level 5) (Strategy Analytics, 2017). It represents the value of the products and services derived from fully automated vehicles and is closely linked to Mobility-as-a-Service (MaaS). According to this study, the Passenger Economy can represent a US$ 7 trillion global opportunity by 2050, 24% of which is allocated to Europe.

(57) According to our analysis, as explained in 3.2.1.

Commission, 2015) to strengthen the digital dimension of CCAM. From these roundtable discussions, the European Automotive - Telecom Alliance (EATA) (ACEA, 2016a) and the 5G Automotive Alliance (5GAA) (Nica, 2016 ([58])) were created in an effort to promote the wider deployment of CCAM and 5G in the automotive sector respectively. R&D funding opportunities have been made available through the Horizon 2020 programme over the last decades and more recently with calls particularly devoted to Automated Road Transport (ART) ([59]). In 2017, Europe organised the first conference on CAD ([60]). Internationally, the G7 declarations on CAD brought together the transport ministers of the G7 states and the European Commissioner for Transport to jointly encourage the developments in the field of CAD. Moving towards low-emission technologies, such as electric powertrains for vehicles, is also a high priority action for Europe. More recently, the three Commissioners for Transport, Budget and Human Resources and the Digital Economy concluded on the opportunity for Europe to lead in the field of connected mobility, highlighting that CCAM builds on the Digital Single Market strategy and is an integral part of the Commission's strategy on low emission mobility and the 2018 Mobility Package (European Commission, 2017g). Relevant pillars are the Commission's C-ITS strategy (European Commission, 2016d) and the updated EU telecoms rules to boost investments in high-speed and quality networks (European Commission, 2016e; European Commission, 2016f).

Working conditions and social challenges take a prominent role in this context of change. The European Commission has put forward an agenda for the future of mobility in the EU, to boost jobs, growth and investment while ensuring a socially fair transition as well as safe and secure travel conditions (European Commission, 2017c). The adaptation of the workforce to the new skills that are demanded by novel technologies is a critical success factor in reaping the benefits associated to them. The anticipation of future needs, closely followed by a stronger societal dialogue and support mechanisms, is emphasized in the communication. Specifically, the Commission is supporting sectoral partnerships in the automotive sector through its "Blueprint for Sectoral Cooperation on Skills" (European Commission, 2017h) under the actions envisaged in the "New Skills Agenda for Europe" initiative ([61]). The aim is to promote cooperation between employers, trade unions, education and training institutions to identify and address skills mismatches and develop skills strategies and update curricula and training modules. To support the work of such sectoral partnerships, the Commission launched a call for proposals under its Erasmus+ programme in early 2017 (European Commission, 2017i). Anticipation, adaptation and investment are strongly required in the transition towards the future mobility. As announced by the end of 2017, a third and last part of the "Europe on the Move" package will be presented along the first half of 2018 (European Commission, 2017j), where CCAM will be a key pillar.

The need for a European shared strategy on CAVs has been stressed by the GEAR 2030 HLG in its final report from 2017, as it was previously underlined in the Amsterdam Declaration and in the C-ITS strategy (European Commission, 2017d). This covers a regulatory framework that enables the market deployment of these vehicles, as well as to continue with research and testing efforts at EU and Member State levels. It also calls for the assessment of long-term impacts of CAVs, especially on jobs and ethical aspects, which can be discussed and integrated into broader EU policies aimed at ensuring social acceptance. The importance of facilitating a societal dialogue to contribute to the public acceptance of these technologies is emphasised, involving the European Commission, all social partners, Member States, local and regional authorities, as well as through pilot and research initiatives. In line with this, the Council of the European Union concluded end of

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[58] 5G Automotive Association (5GAA) website available at: http://5gaa.org/ (last accessed 13 April 2018).

[59] European Commission Innovation and Networks Executive Agency (INEA) H2020 Automated Road Transport list of related projects available at: https://ec.europa.eu/inea/en/horizon-2020/h2020-transport/projects-by-field/automated-road-transport (last accessed 5 April 2018).

[60] The 1st European Conference on Connected and Automated Driving website is available at: https://connectedautomateddriving.eu/conference/ (last accessed 13 April 2018).

[61] Details on the New Skills Agenda for Europe can be found in: http://ec.europa.eu/social/main.jsp?catId=1223 (last accessed 5 April 2018).

2017 on the digitalisation of transport, specifically emphasising the importance of a wide societal dialogue and therefore calling on the Commission to "*assess the socio-economic and environmental impact of automation and digitalisation in the field of transport taking into account the new skills needed in that sector, and, if necessary, to propose measures to address those impacts*" (Council of the European Union, 2017).

The importance of creating added-value for society has also been emphasised by the European Economic and Social Committee (EESC), in the opinion document titled "Implications of the digitalisation and robotisation of transport for EU policy-making" adopted mid-2017 (European Economic and Social Committee, 2017). Political debate and involvement of civil society in transport planning processes are highlighted as necessary steps to be undertaken for that purpose. The EESC emphasises the relevance of "*dealing with these structural changes in a proper way, by preparing strategies on how to ensure a fair and smooth transition, decrease negative social impacts and respond to the skills gap, combined with the appropriate monitoring of progress*". Social dialogue and information and consultation actions addressed at workers at all levels are suggested to play a key role in the transition process.

In this framework, the present study aims at shedding light on the possible socio-economic impacts of a transition to a CCAM mobility. Enhancing the present knowledge in this area can be extremely beneficial to inform future EU policies in different fields that lead to a maximisation of the opportunities brought by new technologies and services in mobility.

1.2 Purpose and scope of the study

The present study analyses in a qualitative and, to some extent, also quantitative way the value at stake for both the economy and society as a result of a transition towards a CCAM mobility in Europe. The results of this exploratory study are feeding into the definition of an EU approach towards CCAM, specifically aimed at strengthening the Commission's understanding of the societal aspects linked to it.

The specific goals of this study are herein presented:

- Defining a set of scenarios of the future mobility by road, in consideration of CAV technologies and usage patterns, with a short-to-medium and medium-to-long perspective.
- Identifying the economic sectors in Europe that are most likely to be affected by CCAM as well as which influencing factors might drive future changes in each of these sectors.
- Estimating the ranges of potential impacts for the main affected sectors, with the support of the defined scenarios.
- Analysing the potential effects of CCAM on the European workforce, both in terms of jobs at risk and those that could be increasingly demanded in the future.
- Identifying the skills that may be required in the mobility transition.

The focus of the study is exclusively on road transport for both passengers and freight. It specifically targets the socio-economic effects linked to different degrees of automation (SAE International, 2016). In the context of this study, 2015 has been considered as the baseline date. This report has been informed by desk research jointly with data analysis on the basis of currently available data sources (e.g. Eurostat Database) and supported by dedicated stakeholders' consultation activities. Findings are therefore mainly qualitative and, to the extent possible, they are described for the European context. Given the current lack of data and studies, simplified assumptions have been necessary and should be reviewed in subsequent analysis efforts that follow the present study.

While it is impossible to separate the CCAM trend from other on-going and future trends (like the electrification of transport or on-demand mobility services, among others), this study aims at specifically addressing the automation and connectivity trends in particular. Some references to these parallel trends are anyhow made in specific parts of the report.

The report uses the term Automated Vehicle (AV) to refer to the different automation systems capable of performing part or all of the Dynamic Driving Task (DDT), as recommended by SAE (SAE International, 2016) (i.e. from level 0 to level 5 automation). Autonomous would be thus equivalent to fully automated (i.e. level 5 automation). In line with these terms, Connected and Automated Vehicle (CAV) is also used along the report, given that in the future connectivity and automation will merge (European Commission, 2016d). The CCAM (Cooperative, Connected, and Automated Mobility) acronym is also widely used throughout the report, with a special focus on the road transport mode. Finally, in the employment context, the term automation can be sometimes used to broadly refer to the replacement of labour input by machine input for some types of tasks within production and distribution processes (Fernández-Macías, 2017).

The remainder of the report is organised as follows:

- Section 2 describes the automation levels and automation deployment scenarios which are the basis of the study.
- Section 3 provides a review of the potential economic and societal impacts of CCAM.
- Section 4 points out which are the limitations of the study and which future lines of work could possibly emerge from this work.
- Finally, Section 5 summarises the main findings of the study.

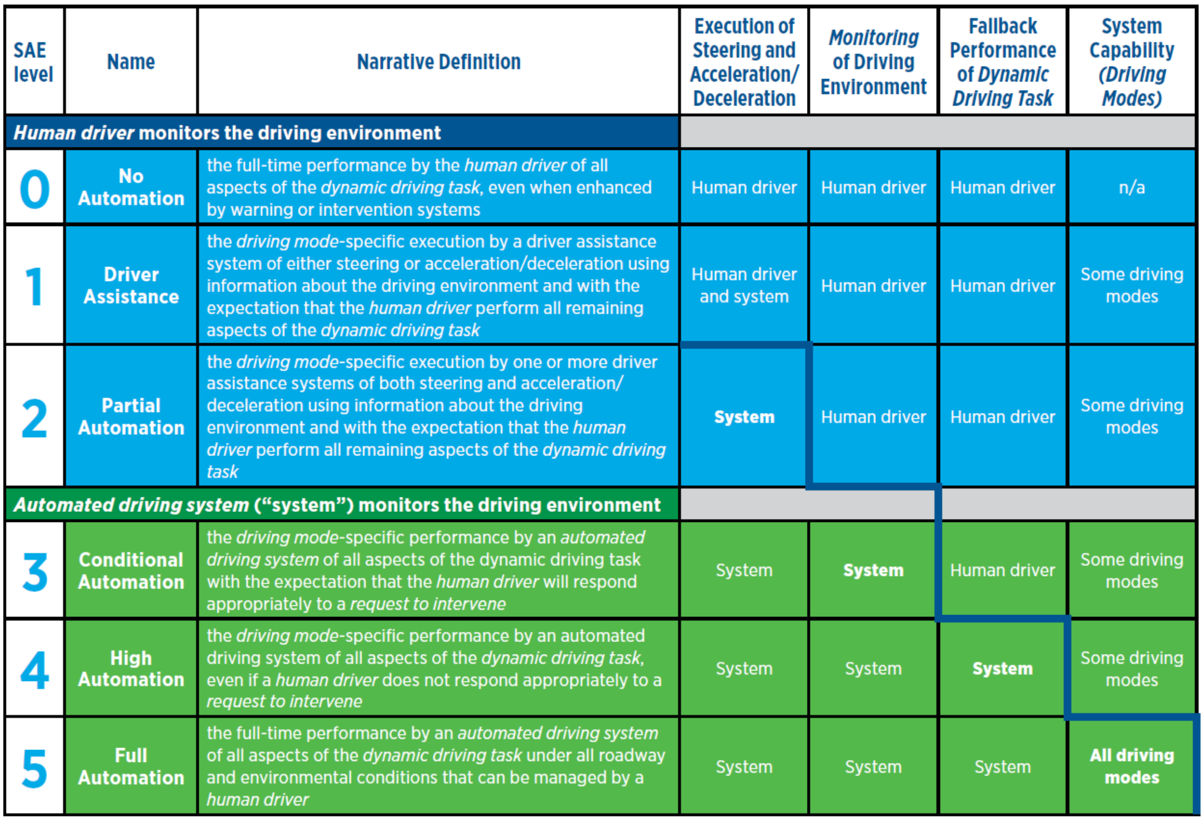
2 Reference automation levels and deployment scenarios

2.1 Automation levels

Firstly, it is necessary to define the systems under study. For this purpose, we refer to the harmonised classification system for automated driving levels provided under SAE J3016 recommended practice "*Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems*" (SAE International, 2016). SAE J3016 currently stands as the most widely adopted classification. Automation levels are defined on the basis of whether it is the human or the machine in charge of the DDT, ranging from level 0 where the DDT is entirely performed by the human driver (no automation) to level 5 where the DDT is entirely performed by the automated driving system (full automation) (see Figure 4). The DDT comprises both the lateral control (steering) and the longitudinal control (accelerating, braking) of the vehicle, together with the monitoring of the environment. The introduction of highly automated driving functions will probably take place incrementally (ERTRAC, 2017), with first systems introduced in specific contexts and scenarios of lower complexity (e.g. motorway driving) and gradually covering broader and more complex driving situations. This evolutionary approach (also called "Something everywhere" approach) is generally embraced by traditional car manufacturers which offer AVs with varying levels of automation and increasingly sophisticated Advanced Driver Assistance Systems (ADAS). It involves initially having lower levels of automation but covering different road environments and situations. On the contrary, the revolutionary (otherwise known as "Everything somewhere") approach is primarily focusing on urban areas and refers to a high level of automation in dedicated spaces. It is usually embraced by disruptive players (e.g. technology companies).

This study is using the SAE classification and to the extent possible, it aims at identifying different ranges of effects for the distinct levels of automation through the use of scenarios.

Figure 4. Summary of SAE international's levels of driving automation for on-road vehicles



SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	**High Automation**	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Source: SAE International, 2014 (Copyright © 2014 SAE International).

2.2 Automation deployment scenarios

2.2.1 CCAM policy and technology development

As noted in the final report from GEAR 2030 HLG (European Commission, 2017d), CCAM brings new policy and regulatory challenges for both the European Commission and Member states on a number of areas, such as road safety, environment, competitiveness and jobs, societal and ethical issues, to name a few. What makes the situation particularly challenging is the need to develop a new coherent legal framework for systems that do not yet exist, without hampering innovation. Below, a few highlights from GEAR 2030 final report are provided.

With some Member States already having in place a national strategy for CAVs (e.g. France, Germany, United Kingdom, The Netherlands, Sweden), testing on a large scale is part of the current and forthcoming activities in several EU countries. Large scale testing will clearly contribute to technological progress and the development of rules, as well as to increase public acceptance and cooperation among stakeholders (European Commission, 2017d). The existing 1949 Geneva and 1968 Vienna conventions on road traffic allow for testing of CAVs at the level of EU Member States. However, there is a need to confirm at the United Nations Economic Commission for Europe (UNECE) the compatibility of both conventions with higher levels of automation (still with a driver) and to accelerate the discussions on the high/full automation cases where a driver will not be needed (especially because of urban shuttles that can be available soon). Apart from traffic rules, vehicle legislation (e.g. Directive 2007/46/EC on vehicle type approval) will also need to ensure the safety compliance of new vehicles. UNECE regulations for vehicle safety rules are being adapted (e.g. Regulation 79 on steering) but, in the meantime, a national ad-hoc safety assessment is being used for the vehicle approval. The need to consider new categories of vehicles (e.g. new vehicle design) as well as updates through the vehicle lifetime (e.g. software) has been acknowledged in the framework of the type-approval legislation. For what concerns the sharing of data in digital maps, the Intelligent Transport Systems (ITS) Directive 2010/40/EU provides a legal and technical framework. Driver training (e.g. driving licence directive, professional driving directive) should also be discussed in the near future. New road safety concerns (like confusion/distraction or misuse) could appear and would need to be tackled through the in-vehicle Human-Machine Interface (HMI) and other means.

Data recording has been identified as a useful means to clarify liability assignments in case of an accident with a CAV, thus as an element to be required in the vehicle type approval legislation. Although both the Motor Insurance Directive (MID) and the Product Liability Directive (PLD) are understood to be valid for the near term, they may need to be revised in the future and the European Commission will monitor this need as well as the need for additional EU legal instruments. As part of the Digital Single Market Strategy, the Commission is addressing liability issues, as well as data sharing and ownership rules, which are crucial for automated driving (European Commission, 2017c). In the context of the C-ITS strategy (European Commission, 2016d), the European Commission is tackling data protection and cybersecurity issues among others and is currently preparing a Commission Delegated Regulation on the specifications on C-ITS under the ITS Directive 2010/40/EU (European Commission, 2017k) with the aim of establishing right and clear framework conditions to improve the interoperability and continuity of C-ITS across Europe.

From a technological point of view, one relevant on-going debate focuses on the communication technologies to use in future CAVs (Fildes and Campbell, 2017). The use of cellular networks could increase to enable the exchanges of large amounts of data as well as for infotainment purposes inside the vehicle. In addition, existing communication technologies (i.e. ETSI-ITS G5) together with forthcoming and future ones (i.e. LTE-V2X, satellites, 5G) could better support Vehicle-to-Everything (V2X) (which will be essential for trucks platooning) and vehicle positioning. As an example, Volkswagen plans to equip its vehicles with ETSI-ITS G5 from 2019 (Schiebe, 2017).

Autonomous driving technology development is rapidly progressing, although some of the ambitious targets set by key players in the field are being delayed (Hawkins, 2017). Technological challenges remain strong to make fully automated driving a reality (Marshall, 2017), with the training algorithms being a crucial step to be made in order to ensure a safe and efficient vehicle operation in every driving situation (Nash, 2018). Another important open question is whether level 3 technologies will be actually deployed in the market, as some manufacturers are already expressing concerns and opting for deploying technologies up to level 2 and subsequently level 4 and 5 AVs (Albright et al., 2017).

One significant risk, in the EU and other regions of the world, is the fragmentation of regulatory approaches. This is why the European Commission is committed to the development of an EU strategy on CCAM, which contributes to the protection of jobs of European citizens and the materialisation of significant societal benefits, as well as to the success and competitiveness of European industries. However, steps are already being taken by Member States individually, which would need to converge towards a single European approach in the future. For instance, this is the case of Germany, that amended the Road Traffic Act (Strassenverkehrsgesetz, StVG) in June 2017 with rules addressed to level 3 and level 4 automated driving (Burianski and Thiessen, 2017). These rules allow that, under certain conditions, the driver may divert his/her attention away from traffic and vehicle control, but still needs to be in the car and is obliged to take over the driving task following a request by the driving system or if the conditions for using the automated driving functionality are recognizably no longer fulfilled. The use of a black box that records who is in control of the vehicle at any time is foreseen. Besides, Germany established an Ethics Commission on CAD in September 2016, chaired by Professor Udo Di Fabio, a former judge of the Federal Constitutional Court of Germany, and including experts from academia, society, the automotive industry and the digital technology sector. In June 2017, the Commission delivered a report with 20 ethical rules set as initial guidelines for policymakers and lawmakers, setting out special requirements in terms of safety, human dignity, personal freedom of choice and data autonomy (German Federal Ministry of Transport and Digital Infrastructure, 2017b).

Under such a challenging policy and technological context, the evolution of CAVs could take different forms, also on the basis of users' acceptance. It is nevertheless expected that the period during which these new technologies will coexist with conventional legacy vehicles will be long (European Commission, 2017f). It is also relevant to consider the link with Mobility-as-a-Service (MaaS), given that an autonomous mobility can reinforce MaaS and shared mobility services through the reduction of one significant operational cost, i.e. the driver (Corwin et al., 2015). Similarly, there is a clear interconnection with Electric Vehicles (EVs) (McCauley, 2017), supporting the decarbonisation of transport. Automation, electrification and ride-sharing can reinforce each other and will probably shape the future of road transport and mobility.

2.2.2 Users' uptake of CCAM

It is widely believed that CAVs will be the main mode of transport in the future and for this reason a great number of studies are trying to identify people's perceptions towards this upcoming technology. Users' perceptions will be taken into account by manufacturers in order to define the way that this technology will be introduced in everyday life.

On the one hand, the attitudes towards connected vehicles seems to be positive taking into account the strong users' willingness to pay for connected car services (Cookson and Pishue, 2017). On the other hand, in the AVs domain, a recent study has revealed that more than half of the surveyed Europeans (53.3%) would consider buying an AV, while the percentages in the US and Japan are slightly lower (50% and 41% respectively) (Yano Research Institute, 2018). The percentage for the US is in line with (Bansal and Kockelman, 2017) where around half of the respondents indicated to be prepared to pay for full automation. In another international survey (5,000 respondents from 109 countries), the positive reactions for fully AVs are predominant (78%) (Kyriakidis et al., 2015a). However, a significant portion of people (22%) is still showing a negative attitude to them. From the positive answers, 5% of all users would pay more than $30,000. Positive or negative opinions are many times associated to factors such as gender, age, country of origin, etc.

Regarding services that are offered to passengers of AVs, in a survey among 1,500 users from Germany, Japan and the US (Dungs et al., 2016), it was found that 75% of users are willing to pay for such services; the average amount is approximately 190 euros. The categories with the highest percentage of willingness to pay are "Communication" (e.g. social networks), "Productivity" (e.g. work) and "Basic requirements" (e.g. sleep), while on the other side the lowest percentage one is related to "Entertainment" (e.g. games) services.

The attitude towards AVs can differ significantly between the two genders. This gender differentiation in terms of willingness to use such vehicles is directly influenced by emotions that vary in both positive and negative ways (Hohenberger et al., 2016, Kyriakidis et al., 2015a), that tend to affect men differently from women. In a sample of around 1,600 German participants, Hohenberger et al. (2016), found out that, compared to men, women are dominated by negative feelings, such as anxiety and "not pleasure". These feelings make women less willing to use automated cars, while this "not pleasure" feeling turns into real pleasure to men, followed by less anxiety which finally leads to eagerness to use AVs.

There is also a clear difference in attitudes with regard to age. The effect of age on users' acceptance is mainly linked to the existence of significant generation differences not only in the willingness to pay for AV services but also in the adoption of automation features. Elderly people exhibit a lower willingness to pay for AVs (Bansal and Kockelman, 2017), while younger people seem to be ready to pay 50% more for such services compared to older users (Dungs et al., 2016). This readiness to pay is directly related to their willingness to use fully automated vehicles that is expressed by 40% of users in the age group of 25-34 years old (in a nationwide sample of more than 3,000 individuals), and follows a downturn when age increases. In the age group of 45-54 years old, the willingness to use full automation decreases down to 23.4%. This unwillingness to pay is associated to their lower preference for partial or full autonomy, which finally leads to an inclination towards automation features with a supportive role to the driver, who retains vehicle's control (Abraham et al., 2016). A year later, a similar survey was conducted by the same team in order to make a comparison between 2016 and 2017. The interesting finding is that results from the 2017 survey show a significant decrease in the intention of using fully automated cars and an increasing preference towards automation features supporting the driver. This decrease was observed in all age groups, and particularly among participants aged 25 to 34 years old, whose willingness to use fully AVs decreases by 20%. To take the survey a step further they investigated the hesitations concerning the acquisition of a fully automated car. Issues of control loss by the driver, the conviction that this car will never work properly and feelings of non-trust and unsafety towards fully automated driving are the main interviewers' concerns (Abraham, 2017).

Although private cars are the most common means of transport, public urban transport is also a major asset with 77.6% responding positively to the potential use of autonomous public transport without being significantly affected by factors such as age and sex (Pakusch and Bossauer, 2017). On the other hand, past experience on autonomous transport seems to have a positive effect on citizens; according to (Pakusch and Bossauer, 2017) 88% of the participants who had already used autonomous public transport would use it again in the future. The same holds with past experience on autonomous driving in private vehicles, which increases the possibility of these drivers to use different and novel transport modes. Regarding the favourable type of autonomous transport means, in a scale from 1 to 5 (from the lowest to the highest preference), participants showed a higher preference on rail-bound means (on average 3.83) compared to non-rail-bound ones (on average 2.87).

A transport option that is gaining popularity in recent years is car sharing, which is a membership based service where customers get access to vehicles for a short period of time. According to (Prieto et al., 2017) car sharing is more likely to be adopted by city center residents and degree graduates. Gender also affects the willingness of use: women seem to take safety into account when it comes to car sharing, thus they are less positive into using it compared to men. Also, new car owners tend to have positive opinion for car sharing, probably in order to avoid wear and increased kilometers travelled. In this context, AV technology has the potential to make car sharing more attractive among users. In conventional car sharing, the user must walk to the place where he/she can access the shared vehicle; in the shared AVs case this is not needed as the vehicle collects the user at their starting point. Moreover, it can improve one-way car sharing scenarios by dealing with the relocation problem (Firnkorn and Müller, 2015). Another advantage of AV technology is that it can be used to combine the positive effects of privately owned with shared vehicles: access to a transport means on request but with affordable cost at the same time (Haboucha et al., 2017).

In spite of the general willingness to use CAVs, there still remains a significant number of interviewers who expresses doubts or rejects this upcoming technology. In this context, just an accident is enough to negatively affect public opinion, like the one that has happened in Arizona on the 19th of March 2018, where Uber's self-driving test car was involved in a mortal accident with a pedestrian (62). Users' acceptance is an area that needs further analysis in the future, especially following direct experiences with CAVs.

2.2.3 Deployment scenarios used in this study

Private mobility and freight transport emerge as two distinct deployment applications of CAV technologies in the future. Focusing on the former (i.e. passenger vehicles), a recent study from the Netherlands has applied a System Dynamics (SD) model to simulate the long-term innovation diffusion of vehicle automation. It considered a base scenario and an optimistic scenario with two variants: conservative and progressive, with the latter scenario representing a strong economic growth, political support and technology development as well as a positive customer attitude (63). Although specific for the Netherlands, the model is intended to be general with a holistic perspective in the boundaries of developed countries. The Nieuwenhuijsen et al. (2018) results are taken as a basis for drawing the scenarios used in our study. The positive focus adopted in the paper helps to target the identification of the strongest effects (both positive and negative) that could come associated to CCAM. Therefore, we have developed three scenarios (scenarios 1, 2 and 3) corresponding to the base scenario, conservative optimistic scenario and progressive optimistic scenario of the Dutch study, and reflecting three different levels of development in the three key areas: technology, policy and users. In addition, we have developed a baseline scenario, which is not considering the automation trend and relies on the 2015-2050 projections made in the EU Reference Scenario 2016 (European Commission, 2016a (64)) and other data from 2015 (e.g. Eurostat Database, ACEA Statistics). For all the scenarios, two timeframes are considered: 2025 and 2050. Market penetration (65) figures are then taken from the Dutch paper to serve as a qualitative indication of the proportion of different automation levels in vehicle travel, but are not used as a quantitative input in any of the study calculations. Even if the figures provided in this study seem to be quite optimistic (66), they are more reliable than just consumers' or experts' points of view as they aim at tackling the dynamic and complex nature of the innovation system of vehicle automation. We thus base our analysis on them from a

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(62) Aftereffect of this fatal accident was Uber's decision to pause all testing in Tempe, Pittsburgh, San Francisco and Toronto.

(63) For more details on the optimistic scenario ("AV in bloom"), please refer to Milakis et al. (2017).

(64) Precisely, taking the modified baseline of EU Reference Scenario 2016 from Hill et al. (forthcoming 2018).

(65) In the context of the Nieuwenhuijsen et al. (2018) study, market penetration of a given automation level seems to be interpreted as the percentage of the fleet size of the specific level of automation compared to the total fleet size. Fleet size is then specified as the number of vehicles in use at a certain moment in time in a certain region. There is some ambiguity in the use of distinct terms (market shares, fleet shares, vehicles in use), so it is important to clarify that we have interpreted the figures given as amount of travel done with each automation level.

(66) SAE level 5 vehicles are not expected to be available before 2030, except for testing (ERTRAC, 2017), although some sources indicate 2025 as expected date for fully automated vehicles (Mosquet et al., 2015; Leech et al., 2015). Nieuwenhuijsen et al. (2018) assume some level 4 and 5 vehicles to exist in 2025 in the optimistic scenarios (both conservative and progressive optimistic scenarios).

qualitative perspective, so that we can understand the maximum level of automation reached at a certain point in time and how representative it is in the total amount of travel done at that moment. For the passenger transport scenarios, assumptions on the amount of travel served by Individually-Owned (IO) vehicles and MaaS respectively are made, considering an increasing trend over time towards MaaS in all scenarios and from scenario 1 to scenarios 2 and 3. Passenger transport scenarios are presented in Table 3.

For the freight transport application, Wadud (2017) Total Cost of Ownership (TCO) analysis is taken as a reference, where commercial vehicle applications appear as a likely early adoption case of automated driving technologies. Approximate shares of different automated driving levels are estimated, based on Nieuwenhuijsen et al. (2018) and assuming that shares of higher levels of automation would be higher for freight transport than for passenger transport. In this context, truck platooning is specifically mentioned in the various scenarios, differentiating between platooning applications that still require a driver on-board and those future use cases where the driver would not be necessary anymore. Freight transport scenarios are presented in Table 4.

For clarification along the report, the presented scenarios have been used in a qualitative way for the calculation of estimations per sector (namely in the sectors: automotive, electronics and software, insurance and power).

Table 3. Deployment scenarios matrix indicating shares of vehicle travel of non-AVs versus AVs for passenger transport

SCENARIOS	**LEVELS OF DEVELOPMENT PER AREA**			**PASSENGER TRANSPORT ASSUMPTIONS (67)**		
	TECHNOLOGY	**POLICY**	**USERS**		2025	2050
Baseline	Eurostat and EU Reference Scenario 2016 (data from 2015), without accounting for CAV technologies					
Scenario 1. Low uptake	Slow	Little	Few	Vehicle travel (68)	14% Non-AV - **86% AV** (L1 21%, **L2 51%**, L3 14%)	**100% AV** (L2 34%, **L3 62%**, L4 2%, L5 2%)
				Rate IO - MaaS (69)	**80% IO -** 20% MaaS	**70% IO -** 30% MaaS
Scenario 2. Medium uptake	Moderate	Moderate	Moderate	Vehicle travel	4% Non-AV - **96% AV** (L1 8%, L2 24%, **L3 49%**, L4 7%, L5 8%)	**100% AV** (L2 3%, L3 9%, L4 29%, **L5 59%**)
				Rate IO - MaaS	**60% IO -** 40% MaaS	40% IO **- 60% MaaS**
Scenario 3. High uptake	Fast	Strong	Many	Vehicle travel	1% Non-AV - **99% AV** (L1 3%, L2 10%, L3 28%, L4 23%, **L5 35%**)	**100% AV** (L3 1%, L4 13%, **L5 86%**)
				Rate IO - MaaS	40% IO - **60% MaaS**	10% IO - **90% MaaS**

Source: Own elaborations.

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(67) Passenger transport is intended as passenger vehicle mobility in the context of this study.
(68) Approximate shares of different automated driving levels, based on Nieuwenhuijsen et al. (2018); this footnote is applicable to all scenarios and timeframes
(69) Assumptions of amount of travel made by IO vehicles versus travel made by MaaS; this footnote is applicable to all scenarios and timeframes

Table 4. Deployment scenarios matrix indicating shares of vehicle travel of non-AVs versus AVs for freight transport

SCENARIOS	**LEVELS OF DEVELOPMENT PER AREA**			**FREIGHT TRANSPORT ASSUMPTIONS (70)**		
	TECHNOLOGY	**POLICY**	**USERS**		2025	2050
Baseline	Eurostat and EU Reference Scenario 2016 (data from 2015), without accounting for CAV technologies					
Scenario 1. Low uptake	Slow	Little	Few	Vehicle travel (71)	6% Non-AV - **94% AV** (L1 19%, L2 25%, **L3 50%**)	**100% AV** (**L3 40%**, L4 30%, L5 30%)
				Platooning (72)	Platooning **not** yet available	Platooning **with** drivers
Scenario 2. Medium uptake	Moderate	Moderate	Moderate	Vehicle travel	**100% AV** (L1 5%, L2 20%, **L3 30%**, L4 25%, L5 20%)	**100% AV** (L3 5%, L4 25%, **L5 70%**)
				Platooning	Platooning **with** drivers	Platooning **without** drivers
Scenario 3. High uptake	Fast	Strong	Many	Vehicle travel	**100% AV** (L2 10%, L3 20%, L4 20%, **L5 50%**)	**100% AV** (L4 10%, **L5 90%**)
				Platooning	Platooning **with** drivers	Platooning **without** drivers

Source: Own elaborations.

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(70) Freight transport covers Light Commercial Vehicles (LCV), Medium Commercial Vehicles (MCV) and Heavy Commercial Vehicles (HCV).

(71) On the basis of the passenger transport scenarios defined in Table 3, freight transport travel made with different levels of automation is estimated. The main reasoning behind these estimations is that CAV technologies would be available for freight transport applications sooner than for passenger transport ones (therefore vehicle travel shares of AVs would be expected to be higher, e.g. a 5-10% higher) and the highest level of automation available at each timeframe would represent a higher share; this footnote is applicable to all scenarios and timeframes.

(72) Platooning applications are distinguished for 2025 and 2050, specifically referring to the need to have drivers on-board the vehicles or not.

3 Socio-economic impacts

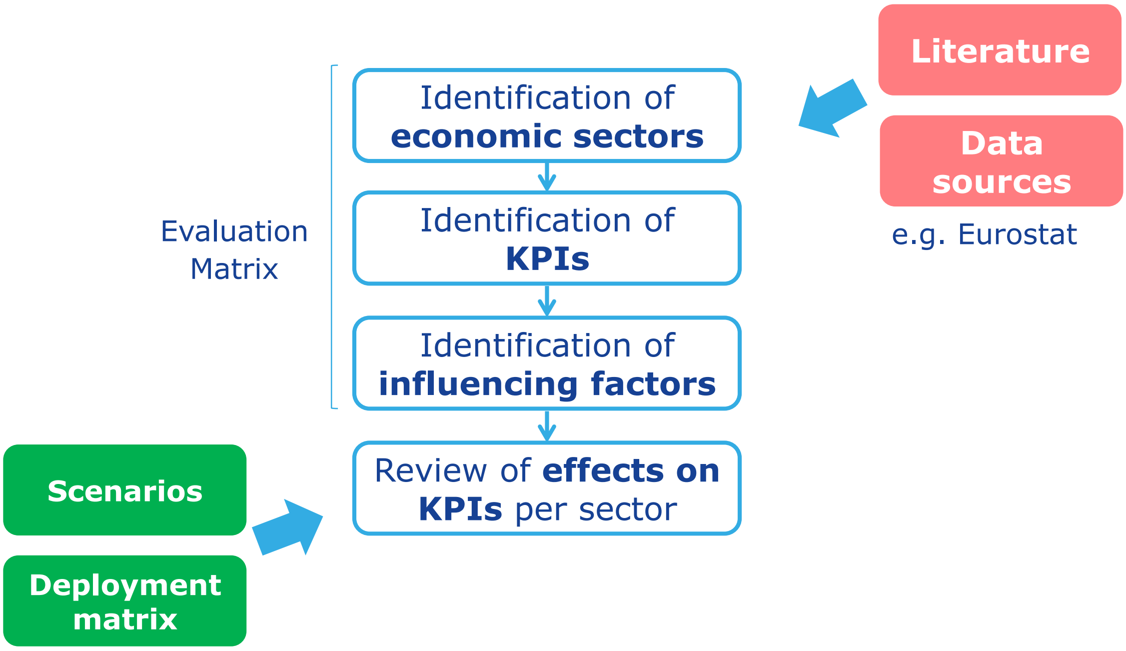
3.1 Evaluation framework

3.1.1 Conceptual framework

An important aspect to investigate when dealing with AVs and their implementation is the impact that they have on the society, in terms of mobility as well as in relation to the socio-economic impact that these new technologies can cause in our daily activities.

The introduction of AVs in our society has impacts on many economic sectors that are affected directly or indirectly. In order to define the magnitude of this phenomenon it is necessary to establish a robust methodological framework which will facilitate the definition of the affected sectors and the more appropriate KPIs that constitute the base for the estimation of the socio-economic impacts. The methodological framework followed in the study is shown in Figure 5.

Figure 5. Methodological framework followed in the study



Source: Own elaborations.

A precise definition of the economic sectors affected by the introduction of AVs is decisive and is based on a careful desk research on the topic. Few studies have already investigated such topic, considering also its very recent deployment and its complexity. A first step towards this type of research is the one by Clements and Kockelman (2017) that performed a similar research in United States (US). In their study, the authors, through a qualitative approach, examine the socio-economic effects of the introduction of AVs in many economics sectors, such as: the automotive industry, electronics and software technology, trucking and freight movement, personal transport, auto repair, medical services, legal assistance, construction and infrastructure, land development, digital media, police (traffic violation), oil and gas. In their conclusions, they provide an estimation of economy-wide effects that could lead to an increase of 8% of US Gross Domestic Product (GDP). Considering the novelty of this topic and the lack of reliable and unique data, a cautious qualitative approach appears to be the best methodology for the time being. A similar methodology has been chosen for the development of the current study, where the definition of the KPIs is fundamental in order to carefully collect available data and also define the possible future scenario of AVs diffusion. An innovation of our study is that we aim to consider different future scenarios and provide a timeframe for the identified impacts.

The impacts that AVs have on the whole society and, more in detail, on some specific sectors will be captured through a qualitative approach where, starting from the current status, hypotheses will be formulated on the basis of specific inputs derived from specialized literature on the topic.

The sectors that have been identified as the ones that will be affected the most by CCAM are: automotive (manufacturing and sales), constructions, data services, digital media, electronics and software, freight and passenger transport, repair and maintenance, power sector, telecommunication, insurance, land development, legal activities, oil and gas, traffic police, education and medical services. However, it is important to consider the following caveats:

- The study does not cover the interaction between these sectors.
- It only looks at output (in monetary terms) and employment. It does not include neither price, income nor substitution effects in each of these sectors because there are insufficient data to make meaningful estimates of these.

These sectors have been combined ad hoc for the specific purpose of this analysis and each of the mentioned ones is composed by a list of economic activities strictly linked to the automotive sector and/or its components. The main reference for the data collection is the Structural Business Statistics (SBS) of Eurostat (73). SBS data provides economical and financial information, as well as data on employment for each economic sector according to the Nomenclature statistique des Activités économiques dans la Communauté Européenne (NACE) Rev. 2 classification (Eurostat, 2008). This dataset contains socio-economic information at the most disaggregated level available in Eurostat; this allows capturing the closest values to the ones of each specific activity.

SBS contains information at a very high level of disaggregation, this could lead to a possible data gaps, and hence a certain level of underestimation has to be taken into account. Being aware of such limitation, we believe that SBS data is the most appropriate for the purpose of the present analysis.

Despite the effort of capturing the most accurate and refined data, it is important to highlight that, in some cases, some sectors comprise a list of economic activities, among which few of them are actually relevant for the present analysis; this entails a possible overestimation of the assessment hereafter presented.

In the present study each economic sector is defined through the reference to one or more NACE Rev. 2 economic activities, as it is illustrated in each sector's analysis. A comprehensive definition of each NACE Rev. 2 sector is available in Annex 1.

For each of the economic activities a list of relevant common KPIs has been identified, according to the last SBS available data in Eurostat, which are the following: number of persons employed, turnover, number of enterprises, personnel costs, Value Added (VA). The analysis is looking at the entire EU, therefore the EU-28 aggregated values provided in SBS were taken, when this figure was not available, we summed up the data for the available Member States. The figures are always referring to the most recent complete available data, which is year 2015. For the sectors where we are providing estimations, the reference currency year is 2015.

Moreover we provide an indication of the share of GVA, % GVA, of each specific economic activity on the overall European GVA. In this case the total European value is provided by the National Account (NA) dataset of Eurostat (74).

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(73) Eurostat Structural Business Statistics (SBS) Database, available at: http://ec.europa.eu/eurostat/data/database?node_code=sbs_na (last accessed 9 February 2018).

(74) Eurostat National Accounts (NA) Database, available at: http://ec.europa.eu/eurostat/data/database?node_code=na10 (last accessed 16 February 2018).

The VA figures for each economic activity is taken from SBS, which provides NACE Rev. 2 classification up to 4 digits, while the NA dataset provides data, NACE Rev. 2 classification, up to 2 digits. In order to be consistent in our calculation, since two different datasets were used, SBS and NA, for each economic activity we identified the ratio between the same level of disaggregation, mainly 2 digits, and apply the found ratio for each 4 digit economic activity identified through the SBS dataset. This additional calculation allows us to weigh each economic activity and sector on the overall GVA, which is provided by the NA dataset. This extra step was considered fundamental in order to avoid results that would combine two different data sources, which are based on different assumptions and methodologies.

Similarly we considered how much, each economic activity is accounting in Europe in terms of people employed. In this case the total European figure about employment was taken from the Labour Force Survey (LFS) of Eurostat ([75]), covering EU-28 for 2015. When looking at the SBS and LFS, NACE Rev. 2 classification at 2 digits, no clear patterns were found that could justify the need for weighting the SBS data over the LFS ones. Having said this, for the calculation of % persons employed in each industry, the two data sets were used.

For both the % GVA and % persons employed, a successive aggregation was made, summing up each economic activity belonging to the same sector in order to have a final total share for the entire sector considered.

For what concerns the employment analysis, data from Eurofound has been used, that includes employment share figures from Eurostat LFS and task indicators from Eurofound's database ([76]).

This dataset constitutes the reference point on which to speculate in order to estimate possible socio-economic effects, based on qualitative and quantitative inputs from literature review, within the framework of the defined scenarios.

3.1.2 Preliminary assumptions

Some preliminary assumptions based on existing literature are summarised below and taken as the basis for the identification of relevant parameters of analysis (KPIs), then used in the assessment of the different sectors:

- AVs will be gradually populating the roads of the EU, following technology and policy developments. Their deployment is based on a number of exogenous assumptions regarding the speed of introduction of AVs. They are not based on economic estimates of the demand for such vehicles, taking into account prices, income and substitution effects.
- Vehicle sales can be certainly affected by a growing trend towards car/ride sharing, but might be offset by a reduction in vehicle's lifetimes as a result of a more intensive vehicle usage.
- Increases in the amount of road travel can be expected as a consequence of the safer and more comfortable driving conditions enabled by AVs, as well as from making it accessible to new user groups (e.g. disabled, elderly). Possible congestion effects of increased travel are not taken into account though.
- Part of the increased demand for road travel can come from modal shifts taking place from rail or air towards road transport, as well as from different forms of group travel (e.g. taxis, buses). It is important to mention that shifts driven by price and substitution effects and their impact on consumer demand for each mode are not calculated.

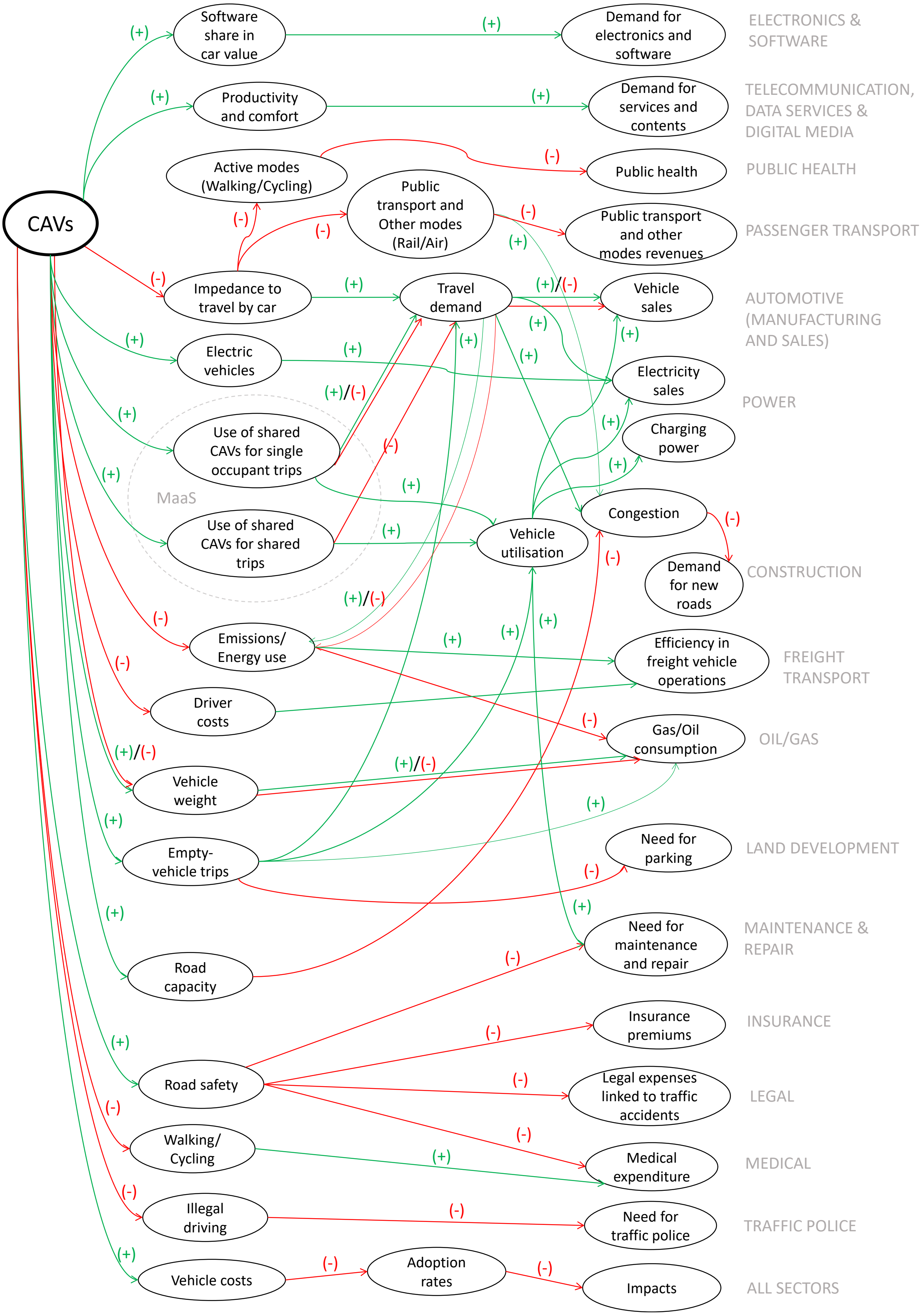
([75]) Eurostat Labour Force Survey (LFS), available at: http://ec.europa.eu/eurostat/data/database?node_code=lfsi (last accessed 20 March 2018).

([76]) Eurofound's European Jobs Monitor (EJM) tasks Database, available at: https://www.eurofound.europa.eu/publications/report/2016/labour-market/what-do-europeans-do-at-work-a-task-based-analysis-european-jobs-monitor-2016 (last accessed 10 February 2018).

- How these potential increases in road travel will affect traffic congestion remains highly uncertain and is dependent on the degree in which AVs will be capable of "coordinating" themselves for a better use of the roads. As a consequence, road trips may slow down and more time is spent in cars. This increases the opportunity cost of time of car travel. Carrying out non-driving tasks reduces the opportunity cost of car travel. It is important to emphasize that the calculations carried out in this study (output, turnover) are based on market prices and do not include opportunity costs (positive or negative) for consumers/drivers. That means that an important part of the economic benefits is not captured in this exercise.
- Productivity gains from the possibility of carrying out non-driving tasks during the ride can be also expected (but are not estimated in this study).
- AVs will become a sort of "Computer-on-wheels", where software components will increasingly gain a dominant position with hardware decreasing its share on the automotive value chain.
- Traffic accidents are expected to decrease, especially by tackling those where human errors were present, which as a consequence will decrease costs of insurance, legal services, medical services, auto repairs, etc.
- Fuel consumption reduces in trucks platoons, and it is possible to avoid hours-of-service restrictions, leading to savings to truck companies. Driver tasks would change, possibly leading to losing driver jobs in the long-term. The energy impact of specific fuel savings will possibly be offset by the additional fuel consumption linked to an increase in road traffic kilometres.
- Revenues from traffic fines and parking facilities in urban areas might suffer a severe reduction, also decreasing the demand for traffic police. However, it is important to note that these are excluded from the economic benefits, as they represent a transfer between drivers and taxpayers, not a net economic value gain.
- Ultimately, these vehicles will also impact land use and investments in infrastructure, with e.g. remote parking facilities.

A representation of some possible impacts paths is made in Figure 6 below, highlighting the economic sectors that would be affected.

Figure 6. Impact path of CAVs (+/- signs indicate increases or decreases and not whether effects are positive or negative)



Source: Own elaborations.

3.1.3 Evaluation matrix

On the basis of these preliminary assumptions and the conceptual framework defined before, a set of industries/services that are expected to be highly affected by CCAM (either positively or negatively) have been selected.

The table below (Table 5) presents possible indicators for each of these sectors to approach the question "*How could CAVs affect the EU economy and society?*", specifying possible sources of data (i.e. indicating which Eurostat NACE Rev. 2 economic activities we believe to be linked to each relevant sector) and preliminary indications of which factors might be influencing and how (in which direction, increase or decrease in sector revenues or jobs). These form the basis for the subsequent sectoral analysis.

Table 5. Evaluation matrix focusing on the sectors most likely to be affected by CAV technologies (sectors indicated in grey seem to be affected to a lesser extent)

SECTORS	INDICATORS	UNITS	DATA SOURCES	POSSIBLE INFLUENCING FACTORS AND LIKELY DIRECTIONS OF CHANGE
Automotive (vehicle manufacturing and distribution)	Number of jobs	*Jobs*	Eurostat (NACE C29.10, C27.11, C27.40, C28.11, G45.1, G45.3)	Vehicle sales are expected to **increase** if Vehicle Kilometres Travelled (VKT) increase, personal ownership prevails, as well as through the extended vehicle usage in car/ride sharing. On the other hand, vehicle sales could **decrease** if VKT decreases, e.g. such as in the case that shared mobility prevails. Although, an increased vehicle utilisation will lead to shorter vehicle lifetimes.
	Number of vehicles sold per year	*Vehicles/year*		
	Revenues per year (in vehicle sales)	*Euro/year*		
Electronics and software	Number of jobs	*Jobs*	Eurostat (NACE C26.20, C26.40, C26.51, J62)	Revenues from this sector are expected to **increase** with sensors, controllers, actuators, self-driving software, maps, etc. that will be required for automated driving.
	Revenues per year (in self-driving software, maps, etc.)	*Euro/year*		
Telecommunication	Number of jobs	*Jobs*	Eurostat (NACE J61.2, F42.22, F43.21)	The increased connectivity requirements and data exchanges in an AV will **increase** revenues in this sector.
	Revenues per year	*Euro/year*		
Data services	Number of jobs	*Jobs*	Eurostat (NACE J63.11 and J63.12)	New services linked to vehicle automation and connectivity will **increase** revenues from data services.
	Revenues per year	*Euro/year*		
Digital media	Number of jobs	*Jobs*	Eurostat (NACE J60.20, G47.91, J60.10)	Revenues linked to contents provision could **increase** with greater demand for digital media during commutes. Revenues linked to radio and music could **decrease** if there is a decreased demand for radio and music (preference for visual).
	Revenues per year for content providers	*Euro/year*		

SECTORS	INDICATORS	UNITS	DATA SOURCES	POSSIBLE INFLUENCING FACTORS AND LIKELY DIRECTIONS OF CHANGE
Digital media *(continued)*	Revenues per year in online shopping	*Euro/year*		
	Revenues per year in radio and recorded music	*Euro/year*		
Freight transport	Number of jobs (truck drivers)	*Jobs*	Eurostat (NACE H49.41, H49.42, H49.2, H50.2, H50.4, N77.12)	Truck driver jobs could **decrease** with fully automated trucks. Revenues from road transport commercial operations could **increase** as fuel consumption and travel time decreases with truck platooning, number of truck drivers needed decreases (even if wages could increase with a more technical role, e.g. monitoring the CAV) and if driver time restrictions no longer apply. Possible modal shifts towards road transport (e.g. from rail or sea) could appear as a consequence of the more efficient road operation.
	Revenues per year	*Euro/year*		
	Cost per truck driver	*Euro/hour*		
	Number of hours of transport per driver	*Hours/driver*		
	Number of jobs - freight transport via rail	*Jobs*		
	Revenues coming from freight transport via rail	*Euro/year*		
	Number of jobs - freight transport via water	*Jobs*		
	Revenues coming from freight transport via water	*Euro/year*		

SECTORS	INDICATORS	UNITS	DATA SOURCES	POSSIBLE INFLUENCING FACTORS AND LIKELY DIRECTIONS OF CHANGE
Passenger transport	Cost of driving	*Euro/km*	Eurostat (NACE H49.10, H49.31, H49.32, H49.39, H51.10, M77.11)	Taxi driver jobs could **decrease** with fully automated vehicles. Possible modal shifts towards road transport (e.g. from rail or air) could appear as a consequence of the more efficient and comfortable road travel. As well as from public transport towards private mobility.
	Household expenditure on transport (% of total expenditure or income)	*Euro or %*		
	Number of public transport related jobs	*Jobs*		
	Number of taxi driver jobs	*Jobs*		
	Number of air transport related jobs	*Jobs*		
	Number of rail transport related jobs	*Jobs*		
	Number of rental car related jobs	*Jobs*		
	Rental car revenues per year	*Euro/year*		
	Taxi revenues per year	*Euro/year*		

SECTORS	**INDICATORS**	**UNITS**	**DATA SOURCES**	**POSSIBLE INFLUENCING FACTORS AND LIKELY DIRECTIONS OF CHANGE**
Passenger transport *(continued)*	Airplane revenues per year	*Euro/year*		
	Train revenues per year	*Euro/year*		
Insurance	Number of jobs	*Jobs*	Eurostat (NACE K65.12, K65.20)	Revenues from motor vehicle insurance policies could **decrease** if accidents decrease. But complex liability assignment could lead to more costly liability claims. Collision expenses could increase with CAV's more costly technology.
	Revenues per year (insurance policies)	*Euro/year*		
	Collision expenses	*Euro*		
Maintenance and repair	Number of jobs	*Jobs*	Eurostat (NACE G45.20)	Revenues from vehicle repair linked to crashes would **decrease** with improved road safety circumstances.
	Revenues per year (vehicle repair)	*Euro/year*		
	Revenues per year (other, e.g. vehicle personalization)	*Euro/year*		
Power	Number of jobs	*Jobs*	Eurostat (NACE D35.1)	Future CAVs will likely be electric, leading to **increases** in electricity sales.
	Revenues per year (electricity sales)	*Euro/year*		
Traffic police	Number of jobs	*Jobs*	Eurostat (NACE O84.24)	The size of police force needed for traffic surveillance could **decrease** if drunk driving, speeding, and other misbehaviours become less frequent.
	Size of police force needed (for traffic surveillance)	*Policemen*		

SECTORS	**INDICATORS**	**UNITS**	**DATA SOURCES**	**POSSIBLE INFLUENCING FACTORS AND LIKELY DIRECTIONS OF CHANGE**
Traffic police *(continued)*	Government revenues per year (from traffic fines)	*Euro/year*		
Education	Number of jobs	*Jobs*	Eurostat (NACE O85.32, O85.4, O85.5)	Shifts in education programs could be expected as a result of skills and occupations demanded for future mobility technologies and services.
	Revenues per year	*Euro/year*		
Construction of roads and motorways	Number of jobs	*Jobs*	Eurostat (NACE F42.11)	If CAVs lead to additional traffic demand, new roads might be required, leading to an **increase** in this sector revenues. Demand for new roads construction could instead **decrease** if CAVs lead to a better use of road space. Similarly, future CAVs might allow for different parking space requirements, as well as for reduced infrastructure equipment such as signs, guardrails, rumble strips, etc.
	Revenues per year	*Euro*		
Medical	Number of jobs	*Jobs*	Eurostat (NACE Q86.10)	Demand for medical services would **decrease** if CAVs lead to less number of road accidents.
	Revenues per year	*Euro/year*		
	Number of supplies and doctors	*Doctors*		
	Number of hospital visits / hospitalizations	*Hospital visits / Hospitalizations*		

SECTORS	INDICATORS	UNITS	DATA SOURCES	POSSIBLE INFLUENCING FACTORS AND LIKELY DIRECTIONS OF CHANGE
Legal	Number of jobs	*Jobs*	Eurostat (NACE M69.10)	Revenues from liability claims could **decrease** if CAVs lead to fewer accidents, reducing as well the demand for attorneys.
	Revenues per year (from liability claims)	*Euro/year*		
	Number of attorneys needed (specialized in personal injuries)	*Attorneys*		
Oil and gas (production and distribution)	Number of jobs (extraction)	*Jobs*	Eurostat (NACE B06, G47.3, G46.71)	This sector could suffer **decreases** in revenues if vehicles are more fuel efficient and less parking search time is required. Also, if there is a transition towards EVs. Revenues could instead **increase** in the case of a rise in VKT due to higher accessibility and repositioning of shared CAVs, or if CAVs are bigger/heavier (e.g. comfort features).
	Number of jobs (retail)	*Jobs*		
	Revenues per year	*Euro/year*		
Land development	Number of jobs	*Jobs*	Eurostat (NACE H52.21, M71.11, O84.13)	Revenues in this sector could **increase** with more efficient parking (i.e. knowing free spaces beforehand) but they could also **decrease** with less parking demand.
	Revenues per year (parking)	*Euro/year*		
	Revenues per year (from NEW land developments of former parking areas)	*Euro/year*		

Source: Own elaborations.

3.2 Economic effects across industries

Before proceeding to the sectoral analysis, a review of previous studies that have dealt with the economic impacts of CAVs is provided.

Firstly, a study from Deloitte University Press identified different driving forces, ranging from mature powertrain technologies and lightweight materials to connectivity, automation and new mobility preferences, which can potentially generate a new ecosystem for transport and mobility (Corwin et al., 2015). Significant value shifts are expected in such a future mobility ecosystem, which will require business model changes and new partnerships (business as usual will not work). Mohr et al. (2014) provided an overview of the main business activity changes that different stakeholders would be facing (e.g. OEMs, suppliers, digital players, telecom players), mostly as a result of car connectivity.

Overall, the impacts of CAVs in the economy are expected to be positive (e.g. Clements and Kockelman, 2017). However, it also seems clear that certain industries are going to be negatively affected. For instance, the insurance sector will probably suffer important economic losses as a result of enhances in road safety (estimated at -60% by Clements and Kockelman, 2017). In contrast, the digital sector is expected to generate outstanding benefits (estimated at +33% by Clements and Kockelman, 2017). Improvements in efficiency, productivity and safety for freight transport and logistics activities are identified (European Economic and Social Committee, 2017). Manufacturing and service industries, both big and small and medium-sized enterprises (including start-ups), will also profit from new business opportunities that concern automation and robotics, services for citizens' mobility, solutions for more efficient logistics, or the digitalisation of the whole transport system (European Economic and Social Committee, 2017).

In the analysis done by Clements and Kockelman (2017), thirteen industries are covered by reviewing the existing literature, concluding that economic gains can reach $1.2 trillion in the US. They do not specify any timeframe for these benefits to be achieved.

A recent study from RICARDO identified a $273 billion opportunity in relation to CAVs during the period between 2020 and 2030 (Asselin-Miller et al., 2017). This amount can be divided as follows: $210 billion from connectivity, $41.5 billion from autonomous hardware components, $15 billion from new software and $7.2 billion from autonomous driving chips. These benefits seem to refer to the global market opportunity, as no specific reference to Europe or other areas is made.

A World Economic Forum study of 2016 identified that by 2025 there will be a $0.67 trillion global opportunity as a result of the digital transformation of the automotive industry (World Economic Forum, 2016b).

Only for the UK, these benefits are estimated to be a £51 billion UK opportunity by 2030 (annual economic benefit) (Leech et al., 2015). This figure comes from:

- A £40 billion opportunity coming from consumers (£20 billion from a decreased value of travel time, £15 billion from more efficient trips and £5 billion from reduced costs including insurance, running costs and parking),
- £2 billion coming from producer profits as a result of increased demand and local content,
- £16 billion wider impacts (e.g. reduced travel and freight costs, telecommunication data traffic increases, growth in revenues from sectors like digital media, electronics, etc.),
- £2 billion from taxation, and
- £2 billion from improved safety (assuming a 50% decrease of human error related accidents);
- to which £11 billion are discounted, corresponding to infrastructure investments and rise in road maintenance costs.

This study found that, by 2040, the annual economic benefits are expected to be at £121 billion. In this study, the indicated benefits are additional and not just simply arising from a redistribution of resources.

Another study estimated an annual global value of around $560 billion by 2035 for the core services related to CAVs, including new car revenues, hardware upgrades, apps and other digital features (Römer et al., 2016). Annual savings for the US are set to be around $1.3 trillion, divided as follows: $488 billion in total savings from accident avoidance, $169 billion in fuel savings and $645 billion from an increased productivity.

A study conducted by Strategy Analytics and Intel in 2017 found a global $7 trillion opportunity in revenues from services linked to fully automated vehicles in 2050, of which $1.7 trillion would correspond to Europe (Lanctot, 2017).

These studies are summarised in Table 6, following a chronological order in terms of timeframe for the expected impacts.

Table 6. Summary of previous studies quantifying the economic potential of CAV technologies

Reference	**Estimated economic potential**	**Details/Decomposition**	**Region**	**Timeframe**
Clements and Kockelman, 2017	$1,200 billion	— $418 billion from industry-specific effects — $448 billion in savings from increased productivity — $488 billion in savings from collisions — Discounting $138 billion from collision value overlap (between the $488 billion in savings from collisions and the savings in the auto repair, insurance, legal and medical sectors)	US	No timeframe
Asselin-Miller et al., 2017	$273 billion	— $210 billion from connectivity — $41.5 billion from autonomous hardware components — $15 billion from new software — $7.2 billion from autonomous driving chips	Global	2020 - 2030
World Economic Forum, 2016b	$670 billion	— Value at stake for automotive players as a result of 3 key digital themes (within the digital transformation of the automotive industry): the connected traveller, AVs and the enterprise/ecosystem — (in addition, $3.1 trillion in societal benefits coming from the digital transformation; of which more than $1 trillion would come from reduced accidents and lower insurance premiums)	Global	2025
Leech et al., 2015	£51 billion	— A £40 billion from consumers (£20 billion from a decreased value of travel time, £15 billion from more efficient trips and £5 billion from reduced costs including insurance, running costs and parking) — £2 billion from producer profits — £16 billion wider impacts (e.g. reduced travel and freight costs, telecommunication data traffic increases, growth in revenues from sectors like digital media, electronics, etc.) — £2 billion from taxation — £2 billion from improved safety	UK	2030

Reference	Estimated economic potential	Details/Decomposition	Region	Timeframe
Leech et al., 2015 *(continued)*		— Discounting £11 billion from infrastructure investments and road maintenance costs		
Römer et al., 2016	$284 billion	— $103 billion in special equipment (on-board control, guidance, and communication systems) — $86 billion in mobile apps (V2V telematics and communication) — $95 billion in new vehicles	Global	2030
	$558 billion	— $189 billion in special equipment for high/full automation — $109 billion in mobile apps (V2V telematics and communication) — $260 billion in new vehicles — (in addition to this, $1.3 trillion in savings: $488 billion in total savings from accident avoidance, $169 billion in fuel savings and $645 billion from an increased productivity)	Global	2035
Lanctot, 2017	$7,000 billion	— $3.7 trillion in consumer MaaS — $3 trillion in business / Business-to-Business (B2B) MaaS — $203 billion in new and emerging pilotless vehicle services — (in addition to this, benefits of $234 billion in public safety costs related to traffic accidents in the period 2035-2045)	Global	2050
	$1,700 billion	Global Passenger Economy service revenues, out of the $7 trillion global revenues	Europe	2050
Leech et al., 2015	£121 billion	(No details available)	UK	2050

Source: Own elaborations.

This review clearly reflects large differences in the findings from different studies, which denotes the great uncertainty around the topic. The assumptions made in each of these studies can also differ to a great extent, as does the timeframe considered for the effects. In some cases, they seem to mix up concepts and to lack a proper economic analysis framework (at least, on the basis of the available details). Compared to these previous efforts of assessing socio-economic implications of CAVs, the present study aims at using a scenario-analysis approach that allows to distinguish among different trends and time periods in the context of the EU. The focus is not paid on the economic quantifications as forecasts of the future evolution, but as indications of potential effects given a set of conditions.

Being clear that CAV technologies hold a disruptive potential in radically transforming our mobility system, industries and society, the next sections aim at shedding some light onto the potential range of impacts that can materialise in different sectors of the European economy. For some sectors, these impacts have been quantified for the deployment scenarios defined in the study.

3.2.1 Automotive (vehicle manufacturing and distribution)

3.2.1.1 Scope and size

Under the automotive sector category, we have considered both vehicle manufacturing (including vehicle components like engines or electric lighting equipment) and vehicle sales activities (both wholesale and retail), while activities linked to logistics or vehicle maintenance and repair have been tackled separately (see 3.2.4 and 3.2.7). Also, electronic and software components are left out of the automotive sector (see 3.2.2).

The relevance of EU's automotive sector is clearly reflected in the fact that it provides jobs for more than 5 million people, including around 3 million jobs in vehicle manufacturing and close to 2 million workers in vehicle sales, and that it accounts for approximately 3% of the EU GVA and around 2.5% of total EU employment ([77]). The EU is among the world leader producers of motor vehicles, and it is the area where the automotive sector represents the largest private investor in R&D. The sector is also particularly important given its links to upstream and downstream industries (e.g. steel, textiles, Information and Communication Technologies - ICT, mobility services, repair). In 2015, the EU-28 produced more than 16 million passenger vehicles and almost 2.5 million commercial vehicles ([78]), accounting for 23% of global motor vehicle production. There are currently around 290 million vehicles on Europe's roads (the equivalent of one for every two people), of which 38 million are commercial vehicles. The market of motorcycles is left out of this analysis, as the deployment of CAV technologies in this type of vehicles seems unlikely in the near to medium term (Asselin-Miller et al., 2017).

Detailed figures corresponding to this sector in Europe are given below (Table 7).

([77]) According to our combination of activities to form the automotive sector. Other statistics for the sector are available in https://ec.europa.eu/growth/sectors/automotive_es (last accessed 28 March 2018), which also include maintenance activities and others, that we are studying separately.

([78]) Data of 2016 extracted from ACEA Passenger cars EU and Commercial vehicles EU Statistics, available at: http://www.acea.be/statistics/tag/category/passenger-cars-production and http://www.acea.be/statistics/tag/category/commercial-vehicles (last accessed 2 April 2018).

Table 7. Indicators of the automotive sector

Sector	Subsector	Description	Indicators	Value
Automotive	C27.11	Manufacture of electric motors, generators and transformers	Number of persons employed	254,570
			Turnover (million euros)	50,550.6
			Number of enterprises	12,500
			Personnel costs (million euros)	10,331.9
			Value added (million euros)	13,994.9
			% Persons employed ([79])	**0.12%**
			% GVA ([80])	**0.12%**
	C27.40	Manufacture of electric lighting equipment	Number of persons employed	155,553
			Turnover (million euros)	29,551.7
			Number of enterprises	7,520 ([81])
			Personnel costs (million euros)	6,071.0
			Value added (million euros)	8,887.3
			% Persons employed	**0.07%**
			% GVA	**0.08%**
	C28.11	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines	Number of persons employed	245,976
			Turnover (million euros)	87,085.9
			Number of enterprises	1,700
			Personnel costs (million euros)	15,834.1
			Value added (million euros)	19,397.4
			% Persons employed	**0.11%**
			% GVA	**0.17%**

([79]) Calculated using the total EU-28 figure for persons employed in 2015: 215,231,000 (see footnote 75 for more details). This footnote applies to all the sectors and subsectors for which the share of employment has been calculated.

([80]) Calculated using the total EU-28 figure for GVA in 2015: 13,241,913 million euros (see footnote 74 for more details) and following the weighting procedure explained in 3.1.1. This footnote applies to all the sectors and subsectors for which the share of GVA has been calculated.

([81]) EU-28 value not available; calculated as the sum of the available countries (missing ones: Cyprus, Malta).

Sector	**Subsector**	**Description**	**Indicators**	**Value**
Automotive *(continued)*	C29	Manufacture of motor vehicles	Number of persons employed	2,441,910
			Turnover (million euros)	1,032,492.1
			Number of enterprises	19,500
			Personnel costs (million euros)	123,570.3
			Value added (million euros)	200,414.7
			% Persons employed	**1.13%**
			% GVA	**1.69%**
	G45.1	Sale of cars and light motor vehicles	Number of persons employed	1,471,435
			Turnover (million euros)	878,167.8
			Number of enterprises	210,356.0
			Personnel costs (million euros)	48,703.2
			Value added (million euros)	88,245.8
			% Persons employed	**0.68%**
			% GVA	**0.82%**
	G45.3	Sale of motor vehicle parts and accessories	Number of persons employed	701,567
			Turnover (million euros)	184,690.1
			Number of enterprises	120,946.0
			Personnel costs (million euros)	18,439.2
			Value added (million euros)	28,916.0
			% Persons employed	**0.33%**
			% GVA	**0.27%**
	Total		Number of persons employed	5,271,011
			Turnover (million euros)	2,262,538
			Number of enterprises	372,522
			Value added (million euros)	359,856
			% Persons employed	**2.45%**
			% GVA	**3.15%**

Source: Own elaborations (based on Eurostat data from 2015).

3.2.1.2 Challenges and opportunities

Connectivity and automation will considerably affect the automotive sector, specifically through changes along the value chain (and value share) and new mobility behaviours that will certainly affect the demand for new vehicles and new mobility requirements. At present, 90% of the value of a car lies on hardware whereas 10% of it relates to software but these shares will be interchanged in the future with software becoming increasingly important as a differentiation aspect linked to manufacturers' profits (Römer et al., 2016 as cited in Asselin-Miller et al., 2017). Software could then become 40% of the vehicle value (Römer et al., 2016; Clements and Kockelman, 2017). Contents will become a 20% of the value of a car, and hardware will thus decrease to a 40% (Römer et al., 2016). Thus, business-as-usual based on hardware-selling has the risk of becoming a commodity and less attractive due to decreasing margins (Manyika et al., 2013, as cited in European Commission, 2017l). Critical control points in the new value chain will include the HMI, digital platforms, real-time geospatial information and car sensor data (European Commission, 2017l).

The changes in the value chain and share will require vehicle manufacturers and technology providers to make substantial adaptations of their manufacturing processes and organisations, as well as strategic decisions including investments and partnerships, in a context of high competition among traditional players and new entrants. Numerous examples of partnerships and investments have already been made in the field, e.g. BMW, Audi and Daimler with HERE (Boeriu, 2015) or Bosch with Mercedes (Fingas, 2018). The effects on the economy linked to these changes in the automotive value chain are discussed in the next sections (e.g. software in 3.2.2 or data services and digitalisation in 3.2.3).

Secondly, new trends in mobility are also likely to influence the automotive landscape as it stands at present. MaaS will open up mobility for underserved users like disabled, elderly or young people without a driving license. Automated driving technologies could strengthen these mobility practices by reducing the cost of the driver among others (e.g. insurance) and could eventually lead to a decrease in vehicle ownership, thereby having an effect on vehicle sales (still to be seen if a decrease in vehicle ownership is offset by more intense vehicle use in a MaaS setting). CAV technologies, alone or in conjunction with MaaS, could lead to more private vehicle travel, as a result of more favourable driving conditions, and boost VKT up to significant levels. Ahead of this challenging landscape, traditional vehicle manufacturers and technology companies are establishing partnerships or making investments in companies that offer mobility services, like Daimler with MyTaxi (Boogar, 2014), Volvo with Uber (Ibison, 2016) or Volkswagen with Gett (McCarthy, 2016). How new mobility behaviours (increase mileage and interaction with MaaS trend) could affect the future mobility, and specifically, the revenues of the automotive sector, is discussed next.

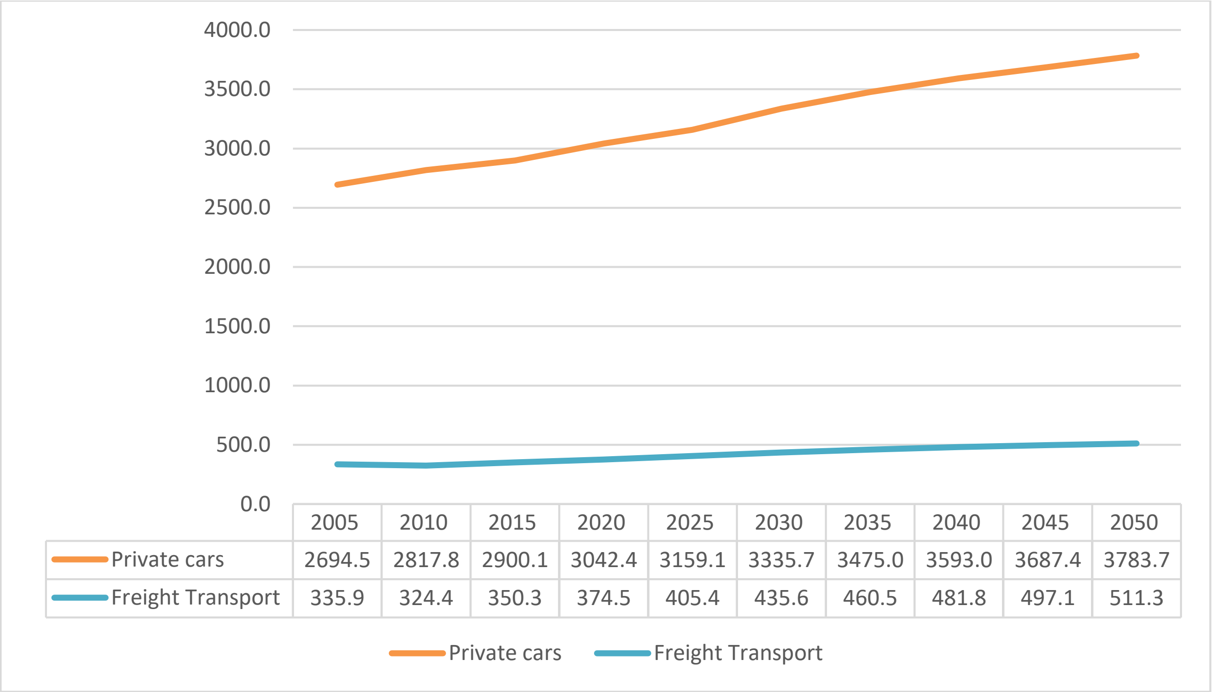
Starting from the current and expected travel activity in Europe (without connectivity/automation), we explore below how CCAM can affect the demand for transport in the future and the resulting effects on the automotive sector activities.

Evolution of the transport activity in the EU (baseline scenario)

Before discussing how CAVs may influence travel demand in the future, an analysis of the transport activity in the EU is made, using VKT data from the EU Reference Scenario 2016 (European Commission, 2016a; precisely, taking the modified baseline of EU Reference Scenario 2016 from Hill et al., forthcoming 2018). In the present study, these projections are considered as the baseline scenario (as described in 2.2.3). According to these projections, increases in VKT are estimated in the EU in the period from now to 2025 and 2050: a growth of about 9% and 30% is identified for passenger vehicles for the periods 2015-2025 and 2015-2050 respectively and 16% and 46% for freight transport for the same respective periods (see Figure 7). Developments in the economic activity drive the higher increases expected for the period up to 2030, both for passenger and freight transport sectors (European Commission, 2016a). The post-2030 passenger transport growth is slower than in the period before, because of an almost stagnant population after

2040 and saturation effects limiting the growth. Freight transport follows a similar trend in the period 2030-2050. Road transport will continue being the prevalent mode for passenger transport, in particular passenger cars, although the pace of growth is lower compared to other modes. It is important to note that the modal share of passenger cars is expected to decrease progressively (as the EU Reference Scenario 2016 cites: from 73% in 2010 to 70% in 2030 and 67% in 2050, possibly as a consequence of saturation levels in car ownership in many EU-15 countries, high congestion, fossil fuel price increases, higher use of collective transport modes like high speed rail and the ageing of the EU population). Other sources project that passenger transport activity is expected to increase by 23% during the period 2010-2030 and 42% for 2010-2050, while freight transport growth is estimated at 36% by 2030 and 60% by 2050 (Gibson et al., 2017). To conclude, EU transport activity is expected to continue growing in the next decades, though at a slower pace than in the past, with road transport maintaining its dominant role (Gibson et al., 2017). Full data set from the modified baseline of EU Reference Scenario 2016 (Hill et al., forthcoming 2018) is available in Annex 2.

Figure 7. Passenger and freight transport activity by road (VKT, in billion vehicle kilometres - Gvkm)



	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Private cars	2694.5	2817.8	2900.1	3042.4	3159.1	3335.7	3475.0	3593.0	3687.4	3783.7
Freight Transport	335.9	324.4	350.3	374.5	405.4	435.6	460.5	481.8	497.1	511.3

Source: Own elaborations (based on modified baseline of EU Reference Scenario 2016, Hill et al., forthcoming 2018).

Possible effects of CCAM in travel activity

CCAM will likely modify the landscape presented in Figure 7, most possibly leading to increases in VKT (as cited by authors like Fagnant and Kockelman, 2015; Cohen and Cavoli, 2017). There are three main mechanisms for which CAVs could lead to changes in vehicle travel demand (Wadud et al., 2016):

- Reduced cost of driver's time (e.g. reduced insurance costs, reduced perceived discomfort costs of driving, perceived costs of travel time),
- New user groups (like elderly, disabled or young people), and
- New mobility service models (MaaS and shared mobility).

While the first and second mechanisms seem to clearly lead to vehicle travel increases (with a wide range of possible increases), the effects on travel from the third one could either lead to increases or decreases in vehicle travel activity. Estimations from the recent literature are provided below.

Concerning the first mechanism (reduced cost of driver's time), a range of travel increases from 4% for low automation levels to 60% for full automation is estimated (applicable for light duty vehicles) (Wadud et al., 2016). As far as the second mechanism (new users) is concerned, personal vehicle travel could increase in the range between 2% and 10% as a result of more drivers among the older and young people groups, as well as more travel per elderly driver (Wadud et al., 2016). Another estimate points at an annual 14% increase in Vehicle Miles Travelled (VMT) in light duty vehicles travel (Harper et al., 2016). Other research studies estimate that new user groups would result in an increase between 2% and 9% (Fagnant and Kockelman, 2015), or even reach a 40% increase (Brown et al. 2014 as cited in Harper et al., 2016). These effects found in the literature are summarised in Table 8.

Table 8. CAV mechanisms leading to changes in travel activity, as identified in the literature

	VKT changes	**Source**
Reduced cost of driver's time	+4% to +60%	Wadud et al., 2016
New user groups	+2% to +10%	Wadud et al., 2016
	+14%	Harper et al., 2016
	+2% to +9%	Fagnant and Kockelman, 2015
	+40%	Brown et al., 2014

Source: Own elaborations.

It is evident that different urban areas across the globe are undergoing a shift towards MaaS (Goodall et al., 2017). Private car ownership (and even holding a driving license) is becoming less popular among young generations ('millennials') (Shirouzu, 2016; Sivak and Schoettle, 2016) that seem to be more prone to use this type of services (Prieto et al., 2017). The number of car sharing users worldwide has increased from approximately 0.4 million to 4.9 million in the 2006-2014 period (Briggs, 2014 as cited in Prieto et al., 2017). European car sharing customers are expected to increase from 700,000 customers (using 21,000 vehicles) in 2011 to 20,000,000 customers (using 240,000 vehicles) in 2020 (Peterson, 2014). The global market for shared vehicles and mobility offerings is predicted to increase 35% a year through 2020 (Bernhart, 2014 as cited in World Economic Forum, 2016b). By 2030, 10% of vehicles sold could be shared vehicles (Bertoncello et al., 2016).

CAVs could reinforce the MaaS trend, by eliminating driver costs and significantly reducing other cost elements (e.g. insurance), making it competitive with public transport (a price below $1 per mile is estimated for robo-taxis by Römer et al., 2016). Some authors anticipate that by 2030, 95% of US Personal Miles Travelled (PMT) will be based on shared on-demand autonomous electric vehicles (Arbib and Seba, 2017). A similar path would be followed in other geographic areas, including Europe (Seba, 2017). This forecast may seem too extreme relative to other estimates, but invites to reflect on a possible future mobility landscape, where transport services might even become free (or nearly free) on the basis of advertisement supported business models (McFarland, 2017; Arbib and Seba, 2017). As an example illustrating these trends, there are automated shuttles currently operating in two European cities: Rotterdam (The Netherlands) and Civaux (France) (Albright et al., 2017).

A detailed discussion of the possible effects on travel activity from this mechanism (new service models) is provided in Box 1.

Box 1. Effects of on-demand CCAM mobility on vehicle travel activity

MaaS could lead to significant travel increases, as a result of the improved accessibility and better driving conditions (even without accounting for automation). Younger and older age groups can particularly enjoy the benefits provided by on-demand mobility services (Silberg et al., 2015). The increase in PMT could reach as much as 3-4 additional trillion VMT by 2050 (i.e. more than double the figures of 2015 in the U.S.) (Silberg et al., 2015). This additional amount of travel will be dependent on the degree to which trips will be shared among users, from no significant increase if trips are shared (Average Vehicle Occupancy - AVO = 2.0), up to the highest growth if vehicles travel empty (thus necessarily being automated; AVO = 0.95). In this context, it is relevant to note that, even if drastically lower costs are enabled by a shared autonomous mobility (Arbib and Seba, 2017), it cannot be taken for granted that users will be willing to share the trip with other passengers, as doing so may only represent a slightly lower cost on the basis of an already low fare (McFarland, 2017).

A study in the Netherlands concluded that car sharing induces 15-20% fewer vehicle kilometres than before using car sharing and over 30% less car ownership amongst car sharers (Nijland and van Meerkerk, 2017). However, car sharing can induce more road travel in non-car users, as a result of modal shifts from walking or cycling (Le Vine et al., 2014). With CAVs used on demand, vehicle usage intensity could significantly increase. Shared AVs may induce an increased travel per vehicle as a result of their repositioning travelling empty to pick up new passengers or reach a certain location, estimated at 11% (Fagnant and Kockelman, 2014) and 75% (Schoettle and Sivak, 2015). Another estimate points at a 10 times usage increase (Arbib and Seba, 2017). Therefore, the personal demand reduction linked to a shared mobility might be cancelled out by the increased empty-running travel. Increases in vehicle asset utilisation could range from a roughly 4% (as vehicles are currently parked 96% of the time) to around 90% of the time. This will certainly have an effect in vehicle lifetimes (about a 40% reduction is indicated in Schoettle and Sivak, 2015).

Notable declines in the number of vehicles would be expected with MaaS and shared mobility, which some authors have estimated at a reduction of 95% of today's private cars (Burghout et al., 2015), and which could have the potential to lower the overall travel demand. A 97% reduction in the number of vehicles is evidenced by the ITF (2016), where each vehicle would be running almost 10 times more kilometres than at present, but the total VKT would reduce by 37% (even during peak hours). Another study points at one car sharing vehicle replacing 9 to 13 individually used vehicles (Shaheen and Chan, 2015). Similarly, another reference notes that one autonomous taxi could replace the demand served by 10 conventionally driven vehicles (Bischoff and Maciejewski, 2016). Wadud et. al (2016) estimated a maximum potential reduction of travel of 20% resulting from previous vehicle owners that reduced their travel activity through car-sharing (upper bound estimate). In the Wadud (2016) study, no changes of VKT are considered for the lower bound estimation, as personal demand reduction can be offset by an increase in empty-vehicle driving to pick up new passengers. The OECD Lisbon-based study (ITF, 2015) provided estimates of potential travel increases coming from on-demand mobility services, namely ride sharing and car sharing, which range from 6% to 89% more VKT depending on these two scenarios and whether high-capacity public transport is available or not in addition to the shared vehicles fleet. Considerable vehicle fleet size reductions would become feasible, in the order of 80-90% (10-20% of vehicles would satisfy the same travel demand previously offered by 100% cars). During the transition period though, some experts have estimated a total vehicle travel increase between 30% and 90% with mixed-fleets of shared AVs and traditional private cars, potentially also increasing the number of vehicles (ITF, 2015).

The effects linked to the third mechanism (new service models), especially the ones that are also related to automation, are summarised in Table 9.

Table 9. CAV-MaaS mechanism leading to changes in travel activity, as identified in the literature

	VKT changes	Source
New mobility service models	-20% to 0%	Wadud et al., 2016
	+6% to 89%	ITF, 2015
	+30% to 90%	ITF, 2015
	-37%	ITF, 2016

Source: Own elaborations.

In spite of these considerations around on demand shared mobility, private vehicle ownership might remain dominant in the future following the AVs luxury and comfort advantages at a small cost difference (Bösch et al., 2018). If this is the case, the projected travel increases might pose significant challenges to our transport system. Road capacity could be challenged by an important growth in demand in conjunction with traffic inefficiencies of automated driving technologies, especially linked to the following two factors: early stages of technology deployment where safety priorities will lead to conservative margins and the interaction with conventional vehicles where unexpected AV behaviours will create traffic inefficiencies/conflicts. Traffic management in such a scenario will certainly require new approaches (Alonso Raposo et al., 2017).

On a more qualitative level, Gruel and Stanford (2016) found that VKT is likely to increase in all three different possible scenarios of future mobility discussed on the basis of the Sterman (2000) baseline model of traffic and congestion, which can be understood to be someway aligned to the three mechanisms formerly explained. However, the size of these respective increases is expected to differ significantly, and no quantification of these changes is given in the paper.

It is worth mentioning that most of these travel effects are linked to full automation dominating the market, which has an unclear timeframe.

From travel activity to vehicle sales

These changes in travel activity linked to CAVs will potentially affect vehicle sales, under the assumption that more vehicle travel leads to more vehicle sales (as assumed by Clements and Kockelman, 2017). What is clear is that the development of CAVs, jointly with a growth of MaaS, will challenge the traditional vehicle manufacturers' business model (Cavoli et al., 2017). To prevent the potential negative effects in vehicle sales linked to an increase in MaaS, many vehicle manufacturers are partnering with transport networking and car/ride sharing companies (see examples in the introduction of this section). Another anticipatory action made by some vehicle manufacturers is linked to enhancing their capabilities in Artificial Intelligence (AI), programming or other areas in order to remain competitive ahead of the new technological challenges in the field (see examples in the introduction of this section). Technology companies are particularly strong in the area of electronics and software and are heavily competing with Original Equipment Manufacturers (OEMs) in the development and commercialisation of AVs. Römer et al. (2016) groups the incumbent OEMs and suppliers together with the new disruptive players in 5 categories and argues their respective potential to capture value, identifying the main challenges to be faced. From this analysis, it is clear that none of them will be able to succeed without support. In this changing landscape, servitisation (i.e. service-based business models) acts as an alternative revenue source to traditional vehicle sales, relying on periodic revenue inputs like subscription services (e.g. OnStar from General Motors) (European Commission, 2017m). MaaS models might replace vehicle sales through generated applications and contents, and automakers might eventually become mobility service providers and fleet operators of CAVs, in strong competition with a range of consumer industries (e.g. web/internet, retail) (Lanctot, 2017). These services are further discussed in 3.2.3.

3.2.1.3 Estimated effects for different scenarios

Given the high uncertainty in the evolution of the future mobility, there is a lack of consistent predictions in travel demand changes. We have made our own estimates that rely on the assumptions made for the deployment scenarios in Table 3 and Table 4 (i.e. share of vehicles being automated, and the respective shares of different levels of automation) as well as on the available literature findings.

For passenger transport, travel activity estimates are based on the following assumptions:

- Taking into account Wadud et al. (2016) estimations, the following levels of impacts corresponding to the effects from mechanisms 1 (reduced cost of driver's time) and 2 (new users) are established:
  - Three levels for mechanism 1: low 4-20%, medium 20-30%, high 40-60%.
  - Two levels for mechanism 2: low 2-6%, high 6-10%.
- Each scenario and timeframe are given a certain level of potential impacts from each mechanism, on the basis of the rates of different automated driving systems given in the passenger transport deployment scenarios. For instance, mechanism 2 is expected not to be present in scenario 1 given that it is linked to full automation which is not present in this scenario (just partially in 2050). For the same reason, mechanism 1 is expected to be low, as only partial benefits might exist in intermediate levels of automation.
- Then, total average figures are calculated for each scenario/timeframe, also summing the corresponding baseline projected increase (taking data for private cars travel activity from the updated baseline scenario of EU Reference Scenario 2016, Hill et al., forthcoming 2018). This has been done because the effects of automation are considered in addition to the ones included in the baseline. However, it is relevant to mention that some overlapping might exist between them, which cannot be identified at this stage.

As a result, estimates for passenger transport are given in Table 10.

Table 10. Changes of VKT per scenario - passenger transport

	CHANGES OF VKT PER SCENARIO - PASSENGER TRANSPORT	
	2015-2025	**2015-2050**
Baseline	**+9%**	**+30%**
Scenario 1. Low uptake	5-20% (mechanism 1 low) => Average **12% + 9% BL** = **21%**	20-40% (mechanism 1 medium) => Average **30% + 30% BL** = **60%**
Scenario 2. Medium uptake	20-40% (mechanism 1 medium) + 2-6% (mechanism 2 low) => Average **34% + 9% BL** = **43%**	40-60% (mechanism 1 high) + 6-10% (mechanism 2 high) => Average **58% + 30% BL** = **88%**
Scenario 3. High uptake	40-60% (mechanism 1 high) + 6-10% (mechanism 2 high) => Average **58% + 9% BL** = **67%**	40-60% (mechanism 1 high) + 6-10% (mechanism 2 high) => Average **58% + 30% BL** = **88%**

Source: Own elaborations.

Effects from mechanism 3 (MaaS/shared mobility) on VKT are ignored in these travel activity calculations, but their effects on potential vehicle sales are considered in a subsequent step on the basis of the scenario assumptions (i.e. share of IO versus MaaS travel, see next step of the calculation for passenger transport).

For freight transport, travel demand estimates are based on the following assumptions:

- Effects from mechanism 2 (new users) and mechanism 3 (MaaS/shared mobility) are expected not to be applicable for freight transport, but still increases in VKT could be possible in the case of more convenient and cheaper travel conditions allowed by autonomous commercial vehicles (shifting travel from rail or water towards road), as well as from the fact that these technologies would allow for longer driving times without the current driving time and night work restrictions (e.g. Regulation (EC) No 561/2006 and Directive 2002/15/EC ([82])).
- The largest transport increase is estimated for scenario 3 in 2050 (representing the highest automation levels and respective travel shares), and corresponds to the reasoning that commercial vehicles could increase from a maximum of 16 hours of driving per day today (which is understood to be in line with current practice, following the necessary resting time of drivers) to about 21 hours of driving per day (i.e. a 30% increase).
- Taking into account these hypothetical circumstances and baseline projections from the updated baseline scenario of EU Reference Scenario 2016 (the part corresponding to freight transport activity, including light and heavy duty vehicles activity, from Hill et al., forthcoming 2018), increases in VKT are derived for the rest of the scenarios, with the overall trend of increasing VKT from scenario 1 to scenario 2 and scenario 3, as well as an increasing trend from 2025 to 2050. This results in increases of 5%, 10%, 15% and 30%.

As a result, estimates for freight transport are given in Table 11.

Table 11. Changes of VKT per scenario - freight transport

	CHANGES OF VKT PER SCENARIO - FREIGHT TRANSPORT	
	2015-2025	**2015-2050**
Baseline	**+16%**	**+46%**
Scenario 1. **Low uptake**	(= Baseline) **+16%**	(= Baseline) **+46%**
Scenario 2. **Medium uptake**	**5% + 16%** = **+21%**	**15% + 46%** = **+61%**
Scenario 3. **High uptake**	**10% + 16%** = **+26%**	**30% + 46%** = **+76%**

Source: Own elaborations.

The next step of the calculations is to convert VKT estimates into vehicle sales estimates. In the case of passenger transport, VKT estimations are translated into vehicle sales changes by using the following formula, which accounts for the shared mobility trend:

Change in Vehicle Sales = Change in VKT(100% IO share + 30% MaaS share)*

IO and MaaS shares are taken from the assumed rates in Table 3, section 2.2.3, for each of the scenarios. The multiplying value of 30% in the MaaS component is resulting from the assumption that, even though new mobility service models will increase vehicle usage intensity (a 75% usage increase is stated in Schoettle and Sivak, 2015 or a 10 times increase in Arbib and Seba, 2017), the resulting decreased vehicle ownership will drive a

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(82) European Commission's Mobility and Transport website on Road Driving time and rest periods, available at: https://ec.europa.eu/transport/modes/road/social_provisions/driving_time_en (last accessed 2 May 2018).

downwards trend in vehicle sales. Specifically, the 30% of MaaS share represents the possibility that less number of vehicles would satisfy the demand for MaaS and that the vehicles used in a shared mobility setting would be replaced more frequently than today given the more intense use of these vehicles. Precisely:

- Assuming that the reduction in the number of vehicles leads to 10% of vehicles able to satisfy the demand for MaaS.
- But assuming that these vehicles are replaced 3 times more frequently.
- Thus, from 100% to 10% and finally, to 30%.

The resulting changes in passenger vehicle sales are shown in Table 12.

Table 12. Changes in vehicle sales per scenario - passenger transport

	CHANGES IN VEHICLE SALES PER SCENARIO - PASSENGER TRANSPORT	
	2015-2025	**2015-2050**
Baseline ([83])	**+9%**	**+30%**
Scenario 1. Low uptake	**+18%**	**+47%**
Scenario 2. Medium uptake	**+31%**	**+51%**
Scenario 3. High uptake	**+39%**	**+33%**

Source: Own elaborations.

In the case of freight transport, vehicle sales are in line with the corresponding VKT % increases, ignoring any effect from MaaS (i.e. using VKT increases of 0-30% as in Table 11). However, the starting point in this case is the baseline vehicle sales (taken from the modified baseline scenario of the EU Reference Scenario 2016, Hill et al., forthcoming 2018) and not the baseline travel demand projections for freight transport, from which the various scenarios/timeframes are calculated.

As a result, estimates for freight vehicle sales are given in Table 13.

Table 13. Changes in vehicle sales per scenario - freight transport

	CHANGES IN VEHICLE SALES PER SCENARIO - FREIGHT TRANSPORT	
	2015-2025	**2015-2050**
Baseline	**+19%**	**+38%**
Scenario 1. Low uptake	(= Baseline) **+19%**	(= Baseline) **+38%**
Scenario 2. Medium uptake	**5% + 19% =** **+24%**	**15% + 38% =** **+53%**
Scenario 3. High uptake	**10% + 19% =** **+29%**	**30% + 38% =** **+68%**

Source: Own elaborations.

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(83) Considering the already on-going MaaS trend and its expected growing evolution in the future without accounting for any automation trend, we consider these figures to be subject to possible reductions.

The total number of motor vehicles registered in the EU in 2015 was 15,781,465 vehicles ([84]). Of these, 13,696,221 were passenger vehicles and 2,039,268 were commercial vehicles, including light, medium and heavy commercial vehicles.

An additional consideration in the estimations of the passenger vehicle effects is the following. We have estimated the turnover effects on the automotive sector based on two different baseline figures of number of passenger vehicles, namely:

- The first calculation builds on the number of passenger cars registered in the EU in 2015 (i.e. 13.7 million passenger vehicles in 2015). This figure is used as an approximation of the final demand for passenger cars in the EU. It represents the situation in which the European market behaves as if it was an autarky (therefore as a closed economy that does not engage in international trade with other countries).
- The second calculation builds on the number of passenger cars produced in the EU in 2015 (i.e. 16 million vehicles in 2015). It represents the situation where Europe assumes global leadership and internalizes all the benefits of the global value chain, i.e. all inputs are produced within the EU, the domestic demand is entirely satisfied and the residual vehicles are exported. Anyhow, it is relevant to note that this figure represents production, which is normally slightly higher than sales. It could thus imply a certain degree of overestimation in the calculations.

These calculations can be found in Table 14 and Table 15. Similar considerations have not been judged necessary for freight transport. The reasons for this are the following. On the one hand, the available data on commercial vehicles import/export shares, production and registration all come from different databases, which use different definitions and aggregations. These differences would compromise the reliability of any assumption that aims to reflect similar situations to the Autarky and Global leadership ones used in the passenger transport. On the other hand, the production and registration figures are very similar, and likewise, the import and export data are comparable. The effects of trying to reflect different market situations would then cancel each other. Therefore, for freight transport, just the 2 million commercial vehicles figure has been considered (Table 16).

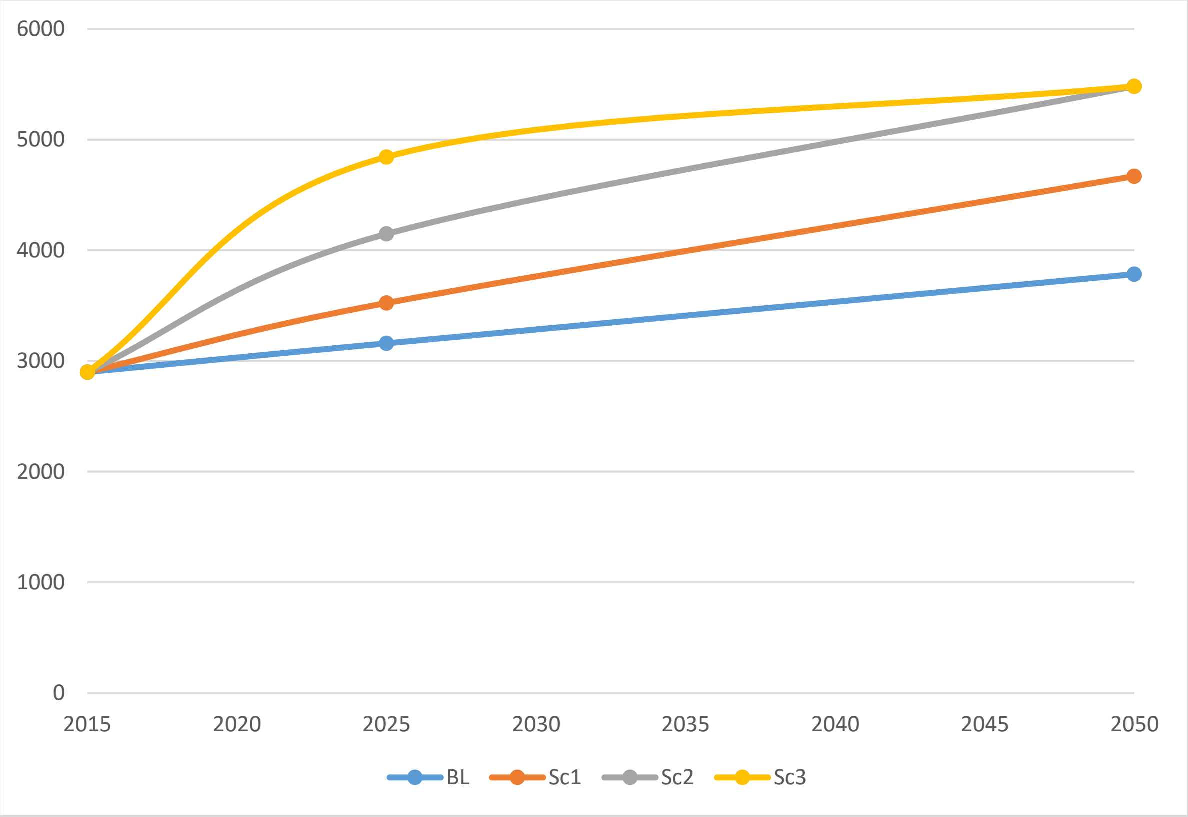
In order to provide effects on sector turnover, an average price per passenger vehicle of 27,496 euros has been considered (from Hill et al., forthcoming 2018). For freight transport, average vehicle prices are taken from different sources and applied in accordance to the fleet distribution in 2025 and 2050. Specifically, using the following average vehicle prices for Light, Medium and Heavy Duty Vehicles respectively: 30,238 euros (from Hill et al., forthcoming 2018), 60,233 euros (average of 7.5, 12 and 18 Tonne vehicle prices from Lastauto Omnibus-Katalog, 2017) and 100,000 euros (rough average price of 4*2 and 6*2 HDVs considering Lastauto Omnibus-Katalog, 2017) and their relative shares in 2025 (according to 2015 data from ACEA Consolidated registrations by country Statistics ([84])) and 2050 (baseline of DIONE fleet impact model, Thiel et al., 2016).

For both passenger and freight transport, the simplified assumption that prices are kept constant over time is made at this stage. It is also important to highlight that the additional cost of automation is not considered in this cost calculation but left for the section dealing with electronics and software (3.2.2).

The following charts (Figure 8, Figure 9, Figure 10 and Figure 11) show the effects on VKT and vehicle sales corresponding to the different scenarios of the present study, both for passenger and commercial vehicles. For passenger transport, the Autarky situation has been chosen to be represented. Specifically, in Figure 9, it is possible to observe long-term lower vehicle sales on scenario 3 as a result of a dominant MaaS-based travel. This is not the case of freight transport, where a growing trend can be observed in all scenarios, both in VKT and sales (see Figure 10 and Figure 11; to note that baseline and scenario 1 are superimposed in both figures).

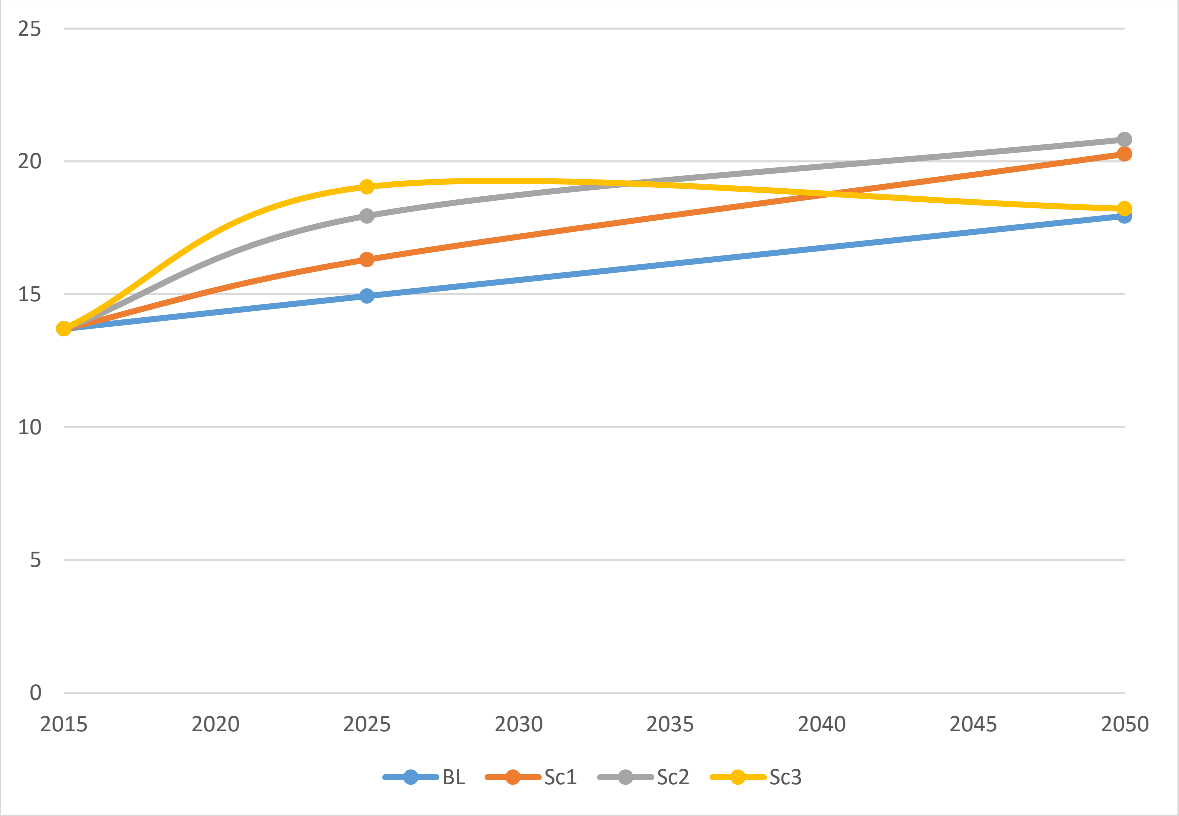
([84]) EU-28 except Cyprus and Malta for which data is not available, according to ACEA Consolidated registrations by country Statistics from 2015, available at: http://www.acea.be/statistics/tag/category/by-country-registrations (last accessed 25 March 2018).

Figure 8. Passenger transport activity (VKT, in Gvkm) for the different study scenarios (Autarky)



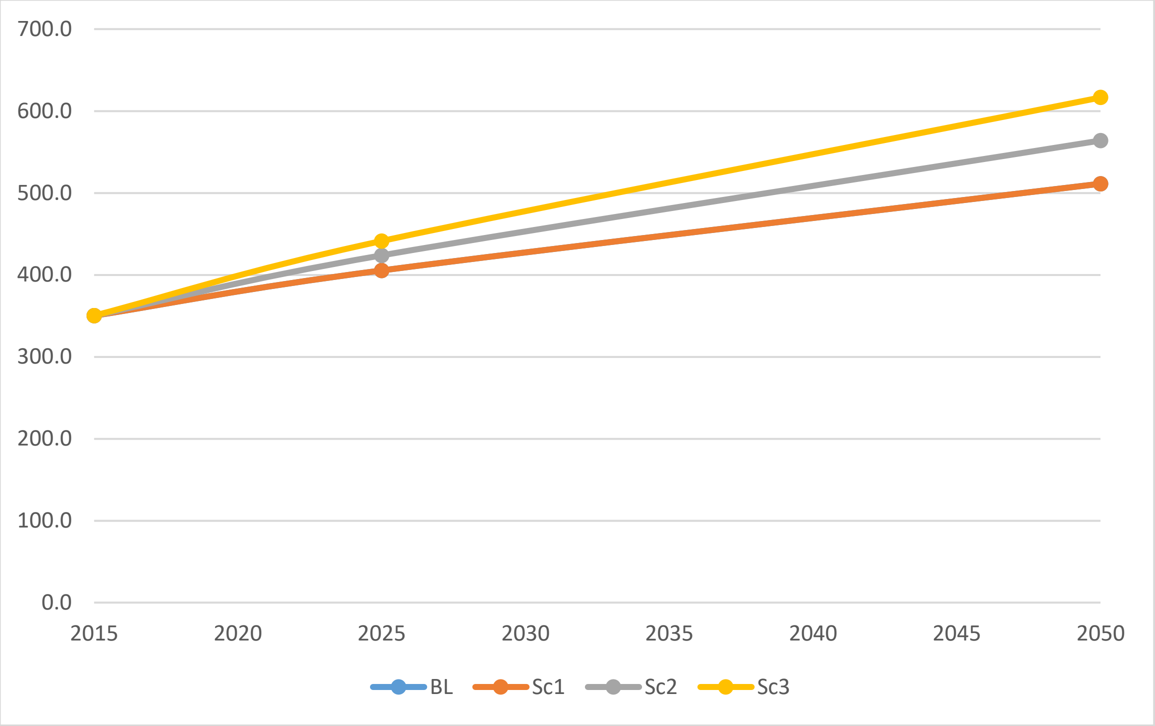
Source: Own elaborations.

Figure 9. Passenger vehicle sales (in million vehicles) for the different study scenarios (Autarky)



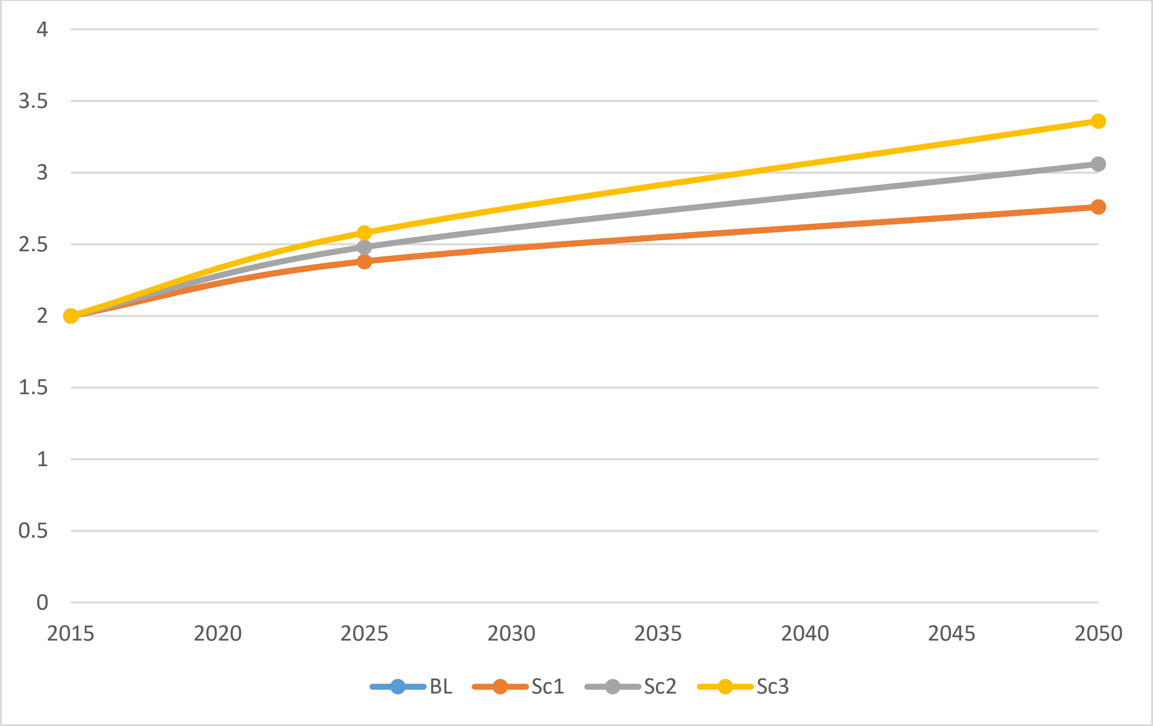
Source: Own elaborations.

Figure 10. Freight transport activity (VKT, in Gvkm) for the different study scenarios



Source: Own elaborations.

Figure 11. Commercial vehicle sales (in million vehicles) for the different study scenarios



Source: Own elaborations.

The two calculations for passenger transport (Autarky versus Global leadership) are given in Table 14 and Table 15, and freight transport calculations are shown in Table 16. In brief, by 2050, revenues could amount to approximately 570 billion euros for passenger vehicles (scenario 2, Autarky) and 130 billion euros for commercial vehicles (scenario 2).

As a result, this could be the range of possible effects for **passenger transport**:

Table 14. Potential effects of AVs in the automotive sector - passenger transport (Autarky)

Effects of AVs on the automotive industry – passenger transport	**Baseline**			**Scenario 1**		**Scenario 2**		**Scenario 3**	
	2015	**2025**	**2050**	**2025**	**2050**	**2025**	**2050**	**2025**	**2050**
Change in new vehicle sales with respect to 2015 (%)	-	+9%	+30%	+18%	+47%	+31%	+51%	+39%	+33%
Number of new vehicles sold (million vehicles)	13.7	14.93	17.81	16.17	20.14	17.95	20.69	19.04	18.22
Change in new vehicle sales with respect to the baseline scenario (million vehicles)	-	+1.23 ([85])	+4.11 ([85])	+1.24	+2.33	+3.02	+2.88	+4.11	+0.41
Revenues from new vehicle sales (billion euros) ([86])	380 ([87])	410	490	445	555	495	570	525	500
Changes in revenues from new vehicle sales with respect to the baseline scenario (billion euros)	-	+30 ([85])	+110 ([85])	+35	+65	+85	+80	+115	+10
Changes in revenues from new vehicle sales with respect to the baseline scenario (%)	-	+8% ([85])	+29% ([85])	+9%	+13%	+21%	+16%	+28%	+2%

Source: Own elaborations.

([85]) The figure represents the change with respect to 2015.

([86]) Revenue figures are rounded for simplification and in accordance to their actual meaning.

([87]) This figure is just an estimate of the revenues in new passenger vehicle sales by 2015 and does not correspond to the actual value. It has been calculated in order to understand the change in revenues for the different scenarios.

Table 15. Potential effects of AVs in the automotive sector - passenger transport (Global leadership)

Effects of AVs on the automotive industry – passenger transport	**Baseline**			**Scenario 1**		**Scenario 2**		**Scenario 3**	
	2015	**2025**	**2050**	**2025**	**2050**	**2025**	**2050**	**2025**	**2050**
Change in new vehicle sales with respect to 2015 (%)	-	+9%	+30%	+18%	+47%	+31%	+51%	+39%	+33%
Number of new vehicles sold (million vehicles)	16.0	17.4	20.8	18.9	23.5	21.0	24.2	22.2	21.3
Change in new vehicle sales with respect to the baseline scenario (million vehicles)	-	+1.4 (88)	+4.8 (88)	+1.4	+2.7	+3.5	+3.4	+4.8	+0.5
Revenues from new vehicle sales (billion euros) (89)	440 (90)	480	570	520	645	575	665	610	585
Changes in revenues from new vehicle sales with respect to the baseline scenario (billion euros)	-	+40 (88)	+130 (88)	+40	+75	+95	+95	+130	+15
Changes in revenues from new vehicle sales with respect to the baseline scenario (%)	-	+8% (88)	+29% (88)	+9%	+13%	+21%	+16%	+28%	+2%

Source: Own elaborations.

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(88) The figure represents the change with respect to 2015.
(89) Revenue figures are rounded for simplification and in accordance to their actual meaning.
(90) This figure is just an estimate of the revenues in new passenger vehicle sales by 2015 and does not correspond to the actual value. It has been calculated in order to understand the change in revenues for the different scenarios.

And this could be the range of possible effects for **freight transport**:

Table 16. Potential effects of AVs in the automotive sector - freight transport

Effects of AVs on the automotive industry – freight transport	**Baseline**			**Scenario 1**		**Scenario 2**		**Scenario 3**	
	2015	**2025**	**2050**	**2025**	**2050**	**2025**	**2050**	**2025**	**2050**
Change in new vehicle sales with respect to 2015 (%)	-	+19%	+38%	+19%	+38%	+24%	+53%	+29%	+68%
Number of new vehicles sold (million vehicles)	2	2.38	2.76	2.38	2.76	2.48	3.06	2.58	3.36
Change in new vehicle sales with respect to the baseline scenario (million vehicles)	-	+0.38 (91)	+0.76 (91)	+0.00	+0.00	+0.10	+0.30	+0.20	+0.60
Revenues from new vehicle sales (billion euros) (92)	80 (93)	95	115	95	115	100	130	100	145
Changes in revenues from new vehicle sales with respect to the baseline scenario (billion euros)	-	+15 (91)	+35 (91)	+0	+0	+5	+15	+5	+30
Changes in revenues from new vehicle sales with respect to the baseline scenario (%)	-	+19% (91)	+44% (91)	+0%	+0%	+5%	+13%	+5%	+26%

Source: Own elaborations.

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(91) The figure represents the change with respect to 2015.
(92) Revenue figures are rounded for simplification and in accordance to their actual meaning.
(93) This figure is just an estimate of the revenues in new commercial vehicle sales by 2015 and does not correspond to the actual value. It has been calculated in order to understand the change in revenues for the different scenarios.

3.2.2 Electronics and software

3.2.2.1 Scope and size

Under the electronics and software sector, we have included four specific Eurostat NACE Rev. 2 sectors: manufacture of computers and peripheral equipment, manufacture of consumer electronics, manufacture of instruments and appliances for measuring, testing and navigation and computer programming, consultancy and related activities. While these sectors cover a broader set of activities than the ones strictly related to motor vehicle equipment and software, further level of detail is unavailable. In the framework of this study, the electronics and software sector is closely linked to the automotive one.

Detailed figures corresponding to this sector in Europe are given below (Table 17).

Table 17. Indicators of the electronics and software sector

Sector	Subsector	Description	Indicators	Value
Electronics and software	C26.20	Manufacture of computers and peripheral equipment	Number of persons employed	80,318
			Turnover (million euros)	135,935.3
			Number of enterprises	5,607.0 (94)
			Personnel costs (million euros)	3,637.6
			Value added (million euros)	4,163.6 (95)
			% Persons employed	**0.04%**
			% GVA	**0.04%**
	C26.40	Manufacture of consumer electronics	Number of persons employed	55,835
			Turnover (million euros)	21,500.9
			Number of enterprises	2,776.0
			Personnel costs (million euros)	1,945.5
			Value added (million euros)	3,300.4
			% Persons employed	**0.03%**
			% GVA	**0.03%**
	C26.51	Manufacture of instruments and appliances for measuring, testing and navigation	Number of persons employed	394,769
			Turnover (million euros)	78,444.2
			Number of enterprises	11,000.0
			Personnel costs (million euros)	22,130.5
			Value added (million euros)	31,242.5
			% Persons employed	**0.18%**
			% GVA	**0.33%**

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(94) EU-28 value not available; calculated as the sum of the available countries (missing one: Ireland).

(95) EU-28 value not available; calculated as the sum of the available countries (missing ones: Estonia, Ireland, France, Luxembourg, Netherlands).

Sector	**Subsector**	**Description**	**Indicators**	**Value**
Electronics and software *(continued)*	J62	Computer programming, consultancy and related activities	Number of persons employed	3,379,005
			Turnover (million euros)	549,508.4
			Number of enterprises	694,851.0
			Personnel costs (million euros)	170,786.1
			Value added (million euros)	255,628.0
			% Persons employed	**1.57%**
			% GVA	**2.07%**
	Total		Number of persons employed	3,909,927
			Turnover (million euros)	785,389
			Number of enterprises	714,234
			Value added (million euros)	294,335
			% Persons employed	**1.82%**
			% GVA	**2.47%**

Source: Own elaborations (based on Eurostat data from 2015).

3.2.2.2 Challenges and opportunities

With cars increasingly becoming computers on wheels, this sector is understood to hold a significant relevance in the future smart mobility. The software in one of the latest Mercedes S-class vehicle models contains approximately 15 times more lines of code than the software in a Boeing 787 (Mosquet et al., 2015) and it is estimated that vehicles in 2020 will have 100-150 million lines of code (Ganguli et al., 2016 as cited in Asselin-Miller et al., 2017; Gillespie, 2016). In terms of processing power, a vehicle today processes up to 25GB/hour (Mohr et al., 2014). NVIDIA has estimated that the computing demands of an AV can be 50-100 times more intensive than those currently placed on the most advanced cars available (Boucherat, 2018).

A 2015 study has predicted that by 2025, there could be 14.5 million vehicles (mostly with partially automated driving functionality, but including 600,000 fully automated vehicles; accounting for 12-13% of global vehicle sales) out of a total of 111 million new vehicles and that by 2035, there will be 18 million partially automated vehicles and 12 million fully automated ones (accounting for 25% of vehicle sales) out of 122 million new vehicles in total (Mosquet et al., 2015). Therefore the combined market for partial and full automation will develop gradually until it reaches 25% of new vehicle sales, which can take 15-20 years (around 2035) (Mosquet et al., 2015). Market estimates for 2025 and 2035 are $42 billion and $77 billion respectively, with 14.5 million and 30 million AVs sold at each respective point in time (Mosquet et al., 2015). Another source points at CAV sales reaching $95 billion by 2030 and $260 billion by 2035 (Römer et al., 2016). It is estimated that 5% of annual vehicle sales by 2025 will be related to fully automated vehicles, following first commercially viable solutions in 2019, of which 80% will be from self-driving add-on packages (such as a more advanced version of the RP-1 product by Cruise) and 20% from fully automated vehicles themselves (World Economic Forum, 2016b).

We explore below how automation and connectivity can affect the activities of this sector.

Software versus hardware

In the automotive value chain, software will gain a predominant role while hardware will decrease its share (the latter dropping from 90% to 40% of the vehicle value, and the former increasing from 10% to 40%, as indicated in Clements and Kockelman, 2017; Römer et al., 2016). By 2030, the market for this new software is estimated to reach $10-20 billion, as a function of the business models used (Asselin-Miller et al., 2017).

In this context, a recent study indicated that 57% of automotive executives predict opening their software/API (Application Programming Interface) to third parties or external software developers (Wee et al., 2015). AImotive, a European company specialized in autonomous driving software, has recently raised funding to keep on developing its proprietary self-driving technology and is already working with automotive manufacturers such as PSA or Volvo (Takahashi, 2018).

Hardware components for automated driving

Whereas software will become progressively crucial, the market for autonomous driving hardware components will also grow (Asselin-Miller et al., 2017). OEMs and a core group of Tier 1 suppliers will most likely continue to be the providers of equipment such as cameras, sensors, lidar, actuators and communication systems. It is estimated that by 2030 the entire market for new components will be around $30-40 billion (Roland Berger, 2014 as cited in Asselin-Miller et al., 2017). Another reference points at a global market increase for these components from US$ 0.4 billion in 2015 to US$ 4 billion by 2020, US$ 20 billion by 2025 and US$ 40 billion by 2030 (Statista, 2018). It has also been estimated that the annual market for special equipment, including on board control, guidance and communication systems, will be $103 billion by 2030 and $189 billion by 2035 (Römer et al., 2016).

In particular, the global market for automotive radar will reach almost US$ 9 billion by 2024 from almost US$ 2 billion in 2015 (Statista, 2018). Also, the market for autonomous driving chips has been estimated to grow by a factor of 36 along the period between 2017 and 2025 (from around $0.2 billion to $7.2 billion) (Poletti, 2016 as cited in Asselin-Miller et al., 2017). It has also been projected that the opportunity for semiconductor providers will reach about US$ 96 billion by 2040 (Statista, 2015a).

After 2030-2035, revenues from special equipment will decrease as technology starts to become a commodity and content, software and services will surpass revenues from special equipment (Römer et al., 2016). With software and contents becoming the most significant part of a CAV's value (40% and 20% as indicated by Römer et al., 2016), the highest profit margins are expected for providers of these two elements. Römer et al. (2016) anticipates that technology companies are the most likely candidate actors to lead this sector. Tier 1 suppliers could also become key players in this area by specializing in software and the components that support it (Römer et al., 2016).

Connected vehicle market

According to Transparency Market Research (2013), global connected car market (which is segmented into infotainment, navigation, and telematics) will reach US$ 131.9 billion by 2019, from US$ 41.3 billion by 2015. In particular, navigation is projected to account for 45% of the market by 2019. In line with this estimate, a global economic potential of 120 billion euros revenue per year is estimated for the connected vehicles equipment (including both hardware and software) (96). Infotainment advances are expected to add $65 billion of operating profits to the overall automotive value chain, of which $41 billion will be coming from sales of infotainment hardware (growing at a Compound Annual Growth Rate - CAGR of 4% from 2016 to 2025), $14 billion from OEM-driven applications and services and $10 billion from mobile-based and third-party applications from outside the automotive industry (World Economic Forum, 2016b).

Connected car market players hold a unique opportunity with the advent of AVs. A significant growth is expected in the connected car market for passenger vehicles, where a global economic potential of 120 billion euros revenue per annum has been estimated, specifically linked to connected car equipment (including both hardware and software) (European Commission, 2017l). Over 90% market penetration of telematics packages is expected to be reached by 2020 (European Commission, 2017l). OEMs and digital players are engaging in co-opetition projects that combine cooperation and competition (see multiple examples in European Commission, 2017l). Another estimate points at 48 million connected car shipments by 2018, that are expected to almost double by 2020 (Statista, 2017). Market segments in the connected car market include automotive infotainment and navigation technologies, EV services, car safety systems, electronic tolling, fleet relationship management, insurance services and fleet management. Thus, the connected car market could also be related to the data services sector and other sectors like freight transport or insurance. This denotes the difficulty in separating the effects for each of these sectors individually.

The cost of CAV technology

Vehicle manufacturers need to make considerable investments in hardware components like sensors (e.g. radar, lidar) and processors, software and Information Technology - IT (e.g. ECU - Electronic Control Unit, maps), systems integration and assembly (Mosquet et al., 2015). The R&D investments needed are estimated to be at $1 billion per OEM over the next decade (Mosquet et al., 2015). Some references from the literature on prices of full automation are given in Box 2.

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(96) European Commission Digital Transformation Monitor Autonomous Cars website: https://ec.europa.eu/growth/tools-databases/dem/monitor/category/autonomous-cars (last accessed 3 April 2018).

Box 2. Full automation premiums

Specifically, the additional equipment on board CAVs ranges from GPS systems to lidars, video cameras, ultrasonic sensors, odometry sensors, computing systems, and connectivity features, adding to the cost of the conventional vehicles (Wadud, 2017). Prices of CAV components are very volatile, because of differences in their technical specifications, scale of production and maturity (Mosquet et al., 2015). One example is the lidar technology that can range from $90 to $8,000 (Mosquet et al., 2015).

Bansal and Kockelman (2017) have indicated significant CAV premiums, namely US$ 30,951 and US$ 23,950 for 2020 and 2025 respectively, which Wadud (2017) judges as too high for any commercial success. Vehicle manufacturers would likely absorb some of these additional costs in order to obtain an initial share of the market (Wadud, 2017). Volvo has declared the intention to produce vehicles for the luxury market segment where the automated driving functionality would be adding US$ 10,000 to the vehicle cost (Naughton, 2016 as stated in Asselin-Miller et al., 2017), but it remains unclear if it refers to both hardware and software, as another estimate by Volvo points at self-driving software making up an additional $10,000 in the vehicle selling price (Burke, 2016 as cited in Wadud, 2017). Tesla currently offers its Autopilot for an additional purchase cost of US$ 4,000, without including the costs from sensors and hardware (5,600 euros, for a basic Autopilot functionality in Europe (97)). Mosquet et al. (2015) estimates that highway autopilot with lane changing and urban autopilot could be priced at $5,000 - $6,000, and that, as a consequence, fully automated vehicles could be expected to add a cost of $10,000 to the vehicle price. For freight vehicles, premiums related to CAV technologies could range between approximately US$ 16,000 and US$ 25,000 for small rigid trucks and between roughly US$ 17,500 to US$ 26,600 for larger trucks (1.4 change applied to convert pounds into US dollars, from prices indicated in Wadud, 2017).

After the market launch of these components, the cost is expected to decrease at a compound annual rate of 4-10% over 10 years (a 10% learning rate is assumed by Wadud, 2017). The premium market segment will thus probably be the first where CAV technologies will be implemented, as vehicle prices are expected to be fairly high at the beginning (Mosquet et al., 2015). The high prices of CAV technologies will probably slow the pace of adoption, in spite of the advantages brought to end consumers. It is also true that, despite the initially large costs of CAVs, distributing its cost over the vehicle lifetime (via depreciation), the annual additional costs of CAV technologies are not dramatically high (Wadud, 2017).

3.2.2.3 Estimated effects for different scenarios

The revenues in this sector will be strongly linked to vehicle production and sales. Each year European automotive suppliers make 75% of each of the 18 million vehicles produced and they represent on average 80% of the added value of a vehicle (98). We recall herein the figures used in the automotive sector, namely: total number of motor vehicles registered in the EU in 2015 of approximately 15.7 million vehicles (13.7 million passenger vehicles and 2 million commercial vehicles). For passenger vehicles, the figure of 16 million vehicles has also been used to reflect the Global leadership situation (13.7 representing the Autarky situation). On the basis of these present vehicle sales and the future projections of new vehicles sold per scenario (taken from the calculations made in the automotive sector, section 3.2.1), the revenues linked to automated driving hardware and software technologies are estimated for both passenger and freight vehicles.

For this purpose, it becomes necessary to identify possible prices of automated driving technologies. This is a challenging task at the moment, given that the cost of automation is too uncertain at present and therefore subject to significant changes. Our calculations are based on an assumed cost of full automation (level 4/5) for passenger vehicles of

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(97) According to Tesla Model S quotation in: https://www.tesla.com/it_IT/models/design?redirect=no (last accessed 3 April 2018).

(98) CLEPA website: https://clepa.eu/who-and-what-we-represent/business-leader/ (last accessed 3 April 2018).

around $10,000 by 2025 (from Mosquet et al., 2015), which is also used in Wadud's TCO analysis (2017). Though it could represent a lower bound estimate when compared to other sources (e.g. Bansal and Kockelman, 2017). For trucks, £15,000 is used (average of the estimated prices for different types of trucks indicated in Wadud, 2017). It could also represent a lower bound estimate. Thus, in euros, the cost of full automation is 8,091 and 16,870 for passenger vehicles and heavy duty vehicles respectively. With a learning rate of 10% in the first years that then decreases to 5% and up to 2.5%, prices for full automation in 2050 decrease down to 2,406 and 5,016 euros respectively. Level 4 technologies are assumed to have a similar price to level 5, given that it is believed that these two levels of automated driving share hardware and software components. Estimated prices for levels 4/5 automation in passenger and commercial vehicles are given in Table 18 and Table 19 respectively.

Although it would be logic to assume that a stronger technological development leads to a reduction in prices, the uncertainty linked to the quantification of these potential reductions on the basis of already uncertain prices has made us assume that prices for AV technologies remain the same across different scenarios.

Table 18. Prices of high/fully automated driving technologies per scenario - passenger transport

	PRICES OF LEVEL 4/5 AV TECHNOLOGIES PER SCENARIO - PASSENGER TRANSPORT	
	2015-2025	**2015-2050**
Baseline	-	-
Scenario 1. Low uptake	**8,091 euros**	**2,406 euros**
Scenario 2. Medium uptake	**8,091 euros**	**2,406 euros**
Scenario 3. High uptake	**8,091 euros**	**2,406 euros**

Source: Own elaborations.

Table 19. Prices of high/fully automated driving technologies per scenario - freight transport

	PRICES OF LEVEL 4/5 AV TECHNOLOGIES PER SCENARIO - FREIGHT TRANSPORT	
	2015-2025	**2015-2050**
Baseline	-	-
Scenario 1. Low uptake	**16,870 euros**	**5,016 euros**
Scenario 2. Medium uptake	**16,870 euros**	**5,016 euros**
Scenario 3. High uptake	**16,870 euros**	**5,016 euros**

Source: Own elaborations.

Other estimations are made for lower levels of automation. For levels 1, 2 and 3 used in passenger vehicles, the following reference data are considered:

- For level 1: 1,000 euros (according to current ADAS packages offered by some manufacturers, KIA, 2018).

— For level 2: price is based on the currently available Autopilot from Tesla, which is 5,600 euros in 2018 (see [97]).

— At this stage, level 3 is assumed to be an average between the price of level 2 and level 4/5 technologies.

These prices are assumed to be valid for 2025, in spite of the plausible decreases in prices that could be expected in the future. Similar learning rates to the ones applied to level 4/5 technologies are then applied to estimate the 2050 prices. In particular, level 1 technologies are assumed to have zero cost by 2050. As assumed in the case of level 4/5 automation, the same prices are kept throughout the different scenarios. Estimated prices for levels 1/2/3 automation in passenger vehicles are given in Table 20.

Table 20. Prices of levels 1, 2 and 3 automated driving technologies per scenario - passenger transport

	PRICES OF LEVEL 1/2/3 AV TECHNOLOGIES PER SCENARIO - PASSENGER TRANSPORT	
	2015-2025	**2015-2050**
Baseline	-	-
Scenario 1. Low uptake	Level 1: **1,000 euros** Level 2: **5,600 euros** Level 3: **6,846 euros**	Level 1: **0 euros** Level 2: **1,665 euros** Level 3: **2,035 euros**
Scenario 2. Medium uptake	Level 1: **1,000 euros** Level 2: **5,600 euros** Level 3: **6,846 euros**	Level 1: **0 euros** Level 2: **1,665 euros** Level 3: **2,035 euros**
Scenario 3. High uptake	Level 1: **1,000 euros** Level 2: **5,600 euros** Level 3: **6,846 euros**	Level 1: **0 euros** Level 2: **1,665 euros** Level 3: **2,035 euros**

Source: Own elaborations.

Prices are assumed to be higher for commercial vehicles, as they normally require a higher amount of sensors and components that can be more costly than the ones used for passenger vehicles. For instance, Roland Berger estimates that trucks would require between $4,000 and $7,000 per each automated driving level ([99]). In the absence of a valid representation of possible prices for this vehicle category and given that there is a broad variety of vehicle types covered in it, we are providing someway conservative estimates of our own for levels 1, 2 and 3, as follows:

— For level 1: 2,000 euros.

— For level 2: 8,000 euros.

— At this stage, similar to the passenger vehicle assumptions, level 3 is assumed to be an average between the price of level 2 and level 4/5 technologies.

Similarly to the passenger vehicle case, learning rates are applied to level 4/5 technologies to estimate the 2050 prices and prices are kept the same throughout the different scenarios. As for passenger cars, level 1 technologies are assumed to add no cost by 2050. Estimated prices for levels 1/2/3 automation in commercial vehicles are given in Table 21.

([99]) Which excludes the $5,000 premium for a fully-automatic or Automated Mechanical Transmission (AMT) needed to make a truck self-driving (Kilcarr, 2015).

Table 21. Prices of levels 1, 2 and 3 automated driving technologies per scenario - freight transport

	PRICES OF LEVEL 1/2/3 AV TECHNOLOGIES PER SCENARIO - FREIGHT TRANSPORT	
	2015-2025	**2015-2050**
Baseline	-	-
Scenario 1. Low uptake	Level 1: **2,000 euros** Level 2: **8,000 euros** Level 3: **12,435 euros**	Level 1: **0 euros** Level 2: **2,379 euros** Level 3: **3,697 euros**
Scenario 2. Medium uptake	Level 1: **2,000 euros** Level 2: **8,000 euros** Level 3: **12,435 euros**	Level 1: **0 euros** Level 2: **2,379 euros** Level 3: **3,697 euros**
Scenario 3. High uptake	Level 1: **2,000 euros** Level 2: **8,000 euros** Level 3: **12,435 euros**	Level 1: **0 euros** Level 2: **2,379 euros** Level 3: **3,697 euros**

Source: Own elaborations.

With the indicated prices of AV technologies (both for passenger and commercial vehicles), market shares of AV technologies in each scenario are considered. For this purpose, vehicle travel shares by Nieuwenhuijsen et al. (2018) are used as market penetration rates in the context of this sector. Given that the corresponding market shares would necessarily be higher than the provided travel estimates, we are adopting a more conservative approach by assuming these figures to be market estimates. The resulting calculations are given in Table 22, Table 23 and Table 24, corresponding to passenger transport (autarky and global leadership situations) and freight transport respectively.

As a conclusion from these analyses, total revenue increases from the sector caused by CCAM could amount to approximately 180 billion euros by 2025 for both passenger and freight AVs. It is important to highlight that the results from the freight transport sector might be overestimated, as the prices of automation might differ significantly among different types of commercial vehicles (having considered the price of an AV truck technology for all freight transport vehicles in these calculations). Also, the volatile prices of CAV technologies make it necessary to warn of the need to interpret these calculations with caution.

As a result, this could be the range of possible effects for **passenger transport**:

Table 22. Potential effects of AVs in the electronics and software sector - passenger transport (Autarky)

Effects of AVs on the electronics and software industry – passenger transport	**Baseline**			**Scenario 1**		**Scenario 2**		**Scenario 3**	
	2015	**2025**	**2050**	**2025**	**2050**	**2025**	**2050**	**2025**	**2050**
Change in new vehicle sales (%)	-	+9%	+30%	+18%	+47%	+31%	+51%	+39%	+33%
Number of new vehicles sold (million vehicles)	13.7	14.93	17.81	16.17	20.14	17.95	20.69	19.04	18.22
Change in new vehicle sales (million vehicles)	-	+1.23 (100)	+4.11 (100)	+1.24	+2.33	+3.02	+2.88	+4.11	+0.41
Revenues per year in self-driving software and hardware linked to new vehicle sales (billion euros)	-	-	-	65	40	110	50	135	45

Source: Own elaborations.

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(100) The figure represents the change with respect to 2015.

Table 23. Potential effects of AVs in the electronics and software sector - passenger transport (Global leadership)

Effects of AVs on the electronics and software industry – passenger transport	Baseline			Scenario 1		Scenario 2		Scenario 3	
	2015	2025	2050	2025	2050	2025	2050	2025	2050
Change in new vehicle sales (%)	-	+9%	+30%	+18%	+47%	+31%	+51%	+39%	+33%
Number of new vehicles sold (million vehicles)	16.0	17.4	20.8	18.9	23.5	21.0	24.2	22.2	21.3
Change in new vehicle sales (million vehicles)	-	+1.4 (101)	+4.8 (101)	+1.4	+2.7	+3.5	+3.4	+4.8	+0.5
Revenues per year in self-driving software and hardware linked to new vehicle sales (billion euros)	-	-	-	75	45	125	60	160	50

Source: Own elaborations.

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(101) The figure represents the change with respect to 2015.

And this could be the range of possible effects for **freight transport**:

Table 24. Potential effects of AVs in the electronics and software sector - freight transport

Effects of AVs on the electronics and software industry – freight transport	**Baseline**			**Scenario 1**		**Scenario 2**		**Scenario 3**	
	2015	**2025**	**2050**	**2025**	**2050**	**2025**	**2050**	**2025**	**2050**
Change in new vehicle sales with respect to 2015 (%)	-	+19%	+38%	+19%	+38%	+24%	+53%	+29%	+68%
Number of new vehicles sold (million vehicles)	2	2.38	2.76	2.38	2.76	2.48	3.06	2.58	3.36
Change in new vehicle sales with respect to the baseline scenario (million vehicles)	-	0.38 ([102])	0.76 ([102])	0.00	0.00	0.10	0.30	0.20	0.60
Revenues per year in self-driving software and hardware linked to new vehicle sales (billion euros)	-	-	-	20	10	30	15	40	15

Source: Own elaborations.

([102]) The figure represents the change with respect to 2015.

3.2.3 Telecommunication, data services and digital media

3.2.3.1 Scope and size

This section gathers three specific sectors that are closely interrelated. The telecommunication sector is composed of: construction of utility projects for electricity and telecommunications, electrical installation and telecommunications. The data services sector comprises information services activities. Finally, the digital media one relates to retail sales, radio broadcasting and television programming and broadcasting activities, i.e. contents such as music, video, games, radio and tv, news, but also interlaced areas such as advertising and e-commerce. They are thus highly connected to the data industry.

Detailed figures corresponding to this sector in Europe are given below (Table 25).

Table 25. Indicators of the telecommunication, data services and digital media sectors

Sector	Subsector	Description	Indicators	Value
Telecommunication	F42.22	Construction of utility projects for electricity and telecommunications	Number of persons employed	206,661
			Turnover (million euros)	30,486.7
			Number of enterprises	10,839.0
			Personnel costs (million euros)	7,373.6
			Value added (million euros)	9,691.4
			% Persons employed	**0.10%**
			% GVA	**0.10%**
	F43.21	Electrical installation	Number of persons employed	1,535,307
			Turnover (million euros)	160,607.2
			Number of enterprises	372,628.0
			Personnel costs (million euros)	44,324.5
			Value added (million euros)	64,144.0
			% Persons employed	**0.71%**
			% GVA	**0.63%**
	J61	Telecommunications	Number of persons employed	1,046,223
			Turnover (million euros)	390,000.0
			Number of enterprises	46,055.0 ([103])
			Personnel costs (million euros)	59,967.6
			Value added (million euros)	170,000.0
			% Persons employed	**0.49%**
			% GVA	**1.33%**
	Total		Number of persons employed	2,788,191
			Turnover (million euros)	581,094
			Number of enterprises	429,522

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[103] EU-28 value not available; calculated as the sum of the available countries (missing one: Malta).

Sector	**Subsector**	**Description**	**Indicators**	**Value**
	Total *(continued)*		Value added (million euros)	243,835
			% Persons employed	**1.30%**
			% GVA	**2.06%**
Data services	J63	Information service activities	Number of persons employed	580,338
			Turnover (million euros)	71,067.4 (104)
			Number of enterprises	130,000.0
			Personnel costs (million euros)	21,581.7 (105)
			Value added (million euros)	40,000.0
			% Persons employed	**0.27%**
			% GVA	**0.32%**
Digital Media	G47.91	Retail sale via mail order houses or via Internet	Number of persons employed	530,798
			Turnover (million euros)	139,435.5
			Number of enterprises	187,260.0
			Personnel costs (million euros)	12,127.3
			Value added (million euros)	21,520.1
			% Persons employed	**0.25%**
			% GVA	**0.19%**
	J60.10	Radio broadcasting	Number of persons employed	58,984
			Turnover (million euros)	6,771.7
			Number of enterprises	6,243.0
			Personnel costs (million euros)	2,707.6
			Value added (million euros)	4,744.9
			% Persons employed	**0.03%**
			% GVA	**0.05%**

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(104) EU-28 value not available; calculated as the sum of the available countries (missing ones: Ireland, Luxembourg).
(105) EU-28 value not available; calculated as the sum of the available countries (missing ones: Ireland, Luxembourg).

Sector	Subsector	Description	Indicators	Value
Digital Media *(continued)*	J60.20	Television programming and broadcasting activities	Number of persons employed	185,582
			Turnover (million euros)	62,603.7
			Number of enterprises	5,416.0
			Personnel costs (million euros)	11,575.4
			Value added (million euros)	32,305.0
			% Persons employed	**0.09%**
			% GVA	**0.34%**
	Total		Number of persons employed	775,364
			Turnover (million euros)	208,811
			Number of enterprises	198,919
			Value added (million euros)	58,570
			% Persons employed	**0.36%**
			% GVA	**0.58%**

Source: Own elaborations (based on Eurostat data from 2015).

3.2.3.2 Challenges and opportunities

The telecommunication sector has entered the CAV landscape in Europe through the High Level Round Table discussions on CAD held since September 2015, as well as through the establishment of the European Automotive – Telecom Alliance (EATA) (ACEA, 2016a), whose main objective is to promote the wider deployment of CAVs, with a first focus on a pre-deployment project for testing CCAM in real settings (ACEA, 2017a). EATA comprises 6 sectorial associations: ACEA, CLEPA, ETNO, ECTA, GSMA and GSA, which represent 38 leading European companies, including telecom operators, vendors, automobile manufacturers and automotive suppliers.

It is very difficult to predict how data services will affect the automotive value chain. McKinsey&Company (Mohr et al., 2014) predicts that the total cost per VKT will not change much but that car data will increase competition in car maintenance and other services, thereby creating downward price pressure and reduced value added in these services. The question then is how data services will lead to a shift in value-added per VKT, from traditional services to data services. With the platformisation of data services we can already observe a lot of shifts in value added to data providers in many non-automotive related sectors and the same is thus likely to happen in the automotive domain (an on-going JRC study on car data markets points in this direction, Martens and Müller-Langer, forthcoming 2018). In fact, it is expected that 30–40% of the value added in the automotive value chain will shift from traditional car manufacturers towards digital platforms in the near future (106). European digital platforms are not at scale due to market fragmentation and the advance of the key US digital platforms (European Commission, 2017l). The creation of European digital platforms could be enhanced by ensuring the availability of enabling and supporting conditions and a regulatory framework that guarantees a level playing-field for businesses (EESC, 2017). The free flow of data is identified as a crucial element to avoid problems associated with accessibility, interoperability and transfer of data, as well as to secure the right data protection and privacy. Access to transport and infrastructure-related mass data from the public sector is considered to be important for all users.

We explore below the growing in-vehicle connectivity trend and data exchanges, linking to opportunities for data monetization and value propositions for consumers.

Vehicle connectivity

The oncoming application of the eCall Regulation (EU) 2015/758 will clearly accelerate the vehicle connectivity trend, as SIM cards will be included in every new vehicle sold from April 2018 to serve the emergency-call functionality (107). Connectivity will thus serve as support of both safety applications (including automated driving) and new functionalities and features for drivers and passengers. There will be more than 28.1 billion connected devices by 2020 (World Economic Forum, 2016b) and more than 90% of cars sold by 2020 will be connected (World Economic Forum, 2016b). Other estimates point at a 75% of new vehicles having internet-connected devices by 2020, and to a worldwide 20% of all vehicles on the road having some form of wireless connectivity by 2020 (Gillespie, 2016).

Connectivity features will become a key functionality in future vehicles, which could be responsible for vehicle brand changes among future vehicle buyers. This stands on the result from Mckinsey&Company, who found that 20% of all new car-buyers would have switched car brands for better connectivity features (Mohr et al., 2014). At a global level, significant increases in revenues from connectivity are expected, namely, from approximately 30 billion euros in 2014 to 170-180 billion euros in 2030 (Mohr et al., 2014). Revenues from connectivity features and services are expected to increase from 4% of car

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(106) European Commission Digital Transformation Monitor Automotive website, available at: https://ec.europa.eu/growth/tools-databases/dem/monitor/category/automotive (last accessed 3 April 2018).

(107) More information on the interoperable EU-wide eCall can be found in the European Commission Mobility and Transport Intelligent Transport Systems website, available at: https://ec.europa.eu/transport/themes/its/road/action_plan/ecall_en (last accessed 3 April 2018).

life cycle revenues at 2014 to approximately 7% by 2020 in the European premium car segment (Mohr et al., 2014). In spite of the global connected car market growth, the overall car life cycle revenues are expected to remain stable. Automation has the potential to further fuel connectivity-related business models, given the fact that it enables the possibility of doing non-driving tasks while travelling.

The value of data

Data transmissions are expected to grow substantially (a 12% annual growth to 2030 is reported in Leech et al., 2015), as vehicles are becoming part of a complex ecosystem where communication is an essential part (Landau, 2017). Upcoming 5G networks, which are expected to become available from 2020, will allow for a reliable, robust and pervasive wireless network to unlock the true potential of automated driving. These 5G networks will be essential in supporting the estimated 4,000 GB of data per day that an AV could generate, and that will need to be shared with other vehicles, infrastructure, the network and eventually, data centres. The global market for V2X technologies in 2030 is projected to reach around 14.8 billion dollars and will be more than 30 billion dollars from 2035 onwards (Statista, 2015b).

The development of a data economy comes as a result of the digital transformation of the automotive industry, which is one of the most data generation-intensive industries across the world (second only after the utilities sector) (World Economic Forum, 2016b). Both commercial and social benefits are expected from it. In particular, by 2025, data exchanges are estimated to create $36 billion of operating profits for OEMS, mainly from third-party monetisation and reduced cost of data acquisition (World Economic Forum, 2016b). However, monetizing the massive amount of car generated data is still in its nascent stages (Bertoncello et al., 2016).

Data holds significant monetisation potential, whether it is in-motion data (like speed, tire pressure, etc.) or data regarding customer opinions and moods and driving experiences (European Commission, 2017l). McKinsey&Company envisages the car data market could generate as much as $750 billion in revenues by 2030 (ranging precisely from $450 to $750 billion as stated in Bertoncello et al., 2016). A rough estimation for EU based on global shares (according to the 19% EU share of global passenger cars registrations/sales in 2015 from ACEA, 2016b) leads to a range of approximately 70-120 billion euros in revenues from monetization of car data in 2030.

Consumer MaaS represents the largest revenue opportunity in the Passenger Economy valued at US$ 3.7 trillion, with services evolving from currently emerging business offerings like on-demand transport, work-commute sharing or event/theme-optimized vehicles (Lanctot, 2017). Businesses will expand by creating "mobile stores" that deliver goods and services directly to the consumer, eliminating the costly elements of staff and place (Peters, 2017). The second largest revenue source of the Passenger Economy is based on business use of MaaS (Lanctot, 2017). Long-haul trucks and other commercial transport solutions based on smaller trucks or vans for local delivery will be used. A third smaller portion of Passenger Economy revenues will be coming from new consumer and B2B services and applications, e.g. experience pods from General Motors and Lyft or pod fleet management services (Lanctot, 2017).

Revenues from pay-per-use services are expected to surpass the revenues from optional on board equipment from 2025 onwards (Römer et al., 2016). Technology companies like Google or Apple might follow a model based on pay per use, fees, flat subscription prices or licensing, and their profit margins could reach 10-15% or even 20-22%. Important revenue sources could be (Römer et al., 2016):

- Giving consumers value-adding services like city guides, local deals, automated parking, etc. in exchange for their personal data
- Monetizing customer data through a network of third-party content and service providers.

Digital features and mobile services are growing into key factors for customer differentiation, at the same time that hardware increasingly becomes a commodity. Unique customer experience provides for additional differentiation (European Commission, 2017l). OEMs, suppliers and digital players can act as digital enablers, digital augmented product providers, digital service providers or aggregators of data and audiences (European Commission, 2017l).

Mobile apps for V2V telematics and V2X communication will reach $86 billion by 2030 and $109 billion by 2035 (Römer et al., 2016). The importance of the connected vehicle market was already emphasized in the previous section 3.2.2.

Value of travel time

A recent estimate indicates that 1.9 trillion minutes will be freed up for users travelling as passengers in an AV by 2030, a figure that would increase up to 5.1 trillion minutes by 2035 (Römer et al., 2016). The average amount of 20 minutes that users spend online every day at present (2.4 billion people, 800 million hours per day, ACEA, 2016c) could increase in consideration of a future automated driving scenario. Clements and Kockelman (2017) hypothesize, on the basis of a Mckinsey&Company study (Lienert, 2015), that $14 billion could be generated annually linked to online shopping, if only 5% of the average commuting time is spent on digital media in a future CAV. It is also important to note that the opportunity cost of time in cars may change and open up possibilities for other activities, much of which will not necessarily be related to media.

For instance, in the UK, a driver spends 274 h/year driving. If this time could be used to improve individual productivity, economic benefits of £20 billion could be gained for the whole UK (Leech et al., 2015 as cited by Wadud, 2017). The value of travel time, which is one of the largest components in the full generalized cost of travel, is expected to reduce significantly in level 4/5 vehicles, as drivers can engage in useful non-driving tasks (Wadud et al., 2016). The Value of Travel Time Saved (VTTS) increases as a function of trip purpose (business-related trips have the highest VTTS of all trips) as well as a function of income (the higher the income, the higher the VTTS) (Wadud, 2017). For passenger cars, VTTS reductions have been estimated at a 25%, 40% and 60% for pessimistic, baseline and optimistic scenarios respectively (Wadud, 2017).

Connectivity-enabled features hold a great potential to generate significant redistribution of revenues (European Commission, 2017b). A CAGR of 24.3% is estimated in the period from 2017 to 2022 covering product and service packages related to safety, autonomous driving and connected services (Baker et al., 2016). Total revenues could amount to $155.9 billion by 2022, from $35.5 billion in 2015. Within these revenues, the share corresponding to autonomous driving is expected to surpass that of connected services by 2022. With increasing opportunities, competition also becomes greater with new entrants from non-automotive sectors.

A future where mobility is offered for free could become real (Bertoncello et al., 2016; Arbib and Seba, 2017) offering the possibility of higher brand exposure and sales as well as better customer experiences (Bertoncello et al., 2016).

A main challenge is to face the cybersecurity risk of connected vehicles, which can compromise the privacy of users' data, as well as their safety. In this context, the reputation of AVs and their manufacturers/suppliers is at stake, should a cybersecurity attack become real, affecting users' trust on AV technologies.

Finally, some references on the willingness of users to share data and use/pay for in-vehicle services are given in Box 3.

Box 3. The users' perspective

Users' willingness to share data is growing over time but the concern on which use is made on the data is also increasing (European Commission, 2017m). An initial pre-condition is to provide customers with value propositions that they find worth the cost, on the basis of the benefits they bring.

In particular, McKinsey&Company identified 30 use cases with car data monetization potential, some of which are enabled by a fully automated driving (e.g. movies or games), others that increase their value thanks to it (e.g. using the car as a platform for selling features or products) and others whose value decrease as a result of full autonomy (e.g. suggestions about driving style). McKinsey&Company (Bertoncello et al., 2016) found that users are in general mostly interested in data services that contribute to make mobility safer or more convenient, as well as in those that help them save time or money. If safety or convenience advantages are linked to a given service, a great majority of users are willing to share personal data. Age seems to be a relevant factor, with young people being more open to adopt data services (in line with Dungs et al., 2016). The same holds true for users that travel often (more than 20 h/week), compared to occasional drivers.

Monetization can take place either integrated in the vehicle price, as a one-time purchase after the vehicle purchase, through a subscription or rechargeable credit or free of charge in exchange of receiving advertising (Bertoncello et al., 2016). Some important economic considerations around multi-sided markets in digital car data can be found in Martens and Müller-Langer (forthcoming 2018). In-vehicle technologies, supported by infrastructural technologies and back-end processes are the main enablers of car data monetization, without forgetting the use of other devices like smartphones or tablets (Bertoncello et al., 2016). Data management capabilities are required, which can represent a significant challenge for incumbent players like OEMs and Tier-1 suppliers (Bertoncello et al., 2016). The players in this field range from technology companies and start-ups to alternative mobility operators, data management service providers, insurers, roadside assistance providers and infrastructure operators (Bertoncello et al., 2016). In this context, strategic partnerships become increasingly necessary.

Similar to Bertoncello et al. (2016), a 2015 user survey identified 21 value-added services covering communication, productivity, basic requirements, well-being, information and entertainment needs (Dungs et al., 2016).

The survey study concluded that a noteworthy majority of users (75% on average across 3 regions, including Germany, US and Japan) are prepared to pay in order to organize their time freely in the car through the use of value-added services (Dungs et al., 2016). The average monthly amount that users would be willing to pay across all needs ranges between approximately 150 euros and 190 euros depending on the usage scenario.

Factors such as personal mileage, user's vehicle segment, or age of the user will affect the willingness to pay for these new services (Dungs et al., 2016). For instance, drivers of mid-sized or high-end vehicles are more willing to pay for services than drivers of small cars and younger users are prepared to pay more than their old counterparts.

There are also regional differences pointing at e.g. a higher acceptance of services among Japanese users compared to German ones, which can partially be explained by their tendency to be more open to new technologies (Dungs et al., 2016). Users from the US demonstrated the highest willingness to pay for these services, which correlates with daily travel time spent in the car (the higher the time spent travelling, the higher the willingness to play; although even in short trips, users exhibited willingness to pay for value-added services).

Also, the types of services differ according to the time spent in the car (Dungs et al., 2016). Given this correlation, the study concludes that the services offered have to be adapted to the usage time in the respective market. The value of travel time gives a clear indication of how much an extra hour of free time in a day is worth in monetary terms to an individual and depends on the country, age group, income and vehicle segment of a user. This study found that the value of travel time is highest among German respondents (i.e. 18 euros), young people (i.e. 29 euros for users in the 18-25 years old group), high earners (i.e. 23 euros for users earning between 75,000 and 99,999 euros a year) and drivers of sport cars (who give a value of time of 22 euros).

Conclusion

Overall, the effects of CCAM on the telecommunication, data services and digital media sectors are expected to be positive. Although specific estimations have not been made for this sector, it would be possible to draw a preliminary approximation to the potential effects from current literature. This way, according to McKinsey&Company projections (Bertoncello et al., 2016), it is possible to identify an upper bound of 120 billion euros in revenues from monetization of car data by 2030 in Europe. If the McKinsey&Company projections hold true, the telecommunication, data services and digital media sectors could potentially face a significant increase in turnovers in the future, in the case these sectors will benefit from the mentioned increase, i.e. if they will retain the property of the gathered data. But competition for car data is clearly strong and regulation aspects will play a significant role in influencing the market competition. The effects in these sectors are understood to be mostly dependent on the connectivity trend, but we could expect a reinforcement effect from vehicle automation, i.e.: the higher the level of automation, the higher the driving time that is freed to perform non-driving activities (and thus, to demand for new services).

3.2.4 Freight transport

3.2.4.1 Scope and size

Within the freight transport sector, we have considered freight rail transport, freight transport by road, removal services, sea and coastal freight water transport, inland freight water transport, renting and leasing of trucks. While the focus of our study is put on road transport, the other modes are also taken into account, given the potential shifts in modal choices that can occur following the automation of road transport.

With the whole transport and storage services sector employing around 11 million people and accounting for near 5% of total GVA in the EU-28 in 2015 (European Commission, 2017a), the sector plays an important role in the global economic activity and has a large impact on growth and employment. Specifically, EU data suggests that more than 3 million people work for the freight sector (considering the freight transport sector, as we have defined it for the purpose of this study), and that it accounts for approximately 1.4% of EU-28 GVA. In 2015, 3,516 billion tonne-kilometre (tkm) were transported in EU-28 (intra-EU air and sea transport included, transport activities between the EU and the rest of the world excluded) (European Commission, 2017a). Road transport was the predominant mode of transport, accounting for 49% of the total, followed by maritime transport, with a share of 31.6%. Rail transport, inland waterways and air transport accounted respectively for 11.9%, 4.2% and 3.3%. During the last ten years the modal split pattern has not changed, road and maritime transport have remained the modes of transport mainly used for moving freight in Europe, even though the increase registered, in billion tkm, is much higher for road transport, 33.7%, than for maritime transport, 19.5%.

Detailed figures corresponding to this sector in Europe are given below (Table 26).

Table 26. Indicators of the freight transport sector

Sector	**Subsector**	**Description**	**Indicators**	**Value**
Freight transport	H49.2	Freight rail transport	Number of persons employed	137,530
			Turnover (million euros)	19,546.3
			Number of enterprises	638.0
			Personnel costs (million euros)	4,477.0
			Value added (million euros)	5,857.1
			% Persons employed	**0.06%**
			% GVA	**0.06%**
	H49.41	Freight transport by road	Number of persons employed	2,991,227
			Turnover (million euros)	328,129.8
			Number of enterprises	558,745.0
			Personnel costs (million euros)	69,876.6
			Value added (million euros)	110,986.5
			% Persons employed	**1.39%**
			% GVA	**1.05%**
	H49.42	Removal services	Number of persons employed	70,000
			Turnover (million euros)	6,000.0
			Number of enterprises	11,226.0 (108)
			Personnel costs (million euros)	1,996.0
			Value added (million euros)	2,461.0 (109)
			% Persons employed	**0.03%**
			% GVA	**0.02%**

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(108) EU-28 value not available; calculated as the sum of the available countries (missing ones: Ireland, Spain).
(109) EU-28 value not available; calculated as the sum of the available countries (missing ones: Estonia, Ireland, Spain).

Sector	Subsector	Description	Indicators	Value
Freight transport *(continued)*	H50.2	Sea and coastal freight water transport	Number of persons employed	89,881
			Turnover (million euros)	92,844.7
			Number of enterprises	5,515.0
			Personnel costs (million euros)	6,121.2
			Value added (million euros)	16,940.2
			% Persons employed	**0.04%**
			% GVA	**0.19%**
	H50.4	Inland freight water transport	Number of persons employed	20,324 (110)
			Turnover (million euros)	5,673.4
			Number of enterprises	5,800.0
			Personnel costs (million euros)	612.1
			Value added (million euros)	803.5 (111)
			% Persons employed	**0.01%**
			% GVA	**0.01%**
	N77.12	Renting and leasing of trucks	Number of persons employed	24,408 (112)
			Turnover (million euros)	8,444.6 (113)
			Number of enterprises	6,694.0
			Personnel costs (million euros)	802.0 (114)
			Value added (million euros)	4,032.5 (115)
			% Persons employed	**0.01%**
			% GVA	**0.04%**

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(110) EU-28 value not available; calculated as the sum of the available countries (missing ones: Denmark, France, Luxembourg, Austria, Portugal, Slovenia, Finland).
(111) EU-28 value not available; calculated as the sum of the available countries (missing ones: Denmark, Luxembourg, Netherlands, Austria, Portugal, Slovenia, Finland).
(112) EU-28 value not available; calculated as the sum of the available countries (missing ones: Czech Republic, Ireland, Spain, Luxembourg, Malta, Austria).
(113) EU-28 value not available; calculated as the sum of the available countries (missing ones: Czech Republic, Ireland, Spain, Luxembourg, Malta, Netherlands, Austria).
(114) EU-28 value not available; calculated as the sum of the available countries (missing ones: Czech Republic, Ireland, Spain, Luxembourg, Malta, Netherlands, Austria).
(115) EU-28 value not available; calculated as the sum of the available countries (missing ones: Czech Republic, Ireland, Spain, Luxembourg, Malta, Netherlands, Austria).

Sector	**Subsector**	**Description**	**Indicators**	**Value**
	Total		Number of persons employed	3,333,370
			Turnover (million euros)	460,639
			Number of enterprises	588,618
			Value added (million euros)	141,081
			% Persons employed	**1.55%**
			% GVA	**1.37%**

Source: Own elaborations (based on Eurostat data from 2015).

3.2.4.2 Challenges and opportunities

Vehicle autonomy can act as a transformational technology by reducing operating costs and improving the reliability of deliveries (World Economic Forum, 2016a). This will be extremely relevant given the significant road travel increases in this sector ([116]). An additional advantage is that truck drivers could be more productive by e.g. handling logistics and maintenance issues that currently constitute a dangerous distraction while driving (World Economic Forum, 2016a). CAV technologies could impact last-mile deliveries to consumers but especially, B2B logistics (World Economic Forum, 2016a).

Truck platooning, which seems to be a near future application of CAV technologies (e.g. Peloton, Volvo as indicated in BI Intelligence, 2017), has the potential to produce many positive effects in the transport sectors, which may impact traffic management, operational transport features and transhipment operations (Tavasszy and Janssen, 2016). Traffic could be reduced due to a decrease of congestion, increasing crossings capacity and improved visibility due to automation. The transport activities could be affected positively due to fuel reduction, longer distance covered and alternative tasks allocated to drivers. On the transhipment activities, the effects could be an increase in efficiency in container terminal and distribution centres planning, together with the employment of platooning for inter-terminal transport. Additional positive effects of platooning on the transport sector are also included in Krause et al. (forthcoming 2018) as well as other possible fuel efficiency mechanisms linked to automation and expected to be observed by 2050, like smoothening speed, reduction of urban parking search and increase in the freight system coordination.

We explore below some effects of truck automation on commercial vehicles operation.

Fuel/energy consumption and emissions

The two most costly elements in commercial vehicles operation are fuel and drivers, both of which can be reduced through truck automation (Gundermann et al., 2015). When it comes to fuel savings, truck platooning could decrease fuel consumption by 2-8% for the leading vehicle and 8-13% for the following vehicle (SARTRE, 2014, as cited in Janssen et al., 2015). Platooning has the potential to decrease fuel consumption by up to 12% (World Economic Forum, 2016a; ([117])) or even 20% (Chu, 2016) thanks to reduced aerodynamic drag. Peloton found that a two-truck convoy improved the fuel efficiency of the lead truck by 4.5%, while the rear truck saw a 10% boost (BI Intelligence, 2017). Fuel savings between 5% and 15% are indicated in another source (CLEPA, 2017).

Moreover, if both the use of alternative energy sources and platooning are considered, a 30% cut in energy consumption is expected to be achieved (Römer et al., 2016).

Besides, based on the assumption that autonomous trucks will be sold in developed markets from 2020 and will attain a market penetration of 5% on new truck sales in developed markets by 2025, societal benefits in the form of a reduction of 25 million metric tons in emissions have been accounted by the WEF (World Economic Forum, 2016a). The reductions of CO2 emissions due to platooning deployment have been calculated in the SARTRE Project, where the reduction of CO2 emissions could range from 7% up to 16% from the trailing vehicles and from 1% up to 8% from the lead vehicle (SARTRE, 2014). In line with the SARTRE Project, ERTRAC experts expect the CO2 emissions decrease due to the introduction of platooning to be in the range of 5% to 12% in 2050 for trucks above 12 tons on highways (Krause et al., forthcoming 2018). Platooning is therefore beneficial for the environment (Janssen et al., 2015).

([116]) E.g. as discussed in 3.2.1 and as indicated for instance by ITF, the volume of road freight transport will almost quadruple from 2010 to 2050, available at: https://www.itf-oecd.org/global-trade-international-freight-transport-quadruple-2050 (last accessed 12 April 2018); see also the data from the EU Reference Scenario 2016 in Annex 2.

([117]) Platooning – automated driving site from Scania, available at: https://www.scania.com/group/en/platooning-automated-driving-for-fuel-savings/ (last accessed 4 April 2018)

Labour costs

Overall operational costs could be decreased by 28% in 2025, compared to the 2016 situation (Nowak et al., 2016). Among three categories of cost (fixed, variable and driver costs), the driver's cost is the one that would experience the greater decrease (Nowak et al., 2016). An analysis of the labour costs savings linked to different platooning business cases is given in Box 4.

Box 4. Platooning business cases

An analysis of possible cost/benefits deriving from platooning introduction in three real-life business cases has been undertaken in Janssen et al. (2015), where, according to carriers' own estimations and authors validation, an estimation of possible savings has been made, which would lead to up to 32,300 euros per truck/year.

In their analysis, the labour cost of the drivers has been considered looking at two platooning scenarios, which foresee an initial situation with two drivers and a more advanced stage with only one driver for two trucks. In the case of two drivers, one is assumed to rest while the truck drives autonomously, the two trucks would change position periodically, hence the resting time would be reduced comparing to the current situation. In their business case, according to the information collected by interviewed carriers, 45 minutes of resting times could be saved per driver per workday. In the case of only one driver, and considering that still some other tasks need to be performed, e.g. loading/unloading, the estimation that they provide is that about 15% to 25% of the labour time could be saved.

According to their estimation and, clearly, to the level of implementation of the technology, this would potentially lead to an increase in the utilization of the truck. The trucks could be used more efficiently and drive for more kilometres; the time gained in resting time could be then used for additional operational employment of the truck.

A recent study by Andersson and Ivehammar (2018) found positive effects for self-driving trucks both in 2030 and 2050, with driver cost savings being the most important benefit. Benefits increase over time, given the expected larger shares of AVs and the reduction in capital costs.

As it is also confirmed in Wadud (2017), driver salaries represent a large share of direct costs in commercial vehicle operations. A 60% reduction in salary costs is assumed for autonomous trucks, given that the remaining 40% is expected to be required for loading/unloading at origin and destination (Wadud, 2017). Automation can lead to labour cost reduction according to its stage of implementation. Starting from increase in productivity and strain reduction, at the early stage of implementation, up to the possibility to accomplish other tasks when reaching higher level of automation (Securing America's Future Energy, 2017).

The role of a professional driver can be radically transformed in the future (starting with early platooning applications), gradually undertaking other duties than driving and possibly turning into a more technical role (Clements and Kockelman, 2017). To which extent this will lead to a reduction in the number of drivers needed still remains an unanswered question that deserves careful attention. It is also important to stress that CAV technologies could help to compensate the shortage of long-haul drivers (Lanctot, 2017), as e.g. Germany is expecting to lose around 250,000 drivers who will retire in the next 10 to 15 years (Hollis, 2016). Effects of CCAM on truck driver jobs are further discussed in the employment section below (section 3.3.1).

Other benefits

The positive effects of platooning introduction are expected to be seen also in safety. As the human error effect would be reduced, it is expected to have a reduction in accidents. (Janssen et al., 2015). It is uncertain thought, due to the lack of quantitative estimation of the impact of platooning in safety, how important the effect could be.

According to the same authors, the introduction of platooning could also lead to an optimization of the road capacity due the reduction in distance between the trucks. In their calculation, the length of road occupied by two platooning trucks could decrease by 46% compared to the current situation without platooning. This would possible imply longer road's life and also investment in road projects could be postponed.

These benefits would justify the idea that this sector becomes one of the early adopters of CAV technologies (Wadud, 2017) considering, nonetheless, that technical and legislative constraints will contribute to define the pace at which this phenomenon will maximise social benefits and minimize risks (Securing America's Future Energy, 2017).

The potential for increases in road travel as a result of commercial vehicles automation remains largely unknown, but the range of positive effects underlined above would seem valid arguments to expect a more intensified freight transport activity by road in future CCAM scenarios (see calculations made for the automotive sector, section 3.2.1).

Conclusion

To sum up, the effects of CCAM in the freight transport sector are expected to be positive, following the identified savings (e.g. fuel, labour) and other benefits (efficiency, safety). These positive effects will be clearly linked to the automation levels, with most of the benefits expected to be materialised in scenarios where full automation is reached.

3.2.5 Passenger transport

3.2.5.1 Scope and size

The passenger transport sector is a combination of the following economic sectors: passenger rail transport, passenger land transport (including taxi), passenger air transport and car rental/leasing. Different modes of transport have been selected in order to reflect possible modal shifts in the context of automation in driving, having knowledge of the relevance of each respective sector.

Total EU-28 passenger transport activities, in 2015, are estimated to account for 6,602 billion passenger-kilometre (pkm) (including intra-EU air and sea transport but not transport activities between the EU and the rest of the world) (European Commission, 2017a). The great majority of the people moved with cars, accounting for 71.5% of the total. Intra-EU air transport contributed for 9.8%, followed by buses and coaches, 8.2% and railways accounting for 6.7% of the total. During the last ten years, passengers cars increased by 20.9%, leading to a slightly decrease in the modal split, while air transport, saw an increase of 86.5% and maritime transport is the only mode of transport less frequently chosen in Europe, which registered a decrease equal to 29.7% during the same period.

Detailed figures corresponding to this sector in Europe are given below (Table 27).

Table 27. Indicators of the passenger transport sector

Sector	**Subsector**	**Description**	**Indicators**	**Value**
Passenger Transport	H49.10	Passenger rail transport, interurban	Number of persons employed	358,917
			Turnover (million euros)	54,566.5
			Number of enterprises	290.0
			Personnel costs (million euros)	18,912.6
			Value added (million euros)	25,490.7
			% Persons employed	**0.17%**
			% GVA	**0.24%**
	H49.31	Urban and suburban passenger land transport	Number of persons employed	895,780
			Turnover (million euros)	79,161.7
			Number of enterprises	14,885.0
			Personnel costs (million euros)	33,167.4
			Value added (million euros)	47,583.1
			% Persons employed	**0.42%**
			% GVA	**0.45%**
	H49.32	Taxi operation	Number of persons employed	614,055
			Turnover (million euros)	22,827.1
			Number of enterprises	306,765.0
			Personnel costs (million euros)	6,599.4
			Value added (million euros)	13,408.3
			% Persons employed	**0.29%**
			% GVA	**0.13%**
	H49.39	Other passenger land transport not elsewhere classified (n.e.c.)	Number of persons employed	546,527
			Turnover (million euros)	37,818.5
			Number of enterprises	49,885.0
			Personnel costs (million euros)	13,875.3

Sector	**Subsector**	**Description**	**Indicators**	**Value**
Passenger Transport *(continued)*	H49.39 *(continued)*	Other passenger land transport not elsewhere classified (n.e.c.) *(continued)*	Value added (million euros)	20,489.7
			% Persons employed	**0.25%**
			% GVA	**0.19%**
	H51.10	Passenger air transport	Number of persons employed	344,455
			Turnover (million euros)	134,026.1
			Number of enterprises	4,000.0
			Personnel costs (million euros)	23,325.1
			Value added (million euros)	31,720.8
			% Persons employed	**0.16%**
			% GVA	**0.30%**
	N77.11	Renting and leasing of cars and light motor vehicles	Number of persons employed	148,297
			Turnover (million euros)	66,028.4
			Number of enterprises	35,142.0
			Personnel costs (million euros)	4,974.5
			Value added (million euros)	36,265.5
			% Persons employed	**0.07%**
			% GVA	**0.38%**
	Total		Number of persons employed	2,908,031
			Turnover (million euros)	394,428
			Number of enterprises	410,967
			Value added (million euros)	174,958
			% Persons employed	**1.35%**
			% GVA	**1.69%**

Source: Own elaborations (based on Eurostat data from 2015).

3.2.5.2 Challenges and opportunities

Long-term personal travel patterns show that the time spent travelling has remained stable over the last 50 years, at around an hour a day, following also the so called Marchetti's constant of one hour commuting per day (Marchetti, 1994). Whereas trips and time spent travelling have not changed much along this period, distance travelled has increased meaningfully (namely by 71% since 1965) (UK Department for Transport, 2015). Car availability of households has also increased, with a large growth in multi-car households: from 5% of households that had two or more cars/vans in 1965 to 32% in 2014.

Vehicle ownership varies across the EU Member States, but in recent years, at least a 50% of households own at least one car (ACEA, 2017b).

Modes of travel have also changed, showing a rise in the use of the car over other modes such as bus or bicycle. With a growing demand for mobility, new attitudes to it are also emerging.

We explore below how automation might impact mode choice in the future, including shifts from taxi, public transport, train, walking or cycling towards AVs.

Modal shifts

In Fraedrich et al. (2016), the users perspective on possible implications of AVs in mobility behaviour was captured through interviews conducted with a sample of transport users. The respondents were asked how they would think that the introduction of AVs could affect their mode choice. The transport means considered were: taxi, public transport, train and foot/bike. The biggest decline in usage was foreseen for taxi, as it would be expectable, while the less affected could be walking and biking. In their analysis, the authors pointed out that a possible increase in car usage could be seen for inexperienced, insecure or elderly drivers leading to growth in car ownership and decline in public transport modes. In the end, a shared automated taxi trip could be so economic that it would compete with public transport and offer door-to-door mobility.

According to the POLIS document of road automation in cities (POLIS, 2018; specifically the studies from ITF and city of Amsterdam-commissioned study Impact of self-driving vehicles on the city of Amsterdam), the increased use of autonomous cars would be on detrimental to more sustainable modes, such as public transport, walking and cycling leading to an increase of kilometres travelled, hence causing congestion increase and possible negative effects on public health. According to the study, since price would not play anymore a key role in car ownership, the automation option would be chosen more frequently due to the possibility to use the driving time for other activities.

A decline in transit demand is also observed in the study by Levin and Boyles (2015), as a result of the avoidance of parking costs through the option of a drop-off and return trip enabled by AVs. A reduction in public transport cost sufficient to be competitive against the avoidance of parking fees (just the additional fuel consumption of a round trip) seems difficult to achieve. The authors point at road congestion issues that will appear as a result of the additional trips but the enhanced capacity features enabled by AVs seem to offset potential network problems. Since higher congestion also means higher fuel consumption, lower Value-of-Time (VOT) travellers may have an incentive to use transit.

Operating costs and user preferences

How autonomous cars will affect other modes of transport will change also according to the operating costs and users preferences linked to the different options. According to estimations provided in Litman (2018), operational costs will be relatively higher in AVs than human driven cars, but less costly compared to taxis. In the future, it would be cheaper to share AVs than use taxis or human car-sharing. A few considerations about the expected costs of operation of different transport modes is given in Box 5.

Box 5. Changes in operational costs of different transport modes with automation and MaaS

Cars as a service could offer the same level of service than the one offered by car ownership but at a much reduced cost, namely 10 times cheaper (Arbib and Seba, 2017). The asset utilisation will increase manifold from a roughly 4% (as vehicles are parked 96% of the time) to around 90% of the time.

It can also be argued that, even if costs are likely to decrease in a MaaS mobility scenario as a result of higher vehicle utilization, by making prices more transparent, travelling by car can appear to be more expensive (Gruel and Stanford, 2016).

The cost of conveying one passenger-mile by robo-taxi would be 35% less than using a conventional taxi at an average taxi occupancy rate of 1.2 passengers and will compete with owning a private vehicle when occupancy rate is 2 (Mosquet et al., 2015). This could affect vehicle sales and reduce the number of vehicles. Robo-taxis could even reach a price of $1 per mile or less, competing with public transport (Römer et al., 2016).

In case of autonomous taxis, as referred in Wadud (2017), professional driver costs could be significantly reduced but not completely, as it will still be required to consider operations such as back office infrastructure, additional equipment in vehicles for ensuring safety, etc. Thus between 20% and 40% of today's salary costs would at least be required.

A reduction of fuel consumption would also contribute to lowering operational costs. Wadud (2017) conservatively estimates fuel savings with AVs to be between 5% and 10% of current fuel consumption (Wadud, 2017).

Operational cost is just one factor affecting transport demand, which is also influenced by other components such as changing user preferences, improved travel options, demographic trends, price changes, planning innovations and ITS (Litman, 2018).

In the context of pursuing an enhanced multimodal mobility, it becomes clear that users' choices will be influenced by the increased road automation.

Conclusion

To conclude, changes in the shares of use of different transport modes could seem likely in a future CCAM scenario, although it is not possible to quantify those at the present stage. Price is identified as an important factor affecting users' decision making, but other factors like users' preferences, among others, would also play a key role.

3.2.6 Insurance

3.2.6.1 Scope and size

In the context of this study, the insurance sector is formed of two main economic activity groups: non-life insurance and reinsurance. About half million people work in these industries, making up a 0.8% of the total EU-28 GVA.

Detailed figures corresponding to this sector in Europe are given below (Table 28).

Table 28. Indicators of the insurance sector

Sector	**Subsector**	**Description**	**Indicators**	**Value**
Insurance	K65.12	Non-life insurance	Number of persons employed	470,835
			Turnover (million euros)	348,938.3
			Number of enterprises	2,257.0
			Personnel costs (million euros)	29,243.5
			Value added (million euros)	53,030.7
			% Persons employed	**0.22%**
			% GVA	**0.68%**
	K65.2	Reinsurance	Number of persons employed	14,282
			Turnover (million euros)	82,851.4
			Number of enterprises	91.0
			Personnel costs (million euros)	2,905.2
			Value added (million euros)	10,677.2
			% Persons employed	**0.01%**
			% GVA	**0.09%**
	Total		Number of persons employed	485,117
			Turnover (million euros)	431,790
			Number of enterprises	2,348
			Value added (million euros)	63,707.9
			% Persons employed	**0.23%**
			% GVA	**0.77%**

Source: Own elaborations (based on Eurostat data from 2015).

3.2.6.2 Challenges and opportunities

The insurance sector is said to face a significant disruption with the advent of CAVs. While CAVs may reduce the premiums linked to motor vehicle insurance, they will also create new insurance opportunities in relation to product liability or cybersecurity. The need for changing and adapting insurers' business models has already been recognised (e.g. Karp et al., 2017).

We explore below some of the main impacts from an increased vehicle automation and connectivity to the insurance sector.

Improved road safety

Road safety improvements are already taking place, especially as a result of ITS, assistance technologies and the corresponding policy and legal changes that have occurred in the last decade (e.g. ITS Directive 2010/40/EU ([118])). In this context, the potential of different driving assistance systems and CAVs to reduce accidents has been extensively mentioned in the literature and media (Anderson et al., 2014; Kyriakidis et al., 2015b). In particular, Römer et al. (2016) indicate a 70% traffic accidents decrease with AVs, supported by interviews with industry experts. Another study indicates a crash rate decrease from 4.2 accidents per million miles (corresponding to average human driving) to 3.2 accidents per million miles (Blanco et al., 2016 as cited in European Commission, 2017b), which corresponds to a 24% decrease. However, assuming 0% fatalities for CAVs does not seem realistic at this point in time, as certain types of accidents will hardly be avoided (e.g. jaywalking pedestrians, brake failure) (Sivak and Schoettle, 2015). In addition, during the transition period where mixed traffic will share the roads, safety may actually worsen, at least for conventional vehicles that lack eye contact feedback with CAV vehicles and will have certain expectations of other vehicles' behaviour (Sivak and Schoettle, 2015). These authors also note that it cannot be taken for granted that CAVs would ever perform safer than an experienced middle-age driver.

The expectation is that a reduction in the number of accidents and associated fatalities and injuries will lower insurance premiums. For instance, a 10% reduction of the insurance premium is already offered by the UK insurance industry for cars that have a collision avoidance system (Palmer, 2015 as cited in Wadud, 2017). Nevertheless, discounts are not offered across all Europe in a harmonised way, but just in some specific countries. This is linked to the difficulties in identifying in a systematic way the specific technologies that are equipped in a vehicle and the safety benefits associated to them.

Higher value of CAV technologies

Another aspect of relevance is that the higher value of a CAV will lead to additional premiums, that are to be applied to the corresponding share of premium (at present, a 30% of the insurance premium is for the car and 70% for the person, Miller, A., 2015 as cited in Wadud, 2017). Wadud (2017) estimates a 20% reduction of the insurance premium in early stages of fully automated vehicles deployment. No changes in insurance costs for commercial vehicles are estimated, as the reduction in the premium linked to the safety improvements can be offset by an increase in the premium due to the higher cost of an automated heavy-duty or light-duty vehicle. Another source (Römer et al., 2016) expects a 15% decrease in insurance liability as a result of autonomous driving technologies.

The costs of the claims (including property damage and bodily injury claims) could increase in the future, both as a result of inflation and as a consequence of more costly technologies (e.g. sensors) (Albright et al., 2017). The long-term trend though would be towards a reduction in costs, given that economies of scale would drive the price of technologies down and the damages from accidents involving AVs are expected to be less severe. Different insurance scenarios are analysed by Albright et al. (2017).

([118]) European Commission's Mobility and Transport website on Intelligent transport systems Action Plan and Directive, available at: https://ec.europa.eu/transport/themes/its/road/action_plan_en (last accessed 2 May 2018).

The value of data

Insurers can make use of data to improve profitability, e.g. by offering unique selling propositions that rely on customer segmentation, new value-added services and customer loyalty (Römer et al., 2016). Telematics are widespread in the insurance industry, offering incentives to drivers on a voluntary basis, according to their driving behaviour (e.g. speed limits compliance). This is part of the so called Usage-Based Insurance (UBI) or Pay-As-You-Drive (PAYD) insurance policies.

Incentivizing a better driving behaviour is already identified to have the potential to generate $381 billion in economic benefits to consumers and society from lower premiums and reduced amount of crashes by 2025 (World Economic Forum, 2016b).

The adoption of UBI services is expected to increase from 4% in 2016 to 30% in 2025 (World Economic Forum, 2016b). As a result, discounts of 10-15% in the insurance premium can be expected, linked to a potential decrease of 5% in the number of crashes. A 9% reduction in crashes could also be expected from ADAS and Electronic Stability Control (ESC) by 2025, potentially lowering the insurance premium by 5% (World Economic Forum, 2016b). Consequently, more than $1 trillion in economic benefits to consumers and society over the next 10 years could be expected (World Economic Forum, 2016b).

Changes in liability

The automation trend in driving will probably imply a change in legal responsibility in the event of an accident, with liability shifting from the driver to the car’s manufacturer, software designer, device maker, map producer, etc. (World Economic Forum, 2016b; Karp et al., 2017; Albright et al., 2017). Some manufacturers, like Volvo, Mercedes and Google, have stated that they will accept liability for accidents involving their AVs in the future (Albright et al., 2017). The insurance business will thus move from personal insurance policies towards commercial vehicle and product liability policies (Albright et al., 2017). In this context, there is potential for new revenues, as detailed in Box 6.

Box 6. New insurance business lines for CAVs

Product liability for both CAVs hardware and software will actually constitute a source of new revenues in the future, as well as cyber security risks (e.g. criminal or terrorist hijacking of vehicle controls, identity theft) and infrastructure risks (e.g. malfunction in cloud servers, communication problems), that can amount to $15 billion in new revenues by 2025 (Karp et al., 2017). New insurance revenues will generate at least $81 billion in the US along the period from 2020 and 2025.

Karp et al. (2017) have found that vehicle insurance premiums will start decreasing by 2025 and will reach $25 billion in revenue loss by 2035, exceeding the gains from new insurance lines (i.e. cyber risk, product and infrastructure).

Last, there is also a potential market share sifting from traditional insurance players towards vehicle manufacturers, who offer both insurance and maintenance services to their customers Karp et al. (2017). But in such a case, OEMs are just acting as a distribution channel, in partnership with the insurance companies, who are the ones writing the actual insurance policies.

3.2.6.3 Estimated effects for different scenarios

The insurance sector could be disrupted by the expected drastic reduction in the number of road accidents. Our analysis is mostly focusing on the assumption that the improved road safety conditions might imply significant discounts in motor vehicle premiums. On the basis of discounts currently applied to vehicles equipped with collision avoidance systems (Palmer, 2015, as cited in Wadud, 2017), our estimations indicate potential decreases in insurance premiums of 10-30% in 2025 and 15-40% in 2050 compared to today (see Table 29).

Table 29. Changes in insurance premiums for each scenario

	CHANGES OF INSURANCE PREMIUMS PER SCENARIO	
	2015-2025	**2015-2050**
Baseline	-	-
Scenario 1. Low uptake	**-10%**	**-15%**
Scenario 2. Medium uptake	**-15%**	**-20%**
Scenario 3. High uptake	**-30%**	**40%**

Source: Own elaborations.

These % reductions are applied to the revenues linked to motor vehicle insurance policies in 2015, namely: 133 billion euros (Insurance Europe, 2015). The resulting estimates are given in Table 30.

According to these projections, losses could represent up to 53 billion euros in 2050. With an eventual 90% accident decrease in the future (as Albright et al., 2017 estimates), these reduction ranges in motor vehicle insurance premiums could be larger (as also noted in Albright et al., 2017).

It is important to mention that new revenues from new insurance categories (e.g. cyber security, product liability for software and hardware) are not considered in these calculations. Another significant consideration in this sector is the possibility for some double counting with other sectors, given that a large part of insurance costs is spent on car repair after accidents, health costs and legal costs.

At this stage, the analysis is done without specifically distinguishing between passenger and commercial vehicles.

As a result, the range of possible effects is summarized in Table 30.

Table 30. Potential effects of AVs in the insurance sector

Effects of AVs on the insurance industry	**Baseline**			**Scenario 1**		**Scenario 2**		**Scenario 3**	
	2015	**2025**	**2050**	**2025**	**2050**	**2025**	**2050**	**2025**	**2050**
Change in insurance premiums with respect to 2015 (%)	-	-	-	-10%	-15%	-15%	-20%	-30%	-40%
Revenues per year from motor vehicle premium (billion euros) ([119])	130	-	-	120	115	115	105	95	80
Change in motor vehicle premium revenues with respect to 2015 (billion euros)	-	-	-	-10	-15	-15	-25	-35	-50

Source: Own elaborations.

([119]) Revenue figures are rounded for simplification and in accordance to their actual meaning.

3.2.7 Maintenance and repair

3.2.7.1 Scope and size

This sector has a direct correspondent in the Eurostat NACE Rev. 2 database, covering specifically the activities related to the maintenance and repair of motor vehicles. The EU-28 data suggests that more than 1.5 million people work in this sector, which represents approximately 0.4% of the total EU GVA.

Detailed figures corresponding to this sector in Europe are given below (Table 31).

Table 31. Indicators of the maintenance and repair sector

Sector	**Subsector**	**Description**	**Indicators**	**Value**
Maintenance and repair	G45.20	Maintenance and repair of motor vehicles	Number of persons employed	1,521,382
			Turnover (million euros)	140,000.0
			Number of enterprises	469,141.0
			Personnel costs (million euros)	28,000.0
			Value added (million euros)	44,541.2 (120)
			% Persons employed	**0.71%**
			% GVA	**0.41%**

Source: Own elaborations (based on Eurostat data from 2015).

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(120) EU-28 value not available; calculated as the sum of the available countries (missing one: Malta).

3.2.7.2 Challenges and opportunities

The effects of full automation on maintenance and repair, including tyres, are not clear (Wadud, 2017). In the long-term, lower acceleration/deceleration could be thought to lead to reductions in maintenance costs. But in early stages of deployment, these potential reductions could be offset by higher labour and equipment costs of repair (Wadud, 2017). It could also be expected that a longer vehicle utilisation linked to increases in overall VKT (either in an individual mobility or a MaaS setting) would incur higher maintenance costs, e.g. tyres. Still, given the high uncertainty in these effects and their probably low relative effect in the overall potential economic effects of CCAM, these effects could be ignored at the present stage. Other factors like a reduction of crashes would lead to a lower demand for vehicle repairs.

We explore below some of these potential changes brought in by CAVs to the maintenance and repair sector.

Improved road safety

Maintenance and repair sectors will likely be strongly affected by safer driving conditions that CAVs would enable, similar to what has been explained for the insurance sector. This is, the reduced amount of crashes would lower the demand for repairs of crashed vehicles and thus the revenues linked to them (Thierer and Hagemann, 2015). Repairers could also be challenged by the higher complexity of AVs (e.g. electronics and communication technologies) (European Commission, 2017i).

The relevance of data

Data access would constitute a challenge for maintenance and repair stakeholders (European Commission, 2017d). OEMs could control the dynamic vehicle data generated while driving, which could well reduce the opportunities for maintenance and repair shops (predictive maintenance). Some considerations in this regard are given in Box 7.

Box 7. Increased competition in vehicle maintenance

The identification of a correlation between data from multiple sources and different types of failures and repair needs will enable to improve predictive maintenance, therefore reducing the repair frequency and overall maintenance costs, as well as to improve quality and customer satisfaction (European Commission, 2017b). Gathering such amounts of data allows both car manufacturers and dealers to optimise quality and supply chain processes as well as to minimise warranty costs (European Commission, 2017m).

Telematics-enabled remote diagnostics are expected to add $60 billion of profits for OEMs, suppliers and telematics service providers (World Economic Forum, 2016b). The OEM’s privileged access to car sensor data would make them be well-positioned in this type of offerings (Mohr et al., 2014). Competition in car maintenance would be higher, thereby creating downward price pressure and reduced value added in these services.

Dealers and independent service centres could lose $44 billion in operating profits over the next 10 years (World Economic Forum, 2016b). In this context, a potential shift of $105 billion over the next decade could go from independent service centres and small dealerships to high-end, authorised service centres (World Economic Forum, 2016b). Remote servicing could imply a loss of business with potential value in auto servicing operating profits of $6 billion (World Economic Forum, 2016b).

Those parts retailers that wish to capitalize on digital channels for customer engagement could capture around $26 billion of operating profits but there is the risk of losing $2 billion of operating profits as a result of weaker pricing versus offline channels (World Economic Forum, 2016b).

Another possible effect in this context is that the used-car market could be benefited from vehicle usage monitoring and scoring, reducing the cost of certifying a used vehicle and allowing resellers to sell those vehicles that are in better conditions at higher prices (Bertoncello et al., 2016).

New revenues

A potential source for new revenues in this sector is linked to the increased need for cleaning and repair in a shared mobility scenario (Bösch et al., 2018). Although difficult to quantify, it can constitute an important element in MaaS that cannot be neglected.

Conclusion

Taking into account these different elements, the overall effect of CCAM on the maintenance and repair sector is expected to be negative. Even if no quantification is made for the study scenarios, it is possible to link them with possible qualitative effects. That is to say, the effects are expected to be stronger with higher levels of automation (significant improvement effect on safety), i.e. in scenarios 2 and 3, compared to scenario 1. However, eventual data restriction effects are understood to be independent of the level of automation. Also, it is possible to relate the cleaning and repair effects which could come associated to on-demand mobility services with scenario 3 by 2050 in particular.

3.2.8 Power

3.2.8.1 Scope and size

CCAM can have an indirect impact on the power system, since most CAVs can be expected to be electric cars (McCauley, 2017). Electricity production and grid management are important economic activities. Therefore the effects of CCAM on this sector need to be analysed.

Detailed figures corresponding to this sector in Europe are given below (Table 32).

Table 32. Indicators of the power sector

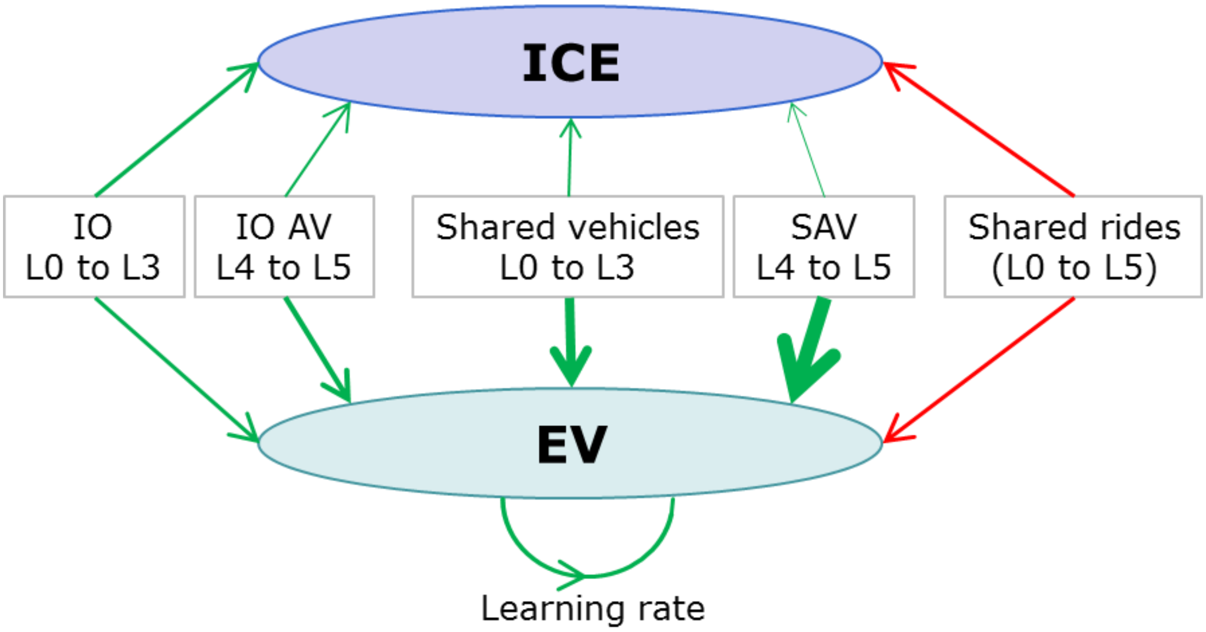
Sector	Subsector	Description	Indicators	Value
Power	D35.1	Electric power generation, transmission and distribution	Number of persons employed	941,130
			Turnover (million euro)	1,203,380
			Number of enterprises	90,000
			Personnel costs (million euro)	55,048.9
			Value added (million euro)	180,686.7
			% Persons employed	**0.44%**
			% GVA	**1.54%**

Source: Own elaborations (based on Eurostat Database, 2015).

3.2.8.2 Challenges and opportunities

EVs are emerging in the market, in competition with Internal Combustion Engine (ICE) as well as other technologies (mainly electricity hybrids ICE, compressed natural gas and hydrogen). The TCO is favourable to EVs when they are heavily used, thanks to their lower fuel and maintenance costs compared to ICE, which compensate for the higher cost of acquisition. CCAM can be provided by thermal vehicles or EVs. The ability to operate a CAV fleet allows for a higher use of a given vehicle than for IO vehicles. The same car can be used by more individuals, thus amortizing better the investment costs through more kilometres travelled.

Figure 12. Impact of automating and sharing vehicles on the EV competitiveness



Source: Own elaborations (121).

The development of ICE or EV (partly) depends on the expected mileage of the vehicle. As shown in Figure 12 the electric mobility is expected to be generally more competitive for CCAM applications. The mere fact of sharing a vehicle, being automated or not, increases the EV advantage. While automation levels 0 to 3 do not allow much behaviour change, automation levels of 4 or 5 imply self-driving vehicles, which could lead to higher VKT especially when the vehicle is shared (robo-taxis). The combination of automation and car-sharing would drastically enhance the competitiveness of EVs. Of course, the learning rate of this relatively new technology would further decrease EV costs.

Ride-sharing would reduce the overall VKT by reducing the number of needed vehicles, but not necessarily the kilometres travelled by each vehicle. Therefore it would have no specific impact on the market share of EVs.

We explore below several implications for the power sector of this additional development of EV due to CCAM. The impacts range from total electricity consumption and load shape, to power sector emissions and integration of renewable energy, and to grid planning and grid services.

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(121) Arrow sizes qualitatively indicate the purchase preferences of individuals and fleet-owners. Green (as opposed to red) indicates a higher (as opposed to lower) demand of a given vehicle technology. (ICE: Internal Combustion Engine vehicle; EV: Electric Vehicle; IO: Individually Owned; AV: Automated Vehicles; SAV: Shared Automated Vehicles; L0 to L5: levels of automation 0 to 5).

Electricity sales

As presented in section 3.2.1, vehicle automation can increase the vehicle transport demand due to a reduced cost of driver's time and the emergence of new users. Sharing vehicles seems to increase the total kilometres driven (Schaeller, 2017) compared to a scheme of IO vehicles (although the uncertainty is still strong at this early stage), possibly because of a lower cost of CCAM leading to a rebound effect, with a displacement by CCAM of public transport demand, walking or cycling (ITF, 2015). This means that MaaS may not be more efficient than today's mobility system in terms of energy use. On the other hand, some efficiency gains are expected through automated driving (less braking, optimized speed, etc.). The vehicles developed for CCAM could also be more adapted to specific needs; for example, smaller and low-speed vehicles could be developed for urban CCAM. This would improve the energy efficiency and lower the electricity demand relatively to IO EVs.

Since on top of this trend of increasing energy consumption, the share of EVs would be higher under a CCAM system, the electricity sales would clearly increase. A study by De Gennaro et al. (2014) finds that in the two areas under study (provinces of Modena and Firenze), the electrification of 8-28% of the urban car fleet implies an increase of below 5% of the total electricity sales (and below 20% of the domestic electricity demand).

Peak power consumption and load curve

Electricity has to be balanced at all times and large-scale storage is costly, so the impact of CCAM on the power system depends on the time of consumption, i.e. the charging load curve of CAVs. It can potentially lead to a higher usage of existing plants or to additional (less used) capacity needs. The risk is that the user preferences do not align with the electricity system optimum. The current low penetration of EVs means very little actual measurements of real EV-owner practices exist, although some studies extrapolate several charging strategies to the conventional fleet usage (De Gennaro et al., 2014) and others look at the benefits of managing the EV load (Babrowski et al., 2014). An illustrative example from Weiss et al. (2017) of an aggregated charging pattern is shown in Figure 13.

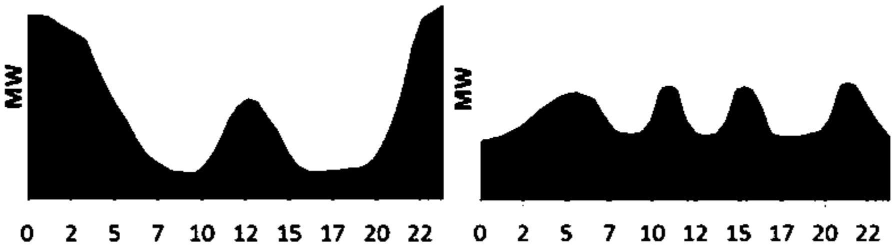
Figure 13. Illustrative charging patterns of IO EVs, without considering any remote-control allowed by CCAM

Source: Weiss et al. (2017) (Copyright © 2017 Elsevier Inc. All rights reserved).

The "default" load pattern of IO vehicle charging, without any load management, can increase strongly the evening electricity peak consumption. The power drawn from the grid between 7pm and 10pm could lead to increased peak power, with higher risks of curtailed load (by lack of generation or grid constraints). On the other hand, the controllability of CAVs gives the opportunity to manage their load and charge during times of low demand. This would allow existing plants to be more used, without increasing the peak power demand.

The resulting load curve of CAVs may become crucial information for electricity utilities and grid managers. While the charging times of an individual car may be unpredictable, a pattern can emerge when averaging over the CAVs fleet or the country. A tentative illustration suggested by Weiss et al. (2017) is shown in Figure 14 (other charging profiles are extrapolated by De Gennaro et al. (2014) depending on the pre-defined strategy applied).

Figure 14. Illustrative charging patterns of CCAM with modest use (left) and CCAM with high use and distributed fast-charging (right)



Source: Weiss et al. (2017) (Copyright © 2017 Elsevier Inc. All rights reserved).

The load will probably be lower during hours of highest transport needs (commuting times of the morning and evening). The charging times will be situated outside these hours, but will also depend on the availability and locations of the charging infrastructure. If the shared vehicles are highly used, ultra-fast charging (hence high voltage) will be more valuable to fleet-owners, leading to spikier and more unpredictable load curves at the local level and potential local grid congestions. At the national level the aggregated load curve might show small peaks before and after each commuting time. However, one may expect a relatively flatter load curve for CAV than IO vehicles (Weiss et al., 2017).

Emissions and renewable energy integration

Peak residual load can be defined as load minus non-dispatchable production (as are wind, solar, or run-of-river hydro). It is equal to the maximum load to be covered by dispatchable plants (like thermal plants, hydro lake or storage).

Peaking power plants usually have a higher content of greenhouse gas and air pollutants, as they are often fossil-fuelled and of low efficiency. A badly managed CAV fleet may increase the power sector emissions by charging at times of high marginal emissions like peak residual load. An adequate management of a fleet of CAVs allows charging preferably in hours of low electricity-related emissions.

It can also help improving the integration of renewable energy sources in the system. For instance, CAVs could avoid additional investments in dispatchable plants by not charging at times of peak residual load (i.e. high demand and low renewable energy availability). They could also avoid some curtailment of surplus non-dispatchable production by charging more at times of low demand and high renewable energy production (e.g. solar production peaks). Therefore, CCAM can increase the value of non-dispatchable energy sources like wind or solar.

Charging infrastructure needs

In a context of high use of CCAM, the main concern becomes to minimize the car unavailability during charging. The charging power will likely increase (Weiss et al., 2017) (current individual charging power reaches 350 kW). The development of the mobility infrastructure could favour centralized charging situated in mobility nodes. Ideally these would match with electricity nodes, so that the grid reinforcements are easier. However, the impact on the grid infrastructure strongly depends on where the vehicles are charged: city centre, suburbs, rural, closeness to a low-voltage feeder or to a high-voltage transformer. A geographical analysis like the one performed in De Gennaro et al. (2014) is needed to identify the infrastructure bottlenecks in order to allow higher shares of EVs, although they also depend on the charging strategy chosen. A UK study (Brandmayr et al.,

2017) shows that even low penetrations of EVs could cause congestions on the distribution grid and local load curtailment; a high CCAM development could exacerbate these grid challenges.

An intermediary storage station could relieve the grid. Acting as a buffer, it would adapt better to the grid capacity. The cars could be charged from the stationary storage plant, although this incurs additional costs, efficiency losses and potentially some waiting time. Another (faster) option is to swap the car batteries at a stationary storage site, which power draw could then be constant or optimized on the prices seen by the storage actor.

Sensitivity to electricity price

The electricity price paid for charging the vehicles will impact the charging strategy. The vehicles will be much more responsive if charged at the wholesale price than if charged at the retail rates. Even more than IO EVs, CAVs fleet-owners will want to optimize their electricity tariffs and may be interested in variable rates in order to minimize their costs by implementing charging strategies.

As they have an almost zero marginal cost, the renewable energy production will push wholesale prices downwards, thus favouring a synchronous CAV charging. Conversely, when renewable electricity production is scarce and fossil-fuel plants are most needed, prices will be higher and CAV may be discouraged to charge. Some even foresee that the battery spare capacity of unused parked cars can be discharged (in Vehicle-to-grid mode, V2G) and valued in the electricity market.

If the load curve is controlled via price signals at the national level, a threshold effect might occur where a big proportion of the vehicles would want to benefit of the same electricity price, leading to load spikes. This could be mitigated by delaying or spreading the charging profiles.

More generally, CAV operators will maximize revenues, so the minimization of charging costs is only one aspect. The optimal use of their fleet, as well as the opportunity costs due to the time spent for vehicle charging, may potentially lead fleet-owners to charge the vehicles outside of the cost-optimal strategy.

The general logic of the tariff design should aim at representing both short- and long-term signals. In particular, CAVs should see an incentive to charge when energy is plentiful (low variable cost of production, i.e. short-term impact) but also where/when it is most compatible with the infrastructure, thus accounting for the high costs of an infrastructure upgrade, whether grid lines or production plants (i.e. long-term impact). This last element could be defined in cooperation with transmission and distribution operators that know best the (national and local) grid constraints.

Services to the grid

CAV batteries connected to the grid could provide ancillary services (frequency reserve, balancing services, voltage support). V2G can also improve the profitability of CAV by providing a peaking capacity on the energy or capacity markets. On a more decentralised scale, CAV could also absorb congestions or avoid load curtailment. These grid services may be easier to implement for a CAV operator than for IO EVs. They are beneficial for the electricity system but must be compared to their opportunity cost. They may complement other flexible technologies and compete with them: stationary storage, grid interconnections or other demand side management options (industry, heating, cooling and refrigeration).

3.2.8.3 Estimated effects for different scenarios

The structure of the vehicle fleet is described based on the assumptions of Table 3 (section 2.2.3) and shown in the table below (Table 33).

Table 33. Distribution of the fleet per scenario - passenger transport

	DISTRIBUTION OF THE FLEET PER SCENARIO - PASSENGER TRANSPORT							
	2025				2050			
	IO L0-3	IO L4-5	Shared L0-3	Shared L4-5	IO L0-3	IO L4-5	Shared L0-3	Shared L4-5
Baseline	100%	-	-	-	100%	-	-	-
Scenario 1. Low uptake	80%	-	20%	-	69%	1%	27%	3%
Scenario 2. Medium uptake	57%	3%	28%	12%	5%	35%	7%	53%
Scenario 3. High uptake	35%	5%	7%	53%	-	10%	-	90%

Source: Own elaborations.

In each segment, the penetration of EVs is evaluated, with the following logic:

- IO vehicles with low automation (L0-3) are assumed to follow the baseline assumptions of EU Reference 2016 (precisely, the updated baseline EU Reference Scenario 2016 by Hill et al., forthcoming 2018).
- Vehicles with high automation level (L4-5) tend to be more often electric, since they are able to drive more (self-driving) than vehicles with low automation.
- Shared vehicles are preferably electric, since they can drive more.
- EVs get more developed with time (we assume 40% less 'availability' (consumer preference, purchasing price) in 2025 than in 2050).

These considerations are translated into assumptions shown in Table 34.

Table 34. EV share of total travel - passenger transport

	2025				2050			
	IO L0-3	IO L4-5	Shared L0-3	Shared L4-5	IO L0-3	IO L4-5	Shared L0-3	Shared L4-5
Assumptions: EV share of total VKT	1%	30%	42%	57%	7%	50%	70%	95%

Source: Own elaborations.

The resulting EV share of total VKT is shown in Table 35.

Table 35. EV share of total travel - passenger transport

	EV SHARE OF TOTAL VKT	
	2025	**2050**
Baseline	**1%**	**7%**
Scenario 1. Low uptake	**9%**	**27%**
Scenario 2. Medium uptake	**20%**	**73%**
Scenario 3. High uptake	**35%**	**91%**

Source: Own elaborations.

The data used (from the updated baseline EU Reference Scenario 2016 by Hill et al., forthcoming 2018) indicates 2,900 Gvkm travelled in 2015 and an energy consumption of 20 kWh per 100 km, decreasing to 13 and 11 kWh in 2025 and 2050 (in these estimations we only consider the part of passenger transport that corresponds to private cars). The scenarios consider the impacts identified in the automotive section (3.2.1) due to baseline projections (+9% in 2025 and +30% in 2050), reduced cost of driver's time and new users; we do not change the occupancy rate. The combination of share of EV on VKT, VKT and electricity consumption per kilometre gives the total electricity consumption of private cars (see Table 36 below).

Table 36. Potential effects of AVs in the power sector - passenger transport

	ELECTRICITY SALES TO EV PRIVATE CARS PER SCENARIO – PASSENGER TRANSPORT	
	2025	**2050**
Baseline	**4 TWh** (1%*2,900 Gvkm*1.09*0.13 kWh/km)	**29 TWh** (7%*2,900 Gvkm*1.3*0.11 kWh/km)
Scenario 1. Low uptake	**43 TWh** (9%*2,900 Gvkm*1.21*0.13 kWh/km)	**140 TWh** (27%*2,900 Gvkm*1.6*0.11 kWh/km)
Scenario 2. Medium uptake	**110 TWh** (20%*2,900 Gvkm*1.43*0.13 kWh/km)	**440 TWh** (73%*2,900 Gvkm*1.88*0.11 kWh/km)
Scenario 3. High uptake	**230 TWh** (35%*2,900 Gvkm*1.67*0.13 kWh/km)	**540 TWh** (91%*2,900 Gvkm*1.88*0.11 kWh/km)

Source: Own elaborations.

This additional electricity consumption due to the accelerated electrification of private cars is significant but remains below 7% of the total European electricity generation in 2025 (estimated at around 3,400 TWh) and reaches 13% in 2050 (compared to a total of around 4,000 TWh). Since the electricity consumption for EV in the baseline scenario is an order of magnitude smaller, most of the power consumption is due to the assumptions on the development of CCAM, with an uncertainty range given by the three scenarios. The additional uncertainty on the occupancy rate of the vehicles is not accounted here. Overall, the impact of CCAM on the development of EV is really noticeable in 2050, and perhaps as soon as 2025 if it develops fast (scenarios 2 and 3).

Moreover, the estimations of consumption per kilometre in future vehicles can appear optimistic. We show in Table 37 what would be the consumption if the driving consumption was the same as today (0.20 kWh/km).

Table 37. Potential effects of AVs in the power sector without improvements of consumption per kilometre- passenger transport

	ELECTRICITY SALES TO EV PRIVATE CARS PER SCENARIO – PASSENGER TRANSPORT **Constant consumption per kilometre**	
	2025	**2050**
Baseline	**6 TWh** (1%*2,900 Gvkm*1.09*0.2 kWh/km)	**53 TWh** (7%*2,900 Gvkm*1.3*0.2 kWh/km)
Scenario 1. Low uptake	**64 TWh** (9%*2,900 Gvkm*1.21*0.2 kWh/km)	**250 TWh** (27%*2,900 Gvkm*1.6*0.2 kWh/km)
Scenario 2. Medium uptake	**170 TWh** (20%*2,900 Gvkm*1.43*0.2 kWh/km)	**790 TWh** (73%*2,900 Gvkm*1.88*0.2 kWh/km)
Scenario 3. High uptake	**340 TWh** (35%*2,900 Gvkm*1.67*0.2 kWh/km)	**980 TWh** (91%*2,900 Gvkm*1.88*0.2 kWh/km)

Source: Own elaborations.

The impact of electric vehicles would then be much higher in a scenario with high uptake of CCAM, up to a quarter of the expected total electricity produced in Europe.

The impacts of CCAM on oil products and electricity sales can also be considered in economic terms. For electricity expenditures, the modified baseline of the EU Reference Scenario 2016 considers an average retail price (with taxes) of electricity of 250 €/MWh (euros of 2015 per megawatt hour) for 2025 and 240 €/MWh for 2050. For the non-electricity fuelled cars (diesel, gasoline, biofuels, gas, hydrogen), it gives a weighted average of retail prices of 1.8 million €/ktoe (million euros of 2015 per thousands of tonnes of oil equivalent) in 2025 and 2.0 million €/ktoe in 2050, with a corresponding weighted energy efficiency of 50 ktoe/Gvkm in 2025 and 38 ktoe/Gvkm in 2050 (62 ktoe/Gvkm in 2015 in the no efficiency improvement case). When applied to the travel demand not covered by EV, it gives the non-electricity expenditures in the private car sector.

The effects are shown in Table 38, with decreasing or constant consumption per kilometre.

Table 38. Potential effects of AVs on the fuel expenditures of private cars, with and without improvements of consumption per kilometre - passenger Transport

	FUEL COSTS OF PRIVATE CARS PER SCENARIO – PASSENGER TRANSPORT			
	Decreasing consumption per km		**Constant consumption per km**	
	2025	**2050**	**2025**	**2050**
Baseline	**290 billion euro** 0.4% being elec. (4 TWh*250 €/MWh + 99%*2,900 Gvkm*1.09*50 ktoe/Gvkm*1.8 M€/ktoe)	**280 billion euro** 2% being elec. (29 TWh*240 €/MWh + 93%*2,900 Gvkm*1.3*38 ktoe/Gvkm*2.0 M€/ktoe)	**360 billion euro** 0.4% being elec. (6 TWh*250 €/MWh + 99%*2,900 Gvkm*1.09*62 ktoe/Gvkm*1.8 M€/ktoe)	**450 billion euro** 3% being elec. (53 TWh*240 €/MWh + 93%*2,900 Gvkm*1.3*62 ktoe/Gvkm*2.0 M€/ktoe)
Scenario 1. Low uptake	**Baseline +5%,** 4% being elec. (43 TWh*250 €/MWh + 91%*2,900 Gvkm*1.21*50 ktoe/Gvkm*1.8 M€/ktoe)	**Baseline +6%,** 11% being elec. (140 TWh*240 €/MWh + 73%*2,900 Gvkm*1.6*38 ktoe/Gvkm*2.0 M€/ktoe)	**Baseline +6%,** 4% being elec. (64 TWh*250 €/MWh + 91%*2,900 Gvkm*1.21*62 ktoe/Gvkm*1.8 M€/ktoe)	**Baseline +7%,** 12% being elec. (250 TWh*240 €/MWh + 73%*2,900 Gvkm*1.6*62 ktoe/Gvkm*2.0 M€/ktoe)
Scenario 2. Medium uptake	**Baseline +15%,** 8% being elec. (110 TWh*250 €/MWh + 80%*2,900 Gvkm*1.43*50 ktoe/Gvkm*1.8 M€/ktoe)	**Baseline -22%,** 48% being elec. (440 TWh*240 €/MWh + 27%*2,900 Gvkm*1.88*38 ktoe/Gvkm*2.0 M€/ktoe)	**Baseline +17%,** 10% being elec. (170 TWh*250 €/MWh + 80%*2,900 Gvkm*1.43*62 ktoe/Gvkm*1.8 M€/ktoe)	**Baseline -18%,** 51% being elec. (790 TWh*240 €/MWh + 27%*2,900 Gvkm*1.88*62 ktoe/Gvkm*2.0 M€/ktoe)
Scenario 3. High uptake	**Baseline +20%,** 16% being elec. (230 TWh*250 €/MWh + 65%*2,900 Gvkm*1.67*50 ktoe/Gvkm*1.8 M€/ktoe)	**Baseline -39%,** 76% being elec. (540 TWh*240 €/MWh + 9%*2,900 Gvkm*1.88*38 ktoe/Gvkm*2.0 M€/ktoe)	**Baseline +24%,** 19% being elec. (340 TWh*250 €/MWh + 65%*2,900 Gvkm*1.67*62 ktoe/Gvkm*1.8 M€/ktoe)	**Baseline -34%,** 78% being elec. (980 TWh*240 €/MWh + 9%*2,900 Gvkm*1.88*62 ktoe/Gvkm*2.0 M€/ktoe)

Source: Own elaborations.

Generally, fuel expenditures are increased by 2025 (+15% to +17% depending on the consumption of future vehicles), mainly because we estimate an increased driving activity, while electrification of transport (which has lower fuel costs than ICE) arrives more progressively. At the 2050 horizon, however, electrification has taken off and fuel expenditures could decrease by around a fifth in Scenario 2.

Finally, an additional calculation is made in Box 8 for what concerns the extra electricity consumption resulting from AVs sensors and computing power.

Box 8. Electricity consumed for sensors and computing power needed for automated driving

The miniaturization of computing capabilities and the evolution in sensor technologies (radars, LIDARs, cameras) lead to different estimations of the energy consumed for autonomous driving. Although some prototypes use around 2.5 kW of electricity, gains in the design of processors are expected to slash this consumption. As an example of the possible impact of these elements on the consumption of an AV, we assume 750 W of power used when driving autonomously (L4-5) in 2025 and 500 W in 2050, with an average speed of 60 km/h. Only the cars of L4-5 autonomy are considered here (assumptions identical to Table 3). This leads to the estimations of Table 39.

The additional consumption due to sensors and computing power needed for autonomous driving adds around 8% to the EV consumption (reaching 15% in scenario 3 in 2025), or around 5% if the consumption per kilometre stays as of today. This additional consumption would reduce the range of electric vehicles and increase the cost of operation.

Table 39. Potential effects of AV sensors and computing power on the power sector - passenger transport

	ELECTRICITY CONSUMED FOR AUTOMATING PRIVATE CARS PER SCENARIO – PASSENGER TRANSPORT	
	2025	**2050**
Scenario 1. Low uptake	**0 TWh** (0%*2,900 Gvkm*1.21/60 km.h^{-1} *750 W)	**2 TWh** (4%*2,900 Gvkm*1.6/60 km.h^{-1} *500 W)
Scenario 2. Medium uptake	**8 TWh** (15%*2,900 Gvkm*1.34/60 km.h^{-1} *750 W)	**40 TWh** (88%*2,900 Gvkm*1.88/60 km.h^{-1} *500 W)
Scenario 3. High uptake	**35 TWh** (58%*2,900 Gvkm*1.67/60 km.h^{-1} *750 W)	**45 TWh** (100%*2,900 Gvkm*1.88/60 km.h^{-1} *500 W)

Source: Own elaborations.

The estimations above indicate an impact of up to a quarter of the expected electricity production (with a high uncertainty, especially on the consumption per kilometre), which can be managed easily if the production capacities are well managed. The constraints on the peak power remain relevant, however. Concerning impacts of CCAM other than total electricity sales, they depend on the strategy used for operating the car fleet. Some strategies would benefit the power system (for example by optimizing the existing plant use or the grid management), thus reducing the overall power system cost. Other strategies may minimize the greenhouse gas emissions. But the operators of shared vehicles will certainly pay attention to the opportunity cost due to the electricity charging time. The customer needs and comfort will probably impact strongly the behaviour of most fleet-owners. Some customer segments may express preferences aligned with some of the previous goals (e.g. a commercial argument of green electricity used in their mobility service). However, a further alignment to these goals will need policy action in the fields of tariff design and infrastructure planning.

On the governance aspect, the organisation of the sector is yet unclear. Who could operate the car fleet, who should pay for the infrastructure and where should it be developed? The main actors involved are car owners, car users, distribution grid operators, but also local governments, new actors (fossil energy retailers, technology companies like Google or Apple), power producers, retailers or all involved intermediaries.

3.2.9 Other sectors

Apart from the sectors that have been covered in previous sections, we have identified other businesses or activities that might be affected by CCAM in the future. Among these, there are the following: construction of roads and motorways, oil and gas, legal, or public services (such as traffic police, land development, education or medical). The effects of CCAM on these sectors can seem too distant (because of the association to full autonomy) or unclear at the moment of writing this report, and thus, they are just briefly covered in this section.

As far as the **construction of roads and motorways** is concerned, one possible assumption is that there will be a reduced need to construct new roads if CAVs provide capacity improvements. For instance, the capacity of a lane at 100 km/h could increase from 2,869 cars/h to 4,103 or even 10,730 cars/h thanks to CAV technologies (Peterson, 2014). Similarly, the enhanced vehicle control capabilities and shorter inter-vehicle distances could enable reductions in lane width in a distant future. As the infrastructure increasingly progresses towards digitalisation, a long-term vision where all vehicles on the road are automated and connected could also imply that there will be less need for physical signs (thus, where the digital infrastructure moves from being a complement to being an alternative for traditional infrastructure). Most of these effects are linked to a dominant CAV-enabled mobility, and thus do not seem feasible in mixed traffic conditions.

In terms of **land development**, one significant effect would be the one related to parking. The underlying reason is the possibility that CAVs will allow for a more extensive usage (either on a privately-owned basis or as part of shared fleets of vehicles) that reduces the need for parking or allows for distant parking. Public parking spaces could decrease from 300 to 60 (Peterson, 2014) and the new available space could be dedicated to alternative uses, or to transform current individual and public transport systems (Fraedrich et al. 2016). It will also lead to a reduction in parking fees. In such a setting, it is also plausible that the savings coming from reduced/zero-fees parking enabled by CAVs, could partially be offset by an additional fuel consumption linked to empty-vehicle running up to the parking location (Wadud, 2017). Parking garage owners will have to reduce cost to remain competitive against the cost of additional fuel consumption in the case of AVs running empty instead of being parked (Levin and Boyles, 2015). Apart from these effects linked to parking, the changes in value of travel time could also affect land development patterns. Users might accept longer commuting distances and choose to live in the suburbs, or in more remote, rural areas, while working in the city (Cyganski 2015, Heinrichs 2015, as cited in Fraedrich et al., 2016). A few implications in this regard are discussed in this article (Razin, 2018).

The **oil and gas** (extraction and distribution) industries could also be affected by CCAM, in different ways. On the one hand, there is the possibility that future vehicles become larger and heavier to accommodate new features and increased comfort. (Wadud et al., 2016) estimates that 240 kg could be added to the weight of the average new vehicle by 2050, which is then associated to a potential increase of about 11% in fuel consumption. On the other hand, vehicles could become lighter as a consequence of the improved road safety, thus leading to reductions in fuel use. The transition towards an electrified mobility would also represent a challenge for this sector.

In a long-term future, it would seem feasible that driving permits would not be needed anymore. This would affect the **education** sector, specifically driving schools where training for different types of licences can be obtained. There will certainly be incremental adaptations in driving schools in the short to medium term, responding to new types of permits and prerequisites for more skills from drivers (Römer et al., 2016). More demand for ICT-related education could also be expected in the future.

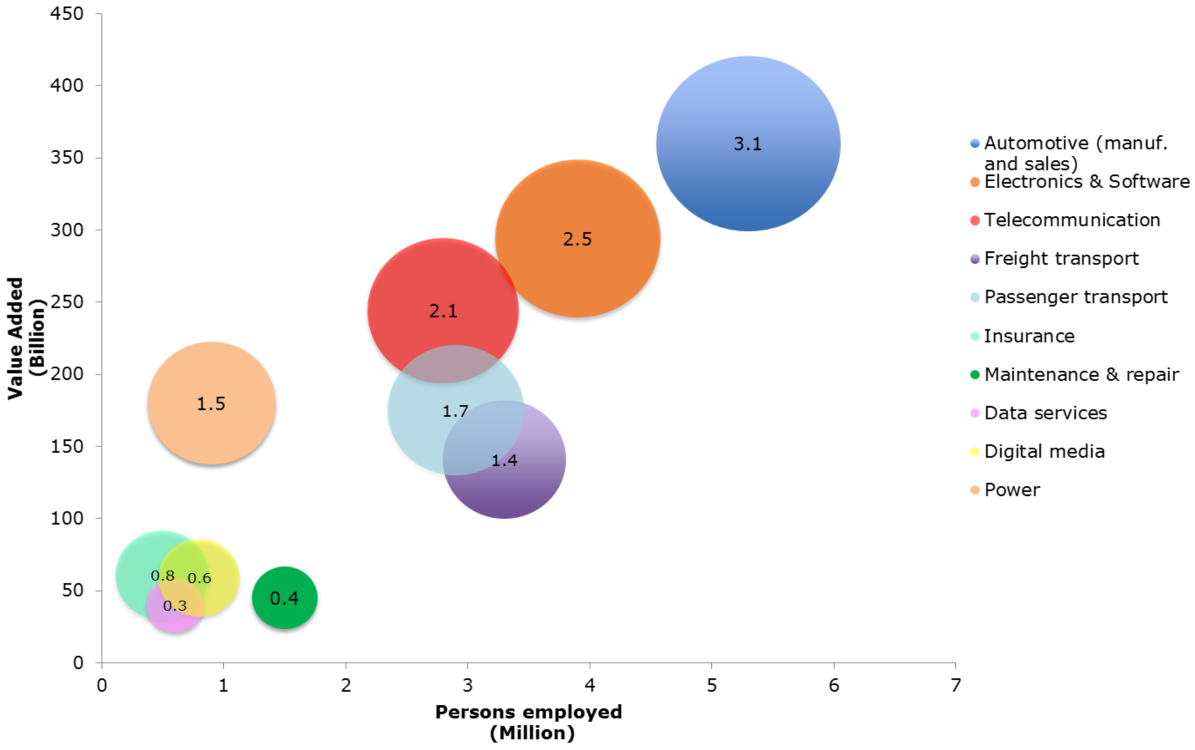
Savings linked to the **medical** sector are also expected, in line with a reduced amount of road accidents. For instance, a reduction of 5% of traffic accidents has been associated to benefits in the order of 7 billion euros annually (Asselin-Miller et al., 2017). This is decomposed in: 2.38 billion euros in fatalities, 3.66 billion euros in serious injuries and 1.17 billion euros in minor injuries. Estimates of costs per fatality, severe and slight injuries are given in (McCarthy et al., 2017), namely: 1.2 million euros per person for fatalities, 272,000 euros per seriously injured person and 13,600 euros per each slightly injured person. It would then be possible to link these figures with estimates in accidents reduction, such as the one from Leech et al. (2015) that points at 2,500 lives saved and 25,000 serious accidents prevented in the period from 2014 to 2030 as a result of CAV technologies. Peterson (2014) also presented some estimations of the expected reductions in road fatalities and injuries, specific for Germany and giving a lower and upper bound estimate: from 3,338 fatalities in 2013 to a range between 1,669 and 334 fatalities, and from 366,000 traffic injuries to a range between 183,000 and 36,600 people injured. No timeframe is given for these decreases though.

3.2.10 Concluding remarks on the economy

Figure 15 shows the current state of the sectors that are most likely to be affected by CCAM, namely their VA, persons employed and share of GVA in the total EU-28.

A summary of the main potential impacts for these sectors is given below.

Figure 15. Current state of the main sectors affected by CCAM, showing VA, persons employed and share of GVA in the total EU-28 (the latter indicated at the centre of each bubble as %)



Source: Own elaborations (based on 2015 data from Eurostat SBS and NA databases).

As far as the **automotive** sector is concerned, CAVs may reinforce vehicle sales in line with travel activity increases. The higher the level of automation, the stronger the effect on VKT, mostly as a result of a reduction in driving costs (including changes in the value of travel time) and new users like young people, elderly or disabled (as cited in e.g. Wadud, 2016). Even though new mobility service models (MaaS) will increase vehicle usage intensity (a 75% usage increase is stated in Schoettle and Sivak, 2015 or a 10 times increase in Arbib and Seba, 2017), the resulting decreased vehicle ownership will considerably impact vehicle sales. Our scenario estimations provide ranges of passenger vehicle sales increases from 18% to 39% during the period 2015-2025 and from 33% to 51% in the period 2015-2050. Specifically, in scenario 3, it is possible to observe long-term lower vehicle sales as a result of a dominant MaaS-based travel. Using current average vehicle prices, total revenues from passenger vehicle sales could exceed 550 billion euros by 2050. It is also expected that the sales of heavy commercial vehicles will increase in response to a more intense road travel activity in the future, which could be further reinforced by a more efficient operation of automated trucks. In this case, a growth of 19-29% could be expected in the period 2015-2025 and 38-68% in the 2015-2050 period. Total revenues from commercial vehicle sales could almost reach 150 billion euros in 2050.

The **electronics and software** sector would clearly benefit from the production and sale of new components and systems needed for automated driving (including hardware and software components). Whereas software will gain a more dominant role with regard to today (from a 10%-90%-0% to a 40%-40%-20% for software, hardware and contents respectively, as stated in Römer et al., 2016), the market for CAVs' hardware components like cameras, lidar, etc. Will also grow (Asselin-Miller et al., 2017). With the previously mentioned vehicle sales projections, total revenues from the sector could almost reach 180 billion euros by 2025 for both passenger and freight automated vehicles.

The **telecommunication, data services and digital media** sectors are also expected to experience significant growth, as in-vehicle connectivity increases and becomes pervasive. Upcoming 5G networks will support the exchange of massive amounts of data generated by a future CAV. The monetization of car data holds a great potential (McKinsey&Company states it could generate from $450 to $750 billion in revenues by 2030, Bertoncello et al., 2016) and users are already demonstrating willingness to pay for services built around this data (Dungs et al., 2016). Considering the current 19% EU share of global passenger cars registrations/sales in 2015 (ACEA, 2016b), the European part of these projections could be around 120 billion euros in revenues from monetization of car data by 2030.

Vehicle automation will act as a transformational technology in the **freight transport** sector by diminishing operating costs and allowing more efficient logistics (World Economic Forum, 2016a). These benefits would justify the idea that this sector becomes one of the early adopters of CAV technologies (Wadud, 2017). The two most costly elements in commercial vehicles operation are fuel and drivers, both of which can be reduced through truck automation (Gundermann et al., 2015). When it comes to fuel savings, truck platooning could decrease fuel consumption by 2-8% for the leading vehicle and 8-13% for the following vehicle (SARTRE, 2014, as cited in Janssen et al., 2015). The role of a professional driver can be radically transformed in the future (starting with early platooning applications), gradually undertaking other duties than driving and possibly turning into a more technical role (Clements and Kockelman, 2017). To which extent this will lead to a reduction in the number of drivers needed still remains an unanswered question that deserves careful attention. It is also important to stress that CAV technologies could help to compensate the shortage of long-haul drivers (Lanctot, 2017), as e.g. Germany is expecting to lose around 250,000 drivers who will retire in the next 10 to 15 years (Hollis, 2016). Effects of CCAM on truck driver jobs are further discussed in the employment section below (section 3.3.1).

For what concerns the **passenger transport** sector, AVs use could be detrimental for more sustainable modes, such as public transport, walking and cycling (POLIS, 2018). According to Litman (2018), operational costs will be relatively higher in AVs than conventional cars, but less costly compared to taxis. Thus, it seems plausible that CAVs will take some users from other modes, e.g. taxis, buses, trains, also reducing vehicle ownership.

The **insurance** sector could be disrupted by the expected drastic reduction in the number of road accidents. The improved road safety conditions might imply significant discounts in motor vehicle premiums. On the basis of discounts currently applied to vehicles equipped with collision avoidance systems (Palmer, 2015, as cited in Wadud, 2017), our estimations indicate potential decreases in insurance premiums of 10-30% in 2025 and 15-40% in 2050 compared to today. These losses could represent up to 53 billion euros in 2050.

A lower crash rate would also drive a large part of the changes expected in the **maintenance and repair** sector, with revenues decreasing as a result of a lower demand for crash-related repairs (Thierer and Hagemann, 2015). Although a lower acceleration/deceleration could also lead to reductions in maintenance, this potential decrease could be offset by higher labour and equipment costs of repair (Wadud, 2017). Telematics will enable predictive maintenance applications that would also lead to lowering repair frequency and overall maintenance costs (European Commission, 2017b). The OEM's privileged access to car sensor data would make them be well-positioned in this type of offerings (Mohr et al., 2014). Competition in car maintenance would be higher, thereby creating downward price pressure and reduced value added in these services. One potential factor leading to a growth in revenues in this sector could be linked to the cleaning and repair activities that could be needed for shared vehicles (Bösch et al., 2018).

CCAM can have an indirect impact on the **power** system, since most CAVs can be expected to be electric cars (McCauley, 2017). The estimated effects indicate increases in electricity sales with time and growing levels of automation.

An overview of the expected direction of change (and, in some cases, a quantified effect) in each of the sectors is given in Table 40.

Table 40. Main economic effect per sector in 2025 and 2050 (revenues change in billion euros or as a qualitative indication of the expected direction of change with respect to baseline scenario)

Industries	**Baseline**		**Effects in 2025 - 2050 scenarios (122)**	
	2025	**2050**	**2025**	**2050**
Automotive (123)	505	605	540-625	645-700
Electronics and software (123, 124)	-	-	85-175	50-65
Telecommunication, data services and digital media	-	-	↑	↑
Freight transport	-	-	↑	↑
Passenger transport	-	-	↓	↓
Insurance (125)	-	-	95-120	80-115
Maintenance and repair	-	-	↓	↓
Power sales for private cars	1	7	11-57	33-130

Source: Own elaborations.

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(122) Figures on total revenues are given for the sectors where detailed estimations have been elaborated, indicating a range of effects in consideration of the different scenarios (Green text represents a positive effect and Red text represents a negative effect). For the rest of sectors, arrows are provided to indicate the expected trend: ↑ shows a positive effect, ↓ shows a negative effect.

(123) For the automotive and electronics and software sectors, figures represent the sum of passenger transport (autarky situation) and freight transport.

(124) The effects in this sector are considered to be in addition to current revenues of the sector.

(125) For the insurance sector, the reference figure is 133 billion euros from motor vehicle insurance policies in 2015.

A few concluding remarks are made below:

- The economic impacts presented in this study can be classified as either price effects (increase of costs), quantitative effects (sales of cars) or structural effects (increase of telecommunication services and reduction of insurance expense). However, at this stage, the estimations have mostly addressed quantitative effects.
- Specific effects on the different EU Member States have not been considered in the present study. However, a few considerations on some possible differences in the national socio-economic effects can be already anticipated. On the one hand, some sectors like the automotive or the electronics and software ones will mainly have an impact on the countries where car manufacturing industries are located. Other heterogeneous effects concern for instance the freight transport sector, which might lead to a significant reorganisation of the European transport sector, given the fact that labour costs are a significant cost factor. On the other hand, sectors like telecommunication, insurance or maintenance and repair will affect EU Member States in a more homogeneous way.
- Comparing our estimations with the current state of the respective sectors, it is possible to note that the automotive sector, in spite of holding a prominent position in terms of VA, employment and GVA, will face lower impacts from CCAM than other sectors, like e.g. electronics and software.
- The most relevant economic effect has to be expected for the sector electronics and software. Considering the change of turnover of 180 billion euros, CCAM leads to a noteworthy increase of ca. 25% of the sector output (note this is to be interpreted as an additional turnover of electronics and software linked to AV sales in 2050 versus the total turnover of the electronics and software sector in 2015; also, to be noted that the sector turnover might suffer from some double counting as the same good might be counted in the turnover of several sub-sectors). However, the EU faces a significant competition in this sector, with relevant global players like Google, Apple or others.
- Even if concrete figures have not been presented, the sectors telecommunication, data services and digital media will benefit significantly from CCAM. Taken into account that these sectors will be influenced by the overall technological development (e.g. development of AI, deep learning, block chain, etc.) the sector could face a capacity problem. In addition, the need for important infrastructure investments is anticipated.
- Considering that we are at the beginning of a substantial mobility transformation, the effects from CCAM have to be compared to the already on-going shifts and cannot be isolated from other emerging trends like electrification of transport or MaaS.
- The increase in power sales due to CCAM should be seen in light of the decrease of other fuel expenditures (mainly oil products). The total of these fuel expenditures (electricity and non-electricity) increases from 290 billion euros in 2025 in the baseline to 300-350 billion euros in the CCAM scenarios, whereas by 2050 the impact of CCAM is mainly a decrease (from 280 billion euros in the baseline to 170-300 billion euros in the scenarios). The development of CCAM goes hand-in-hand with EVs and modifies the structure of fuel usage in cars. Therefore the power retailers emerge as winners and the oil product retailers as losers of this transition.
- In this challenging context, it is of paramount importance to highlight that the losses for the European economy can well exceed the range of potential benefits indicated. The international competition, mainly in the automotive and electronics and software sectors, could lead to a significant reduction of international EU market shares. This can only be avoided if the EU follows the worldwide CCAM trend and aims at becoming a leader of it. A political support is needed in respect of regulations (licences for AVs, insurance law), infrastructure development (roads and telecommunication) and education. Furthermore, the CCAM development goes hand in hand with the development of AI, big data and robotic. A loss of technological skills and market share can result in significant economic losses.

3.3 Dedicated review on employment and skills

3.3.1 Effects of AV technologies on employment

The concerns on job destruction by machines can be dated back to the first industrial revolution. Already in the 16th century in England and Ireland, a stocking-knitting machine worried Queen Elizabeth I about mass unemployment (Acemoglu and Robinson, 2012 as cited in ITF, 2017). Later in the early 1800s, in the Luddite Riots in England highly-skilled artisans protested by destroying looms and machinery against mass production that threatened their business (The White House, 2016; Autor, 2015; Mokyr et al., 2015). In the short run, the deployment of new efficient technologies had a negative impact on workers (The White House, 2016) but in the long run, technology advancements eventually led to higher job creation (ITF, 2017). This was due to so-called capitalization effect (Aghion and Howitt 1994 as cited in Arntz et al., 2016): an increase in productivity encourages more firms to enter the market and raise the number of job openings.

The technologies introduced in the 19th century could replicate routine and codifiable tasks that were at the time performed by highly skilled workers. Machines opened new job opportunities for low-skilled workers who did not previously have the capabilities to produce manufacturing goods and new profitable investments in productivity for the capital owners. This kind of innovation is called unskill-biased technical change as it favours the productivity of lower-skill workforce (The White House, 2016). However, in the 20th century, highly skilled workers with problem-solving skills, adaptability, and creativity acquired relevant skills to change occupation and gain comparative advantage with the machine aid (Autor, 2015). This process is called skill-biased technical change as it favours the productivity of higher-skilled workforce (The White House, 2016). With the advent of AVs, drivers are potentially at risk because the current driving task does not require major training and it is performed by workers with a lower educational background (ITF, 2017). Mechanics will, for example, progressively need more knowledge to be able to handle the repair of new, complex vehicles, lawyers will face higher labour competition with the reduction of traffic cases to solve but software engineers will face a lower competition due to a larger market for their capabilities. In all cases, the sectors will experience skill-biased technical change. The whole economy will experience higher productivity gains but it is important to individuate the European regions and segments of the European population who will be mostly affected by the autonomous driving technology so to act pre-emptively with welfare redistributing policies.

Predicting the effects on employment is however filled with conceptual challenges, most importantly, caused by the fact that labour market adjusts towards general equilibrium. Firms determine wages according to production costs and labour supply function they face. Profit-maximizing firms (Autor et al., 2003 as cited in Arntz et al., 2016) will not substitute workers whose net value is higher than the vehicles because it would not be profitable (Arntz et al., 2016). If AVs are too expensive or workers have a low reservation wage, employees will retain their work position in transport-intensive activities. Hence, the reasoning hereby presented is based on the current state of the world, as future prices are indeed too volatile and uncertain to estimate. In order to deliver the main message, we make the assumption that AVs will be commercially viable and potentially able to substitute for labour.

Christidis et al. (2014) provide a list of factors and gaps that are shaping the future transport labour market in Europe.

Productivity gains

AVs can replicate the same historical trend of the previous technological innovations. Most notably, they will increase firms' labour productivity on the hypothesis that higher investments in autonomous driving technology will drive a decline in its usage cost, following the so called Moore's law on the basis of which the cost of computing halves every second year (Saam et al., forthcoming 2018). The decline in technology's user cost and the labour substitution is expected to lead to higher labour productivity and lower production costs of goods. Then, these lower unit production costs allow firms the possibility to reduce output prices and to make higher profits (mark-ups), which results in higher disposable incomes within the society. A consequent increasing product demand thereby increases the demand for labour for their production (Arntz et al., 2016; Gregory et al., 2016). By way of example, Bessen (2015) examined employment and branch data in US retail banking after the introduction of 400,000 Automatic Teller Machines (ATMs) which were substituting for tasks previously done by human staff. He found that the operating and labour cost reductions encouraged banks to open more branches and total retail banking employment stayed steady (ITF, 2017).

According to Manyika et al. (2017), consumer income will be the largest source of job creation up to 2030 in the world economy. Gregory et al. (2016) estimated a labour demand model at the level of Europe (estimated at region level: NUTS-2 level of detail (126)) and found a decrease in labour demand of 9.6 million jobs as technologies substitute for labour in routine tasks. However, the price drop and a consequent increased product demand led to a net increase in total labour demand of 11.6 million jobs across Europe among the years 1999-2010 due to new technologies. Similarly, Saam et al. (forthcoming 2018) found in their study on the sectorial impact of digitisation of the economy that the annual change in labour market demand was positive in the ICT-producing sectors and ICT service sectors (NACE sectors C26 and C27, a positive effect of around 4%) in the period 2000-2021. On the contrary, the annual change in labour market demand between years 2000 and 2021 seemed to be negative in other sectors (with an effect lower than 0.5% though). The aggregate effect is close to neutral. In terms of Full-Time Equivalents (FTE), this study estimates a total job loss of 15 million FTE employees in the non-ICT sectors while 30 million jobs are estimated to be created in the ICT-related sectors (C26, C27 and J). Nevertheless, these results need to be considered with caution, given the fact that the observed employment change in sectors C26 and C27 is negative in all countries except China. The study covers 12 countries, of which nine are European (namely, Austria, Finland, France, Germany, Italy, Netherlands, Spain, Sweden and United Kingdom), and three non-European countries (US, China and Japan).

Graetz and Michaels (2015) also found that automation at the sector level increased both labour productivity and wages for workers in 17 countries (14 of which are European) over the period 1993-2007 including for transport equipment industry, where the authors actually found a greater effect. However, it had a negative but not significant effect on hours worked for low/middle skilled workers.

MaaS companies may reduce the monetary cost of commuting for people that could share a ride with other passengers and wouldn’t pay the price of ownership of the vehicle. Autonomous driving would reduce the non-monetary cost of driving. Already De Jong and Gunn (2001 as cited in Litman, 2017) estimated an elasticity for car trips with respect to time travelled for commuting in Europe ranging from -0.36 to -0.58 for the Netherlands, Belgium, and Italy confirming the value of -0.41 obtained from the literature. This means that a 10% increase in commuting time decreases the number of commuting trips made by car to 4.1%, which suggests a dislike for driving. Reducing the cost (both monetary and non-monetary) of commuting drives employee-employer joint surplus up. Firstly, it allows for a better job match: firms have broader geographical area where they can recruit from because workers are more willing to commute longer distances (Litman, 2018). Secondly, by increasing the quality of commuting, connected and automated mobility services decrease employees’ disutility from working and thus, increase their net utility. Employers can either set a lower nominal wage, becoming more profitable and therefore, allowing to hire more people (Arnzt et al., 2016) or potentially experience a productivity boost because employees’ time spent on other commitments decreases and the time available for work increases (Gibbons and Machin, 2006). Also, AVs would allow for a better job match, i.e., firms would have broader geographical area where they can recruit from because workers would be more willing to commute longer distances than at present (Litman, 2018).

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(126) An overview of NUTS-2 (Nomenclature des Unités Territoriales Statistiques) classification is available at: http://ec.europa.eu/eurostat/web/nuts/background (last accessed 9 April 2018).

Autonomous cars would then be more appealing for a larger segment of the population and would grant them a larger range of employment possibilities outside their geographical residence location.

Labour Supply (Education and Demographics)

Expectations play a significant role on labour supply. Information over labour market returns determine early career choices of younger people. Routine jobs are gradually offering lower salaries and conversely, abstract jobs are more rewarding. Because of this, younger generations invest in education and are sheering away from professions that are expected to be replaced by automation. ITF (2017) already found a stronger aging trend among truck drivers than among other occupations. Their baseline projections predict a drivers shortage in Europe (as also noted in Todd and Waters, 2018) that is however reversed to drivers surplus by the potential introduction of driverless technologies which drive the labour demand lower than labour supply. The authors estimate three different labour supply scenarios where new entrants in truck-driving profession are proportionally decreasing on expectations over driverless technology implementations. Because of this educational adjustment from expectations, deviations from equilibrium in the labour markets are most welfare damaging when unpredictable. As the level of automation increases, new tasks that ask for higher educational background and good learning capabilities are required from truck drivers. Truck manufacturer companies know it and are already investing in both research and development of technology and employees training (Salvetti, 2017) to ensure a profitable and efficient use of both human capital and technological factors. Potential rewards for workers increase and so will do job conditions. However, few will invest in relevant skills if the technological change is too abrupt because people will not be aware of these rewards at the time of their education investment. Currently, the truck-driving profession attracts a residual part of total labour supply (it holds a disadvantaged position on the average job search order) due to bad working conditions offered (Industry Today, 2013; Christidis et al., 2014). If this state persists for long and the technology pick-up causes a shock, the industry will be potentially short on qualified labour supply. This will put truck transport in the first places of their job search if the gap is accurately advertised. The problem is that most of the future truck drivers are aging and have a relative low level of education (Beede et al., 2017; Christidis et al., 2014; ITF, 2017) and the same happens to other on-the-job drivers (Beede et al., 2017). This leads to a shortage of qualified young people but if the implementation is gradual, future expectations will be more accurate and people will have the time to invest on their education accordingly. Firms are less willing to invest in aging and lower-educated workers because they have a shorter time frame to reap benefits of their training and because they are less motivated and capable of learning (Lallemand and Rycx, 2009). On this topic, the most effective training solution is contentious. Brynjolfsson and McAfee (2014 as cited in ITF, 2017) emphasise improving education in formal schooling while Ford (2015 as cited in ITF, 2017) advocates for a clever use of vocational training.

A Stanford report (Stone et al., 2016) states that education, re-training, and inventing new goods and services may mitigate the negative employment effects only in the short run. In the longer term, the labour market disruptions caused by the development of AI technology will increasingly require governments to evolve into efficient universal social services. The ITF (2017) also stresses the role of government intervention with two complementary strategies influencing the speed of uptake of driverless technology and ensuring adequate support is available to those displaced drivers.

On top of this, government can redistribute welfare gains to the damaged part of the society. Thanks to AVs it is possible to design solutions that grant greater transport efficiency (Litman, 2018) and thus, greater social welfare. A simulation done in Manhattan (Burns et al., 2013) using current taxi travel data, suggests for example the possibility of replacing the current fleet of 13,000 taxi with 9,000 self-driving cars at 12.5% of the current cost per mile.

Labour Demand (Task change and Labour productivity)

The occupations directly impacted by AVs can be summarized in four different categories *drivers*, *visitors*, *hosts*, and *teams* (see Table 41, based on Miller, J., 2015). The categories distinguish if driving is the primary or secondary activity in the current occupation and if automation would substitute or complement human work. Besides, workers whose occupation does not require driving (like mechanics) will likely change the way they perform their work (because they need to stay updated with the latest technological progress) so that they can retain their workplace as long as they acquire the necessary skills to deal with the advancements.

Table 41. Potential impacts of AVs on employment

	Substitute	**Complement**
Primary	*Driver*: The worker can add value to the business only through the driving activity in transit but none at destination. Example: Truck driver	*Hosts*: The worker may add additional value to the business in transit if relieved from the driving activity but does not add value at destination. Example: School bus drivers
Secondary	*Visitors*: The worker adds value to the business at the worksite destination but none in transit. Example: Pest control workers	*Teams*: The worker adds value to the business at the worksite destination but can potentially add value also in transit if relieved from the driving activity. Example: Emergency medical technicians

Source: Own elaborations based on Miller, J. (2015).

Technological advancements increasing labour productivity may enable fewer workers to do the job of the whole firm workforce differently for each category. It is however useful to remind that in general it is not clear how workers will re-qualify to this change of tasks in their occupations and which firms and how many of them will decide instead not to demand for labour support anymore (Beede et al., 2017; Center for Global Policy Solutions, 2017).

Drivers demand will be reduced ceteris paribus because their value added to the job is restricted only to their driving task. As soon as AVs are introduced, their presence would be regarded as unnecessary or excessively expensive.

Visitors and *Teams* are likely to face higher competition due to the labour supply coming from all workers that could not drive before (Miller, J., 2015). Similarly, even other low-skilled occupations could face heavier pressure on their wages due to an increased supply of similar, displaced *drivers* workers (The White House, 2016).

AV technology could leave *Hosts* and *Teams* time to focus on other job responsibilities, thus, boosting their productivity and wages. For example, salespeople who currently spend a considerable amount of time driving could find themselves able to do other work while a car drives them from place to place, or inspectors and appraisers could fill out paperwork while their car drives itself (The White House, 2016).

These effects are likely to cause income inequality and job polarization (Manyika et al., 2017), a trend that Europe is already experiencing (Goos et al., 2009; Goos et al., 2014). In the previous example, inspectors and appraisers could eat up secretaries' comparative advantage and eventually displace the secretaries by performing administrative tasks while driving. Consequently, AVs diminish the comparative advantage of drivers, causing a downwards pressure on low-skilled wages and pushing upwards the wages of high-skilled workers. Consider for example the field sales account job, if that worker is paid three days a week to drive to customers for deal discussions and two days to answer emails and keep sales accounting, then the employer can pay the worker only three days a week because he can do the latter task while the car drives itself to destination. A small team of software engineers will work less than drivers to deliver the same tasks but earn the profit share previously destined by a large number of freight drivers. Firms charging optimal wages take into account the disutility from working and are able to design a pay structure that increases both firm and worker's profit.

As previously mentioned, the prospects are not necessarily dismal. Autor et al. (2003 as cited in Goos et al., 2009) claim that even though technological progress replaces "routine" tasks, motor vehicles operators are already performing complementary and hardly automatable activities (Beede et al., 2017; Center for Global Policy Solutions, 2017) that limit the pure labour substitution but likely consign either the driver or the technology to a secondary role instead (Center for Global Policy Solutions, 2017). The President of the Information Technology and Innovation Foundation Rob Atkinson said: "You're not going to have a robot that can sort of get out of the back of the truck and unload things and all that stuff, or back the truck up into a little zone" (Gamio et al., 2017) but other logistic managers of the same company can potentially both move objects and manage the supply chain while the truck is driving alone. Many other researchers, vehicle manufacturers and AI experts, claim that reaching the level of full automation is extremely difficult to achieve and not likely to happen in the short-medium period (Litman, 2018). The impact of driverless cars in terms of workers adjustment is more likely to affect the task change within occupations (Arnzt et al., 2016; Manyika et al., 2017). Many studies assume that a large share of the current occupations will be substituted completely. Nonetheless, there are different estimations in the extension of the labour substitution effect: the study of Frey and Osborne (2017) finds that 47% of jobs in US are at risk (Bowles, 2014 applies the same methodology on the EU and finds 54% of jobs are at risk) while Arntz et al. (2016) find that only 9% of jobs in OECD countries are at risk instead. The former estimates the share of jobs threatened by automation based on experts' estimation of the threatened occupations. The latter uses the same methodology but with a task-based approach, so based on the same experts predictions but estimating the degree of their automation-risk predictions on the proportion of automatable task within that occupation.

Typically no analysis has focused on new jobs that can emerge from the advent of AVs (Arntz et al., 2016; Beede et al., 2017; The White House, 2016; Miller, J., 2015) but the recent experience can provide some indications. Lin (2011) found that most new US jobs in the 1980-2000 were created in new technologies or in new types of personal services. The website Level 10 (Kaviraj, 2017) provides a list of new occupations, mostly ICT related, originating from AVs development. While new jobs are skewed towards high-education services (ITF, 2017) the final quantities of jobs created and destroyed for both education categories is uncertain.

Consumer preferences play a role in labour demand too. Internet should have, for instance, replaced many service jobs like the travel agent because it can provide the same service but digitally. Instead, it created duplicates of the same service (Gordon, 2000) because of some customers who prefer it to be delivered physically. Similarly, there will be a demand for non-automated vehicles because part of the retail customers have preferences over the driving activity. Furthermore, non-automated vehicles are necessary to perform non-conventional driving tasks (e.g. ambulances, police cars or vehicles for military purposes). The market will offer different versions (automated and not) of the same vehicle. Following this line of thinking, there are some jobs that are necessary as long as there exists at least one car which is not self-driving (e.g. traffic policemen) and occupations that include at least one strictly required task that is not possible to be automated (e.g. school bus drivers need also to care for children) or for which customers have preferences for human labour instead (e.g. luxury limousine service) will be re-dimensioned rather than eliminated. We need then to take into consideration the existence of an employment lower bound which is represented in our scenario, where some employers would still not choose to own an AV even if available due to different preferences (Center for Global Policy Solutions, 2017).

Jobs endangered by CAV technologies

The White House (2016) estimates that 2.2 to 3.1 million currently existing part-time and full-time US jobs are endangered by autonomous driving technology.

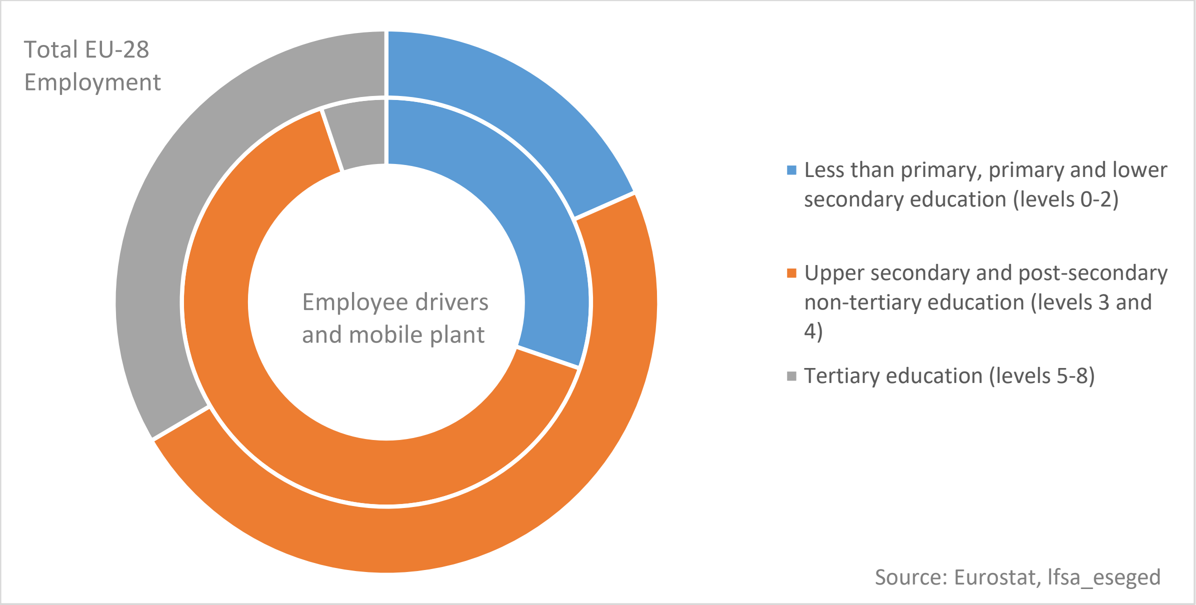
A 2015 analysis based on the UK concluded that CAVs could add 25,000 jobs within the automotive industry and create additional jobs in other sectors of the economy (e.g. telecommunication or digital media) estimated at 320,000 new jobs (Leech et al., 2015). This effect will likely be similar in proportion for other countries with higher human capital endowment and with similar trade intensity in the EU, like Germany.

Our own analysis on employment effects linked to CCAM are presented next. Occupational data follows the International Standard Classification of Occupations ISCO-08 (International Labour Organization, 2012). The data for economic sectors follows the Statistical Classification of Economic Activities in the European Community (NACE Rev. 2). To isolate the employee drivers we use the relevant category in the European Socio-Economic Groups (EseG) ([127]). The data for education follows the International Standard Classification of Education - ISCED 2011 (UNESCO Institute for Statistics, 2012) instead.

Employee drivers and mobile plant operators amount to almost 8 million, or 3.6 of the total EU-28 employment in 2015.

The following graph (Figure 16) compares the educational attainment distribution of employee drivers and mobile plant operators with the one of the entire European Union (28 countries) in 2015.

Figure 16. Education breakdown comparison EU-28 (2015)



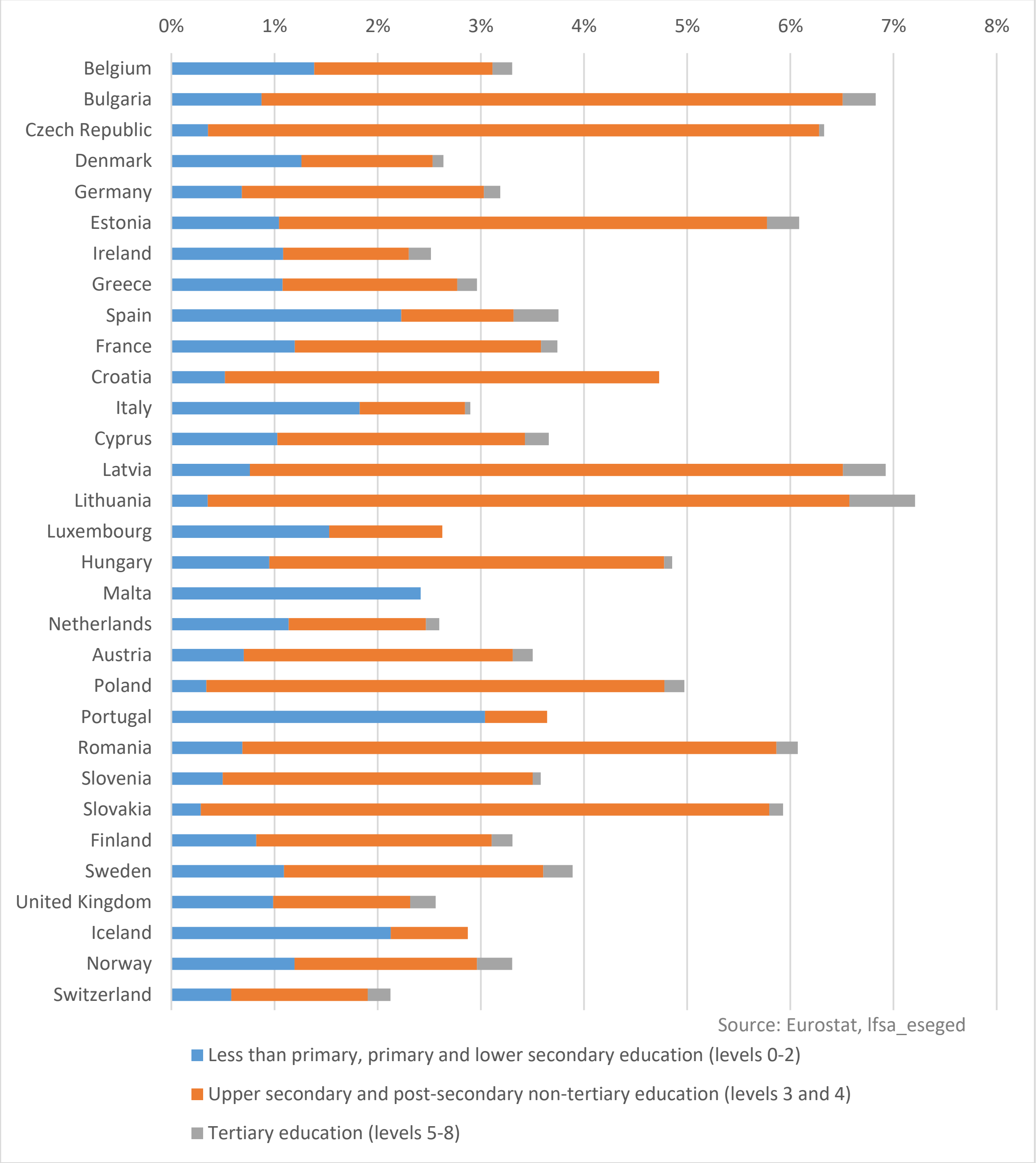
Source: Own elaborations (based on Eurostat LFS).

A 30% of the workers in the category possess a low level of education (ISCED <2: less than lower secondary education) as opposed to the 18% figure in the total EU employment. Only 5% have a high level of education (ISCED >4: tertiary education), much lower than the amount in the EU (i.e. 33%). This comparison highlights a fragility of the sector to innovation, as lower educated workers might not have on average the proper mind-set to adjust to technology or work practices changes.

([127]) ESeG is a derived classification which allows the grouping of individuals with similar economic, social and cultural characteristics throughout the European Union. Definition available at: http://ec.europa.eu/eurostat/statistics-explained/index.php?title=EU_labour_force_survey_-_methodology&oldid=327391#European_Socio-economic_Groups_.28ESeG.29 (last accessed 6 April 2018).

The heterogeneous education distribution across countries is depicted below in Figure 17.

Figure 17. Education breakdown of employee drivers and mobile plant operators in percentage of total employment EU-28 (2015)



Source: Own elaborations (based on Eurostat LFS, ([128])).

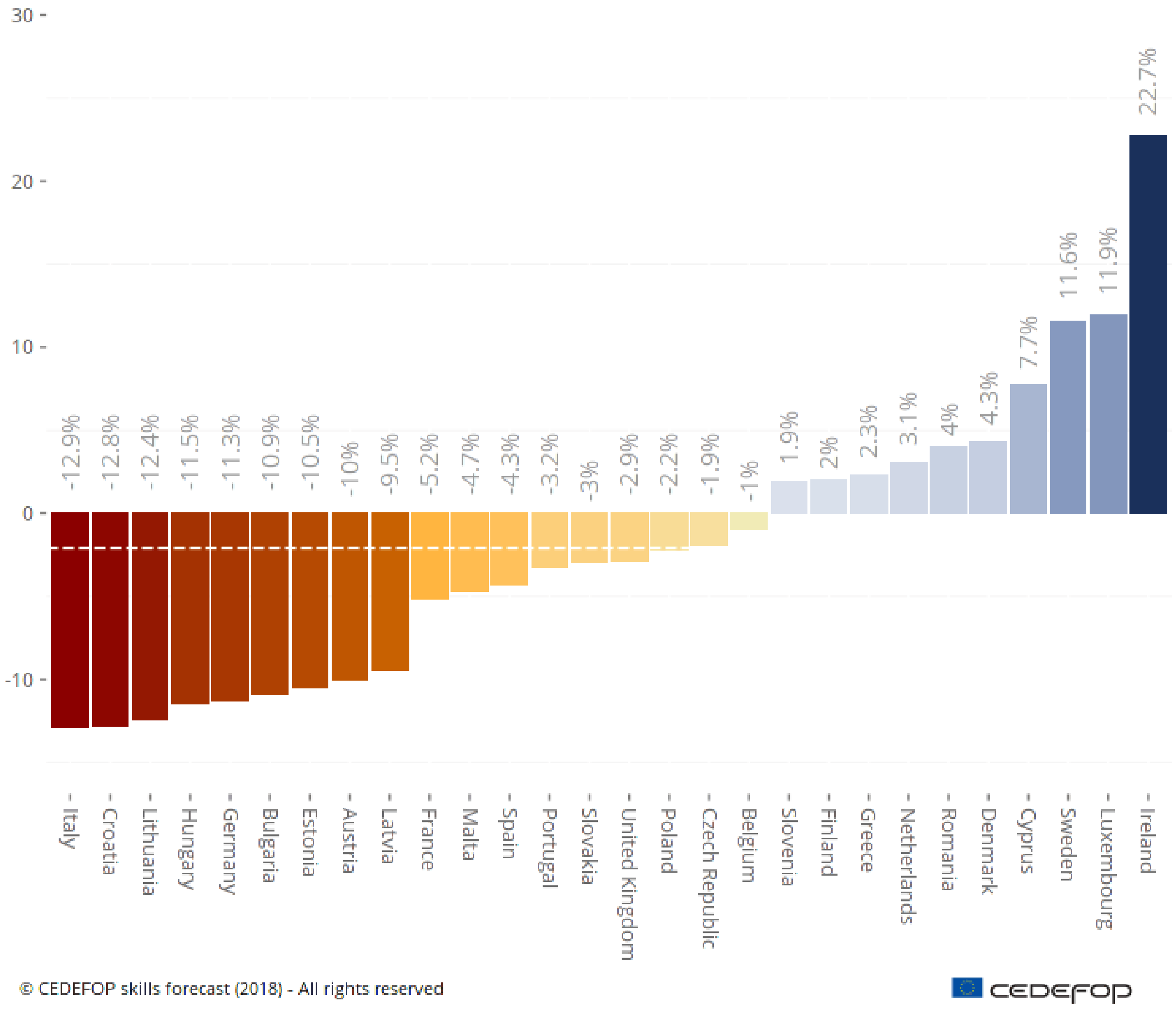
Eastern European countries such as Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Romania and Slovakia have a large share of drivers and mobile plant operators, which makes them more vulnerable in case of complete substitution of labour. On the other hand, it must be also taken into account the economic or borrowing possibilities of the countries to invest on the technology.

([128]) n.b. Secondary education data is not available in Eurostat for Malta and Tertiary education data from Croatia, Luxembourg, Malta and Portugal is also not available in Eurostat.

The low educational share of drivers is highest in southern European countries such as Portugal, Italy, and Spain, where it respectively accounts for 82.7%, 62.9%, and 59.3% of the entire occupations in those countries. Notably, also Iceland and Denmark present a large share of lower educated workers with 68.5% and 47.3%. This may represent a problem if current drivers would need requalification to perform other jobs in the industry.

According to CEDEFOP (2016), employment in the land transport sector is supposed to shrink by around 9% by 2025 but two fifths of those to whom the labour substitution effect may concern will continue to work in the transport and storage sector ([129]). Specifically, 12.5% will be employed in the wholesale and retail, 8% in warehouse and postal services and construction and 3.5% in agriculture. Employment for drivers and vehicle operators in EU is projected to shrink by 4.6% within the same period. The heterogeneous growth across member states is depicted below in Figure 18.

Figure 18. Employment growth rate (%) of drivers and vehicle operators in the 2015-2025 period



Source: CEDEFOP ([130]) (Copyright © CEDEFOP 1996-2018).

([129]) CEDEFOP Skills Panorama Drivers & vehicle operators website, available at: http://skillspanorama.cedefop.europa.eu/en/occupations/drivers-vehicle-operators (last accessed 5 April 2018).

([130]) CEDEFOP Employment trends 2016 Skills forecast website, specific data available at: http://www.cedefop.europa.eu/en/publications-and-resources/data-visualisations/employment-trends?locale=EN&dataSource=SFME&media=png&width=740&entitle=false&question=00.+GrowthRateEmployment&plot=euBars&countryGroup=linear&subset=OccupationsWITHIN08Plantandmachineoperatorsand

However, the usage of broad sectors and occupations definitions make it difficult to separate the data of road transport vehicles from vehicles used on railroads and those used in specialized work environments such as forklifts and tractors, which will have a different adoption cost, regulations and implementation process (Beede et al., 2017).

The category drivers and vehicle operators (ISCO code: 83) includes also locomotive engine drivers and related workers (831), mobile plant operators (834), and ships' deck crews and related workers (835). Thus, making the anaylsis not perfectly applicable to road drivers. Similarly, other surveys, such as O*NET in the US, lack of precise information about the vehicle used (Miller, J., 2015).

Beede et al. (2017) isolate those occupations that use motor vehicles as tools, use more enclosed vehicles than open and place high importance on the usage of operating vehicles or equipment when asked in the survey.

Similarly, the category land transport and transport via pipelines (NACE 49) includes also passenger rail transport (491), freight rail transport (492), and transport via pipeline (495).

In order to have an indication of the correct number of drivers in the EU economy, we proceed with a jobs-based approach (131). Jobs are defined as occupations in sectors, therefore, we crossed the workers occupational status of interest with the sector of interest at division level in 2012 only for EU-15 due to low availability of data.

By doing so, Eurofound (2016) ranks drivers and mobile plant operators (ISCO 83) working in land transport and transport via pipelines (NACE 49) as the seventh job in Europe with the largest number of workers with 3.85 million (Eurofound, 2016); the figure correspond to 1.76% of the total EU-28 employment in 2015. CEDEFOP counts instead almost 5 million people working as drivers and vehicle operators (which includes also industrial vehicles and trains) in the transport and storage sector in EU in 2016 (132), which in total count as 2.21% of the total EU-28 workforce. This approach highlights the improvement benefits of this approach, as the figures are much different to the number of 8 million workers count of Employee drivers and mobile plant operators in 2015 which includes the drivers in all sectors.

The detailed occupations of interest which will be affected the most by AVs will probably be:

— 8322 Car, taxi and van drivers, 8331 Bus and tram drivers, and 8332 Heavy truck and lorry drivers;

— 7231 Motor vehicle mechanics and repairers.

The relevant sectors we are interested in are instead:

— H49.31 Urban and suburban passenger land transport, H49.32 Taxi operation, H49.39 Other passenger land transport, H49.41 Freight transport by road;

— G45.20 Maintenance and repair of motor vehicles.

Thus, specifically, the ISCO occupations and NACE sectors we have focused on are:

— ISCO 83: Drivers and mobile plant operators, which amounts approximately to 3.7% of total employment in EU-15 in 2012.

— ISCO 72: Metal, machinery and related trades, which amounts approximately to 3.5% of total employment in EU-15 in 2012.

— NACE 49: Land transport and transport via pipelines, which amounts approximately to 2.4% of total employment in EU-15 in 2012.

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assemblers&subsetValue=08PlantandmachineoperatorsandassemblersWITHIN83Driversandmobileplantoperators&year=2015&yearTo=2025&onlyEU=1 (last accessed 29 April 2018).

(131) The exact methodology can be found in Fernández-Macías et al. (2016).

(132) Skills Panorama Drivers & vehicle operators website, see footnote (129).

— NACE 45: Wholesale, retail and repair of motor vehicles, which amounts approximately to 1.8% of total employment in EU-15 in 2012.

The reasoning behind is that drivers are most endangered by labour substitution whereas mechanics and maintenance workers will require major training to continue performing their jobs.

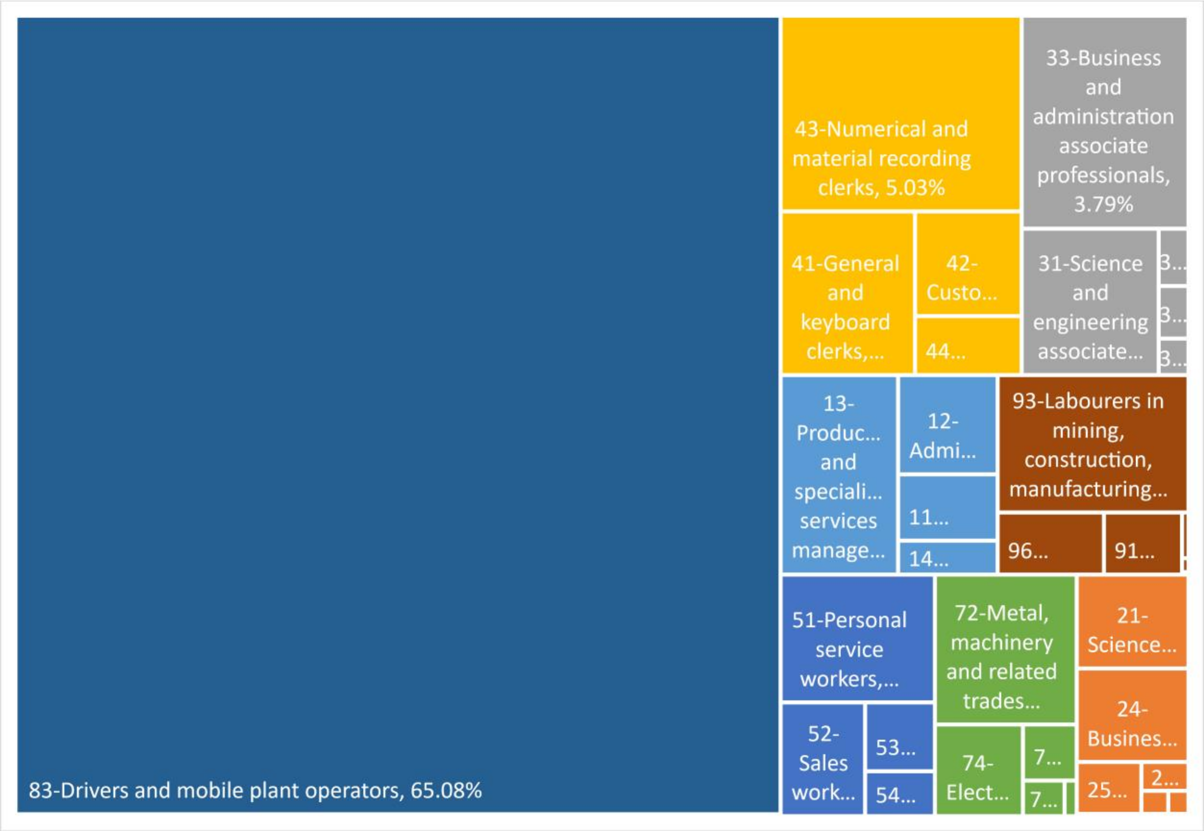
Analysing the two sectors, we found a very significant concentration of specific occupations, as explained next.

The following graphs (Figure 19 and Figure 20) show the occupation (ISCO-08) distribution within sectors (NACE Rev. 2). For reference, ISCO-08 classification of occupations is specified in Table 42 below.

In Figure 19, 65% of people employed in the land transport sector (NACE 49) are in drivers and mobile plant operators occupation (ISCO 83) and amount to approximately 1.5% of total EU-15 employment in 2012. Another 5% are numerical and material recording clerks (ISCO 43), 3.7% are business and administration professionals (ISCO 33) while labourers (ISCO 93), specialized managers (ISCO 13) or general clerks (ISCO 41) each accounts for 2% of the occupations within the sector.

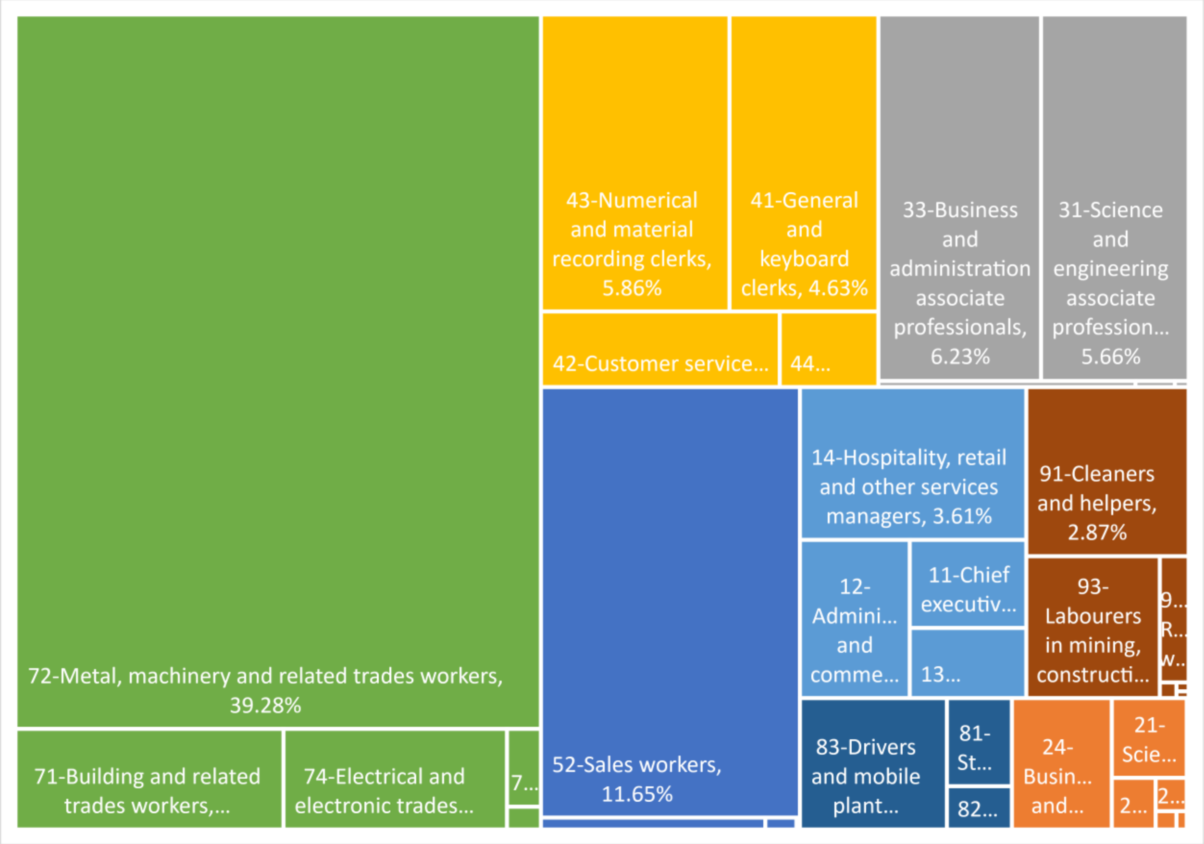
As shown in Figure 20, almost 40% of people employed in the retail and repair sector (NACE 45) are in metal, machinery and related trades occupation (ISCO 72) and amount to 0.7% of total EU-15 employment in 2012. An 11.6% of people are in sales workers occupation (ISCO 52) and a big part is made by support administrative jobs, more than 12% in form of clerical occupations (ISCO 41 to 44), and by some managerial and professional jobs, 6.2% in business and administration (ISCO 33), and 5.6% engineering associate (ISCO 31). According to 2012 data, the presence of ICT professionals (ISCO 25) is scarce in both sectors (NACE 45 and 49), respectively, 0.3% and 0.2%.

Figure 19. Distribution of land transport (NACE 49) in occupations (ISCO-08) EU-15 (2012)



Source: Own elaborations.

Figure 20. Distribution of retail and repair of vehicles (NACE 45) in occupations (ISCO-08) EU-15 (2012)



Source: Own elaborations.

Table 42. Occupation classification (ISCO-08)

Occupation classification (ISCO-08)	
Legislators, senior officials and managers	
11	Chief executives, senior officials and legislators
12	Administrative and commercial managers
13	Production and specialised services managers
14	Hospitality, retail and other services managers
Professionals	
21	Science and engineering professionals
22	Health professionals
23	Teaching professionals
24	Business and administration professionals
25	Information and communications technology professionals
26	Legal, social and cultural professionals
Technicians and associate professionals	
31	Science and engineering associate professionals
32	Health associate professionals
33	Business and administration associate professionals
34	Legal, social, cultural and related associate professionals

Occupation classification (ISCO-08)	
35	Information and communications technicians
Clerks	
41	General and keyboard clerks
42	Customer services clerks
43	Numerical and material recording clerks
44	Other clerical support workers
Service workers and shop and market sales workers	
51	Personal service workers
52	Sales workers
53	Personal care workers
54	Protective services workers
Skilled agricultural and fishery workers	
61	Market-oriented skilled agricultural workers
62	Market-oriented skilled forestry, fishery and hunting workers
Craft and related trades workers	
71	Building and related trades workers, excluding electricians
72	Metal, machinery and related trades workers
73	Handicraft and printing workers
74	Electrical and electronic trades workers
75	Food processing, wood, garment and related trades workers
Plant and machine operators and assemblers	
81	Stationary plant and machine operators
82	Assemblers
83	Drivers and mobile plant operators
Elementary occupations	
91	Cleaners and helpers
92	Agricultural, forestry and fishery labourers
93	Labourers in mining, construction, manufacturing and transport
94	Food preparation assistants
95	Street and related sales and service workers
96	Refuse workers and other elementary workers

Source: International Labour Organization (2012).

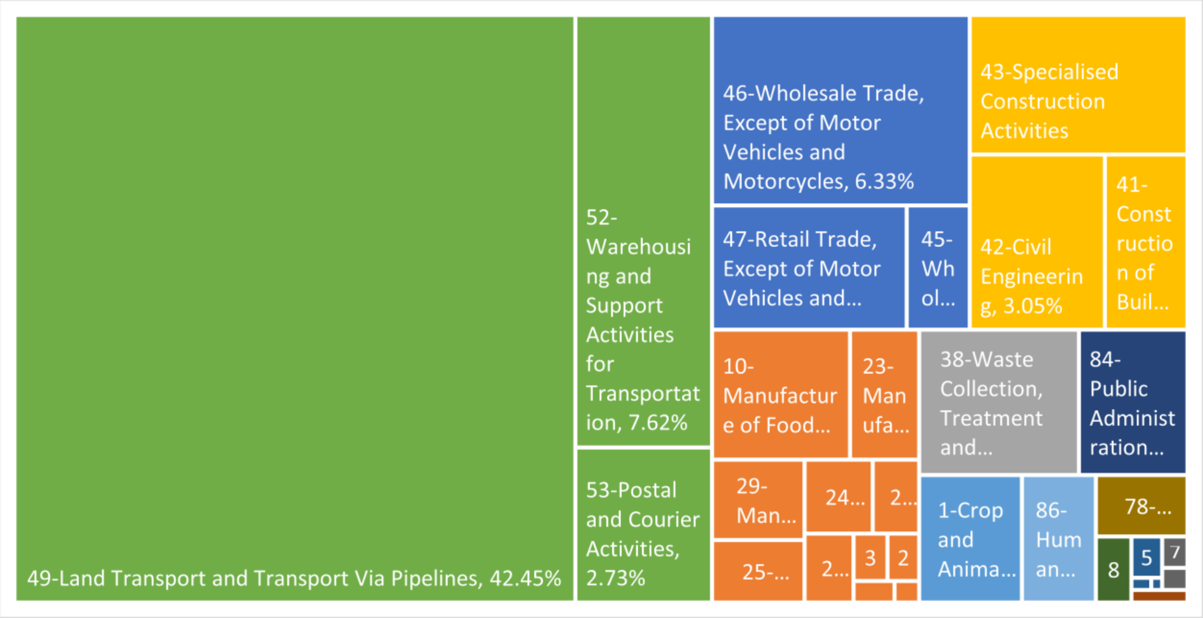
The following graphs (Figure 21, Figure 22 and Figure 23) show the sector (NACE Rev. 2) distribution within occupations (ISCO-08). For reference, a list of NACE Rev. 2 classification of economic activities is given in Table 43.

As shown in Figure 21, a 42.4% of drivers and mobile plant operators (ISCO 83) work in the land transport sector (NACE 49). Therefore, there are many drivers working in other different sectors, such as warehousing and support (NACE 52) with 7.6%, wholesale trade (NACE 46) with 6.3%, construction (NACE 43) with 3.9%, or retail trade (NACE 47) with 3.1%.

In Figure 22, it can be observed that metal and machinery trade workers (ISCO 72) are even more widespread across different sectors. Manufacturing sub-sectors i.e. 25 to 29 aggregately count for more than 40% of the sector shares while 20% are in Wholesale and retail trade and repair of motor vehicles and motorcycles (NACE 45). This category is then clearly broader than just car repair workers and results based on this occupation must be taken with care.

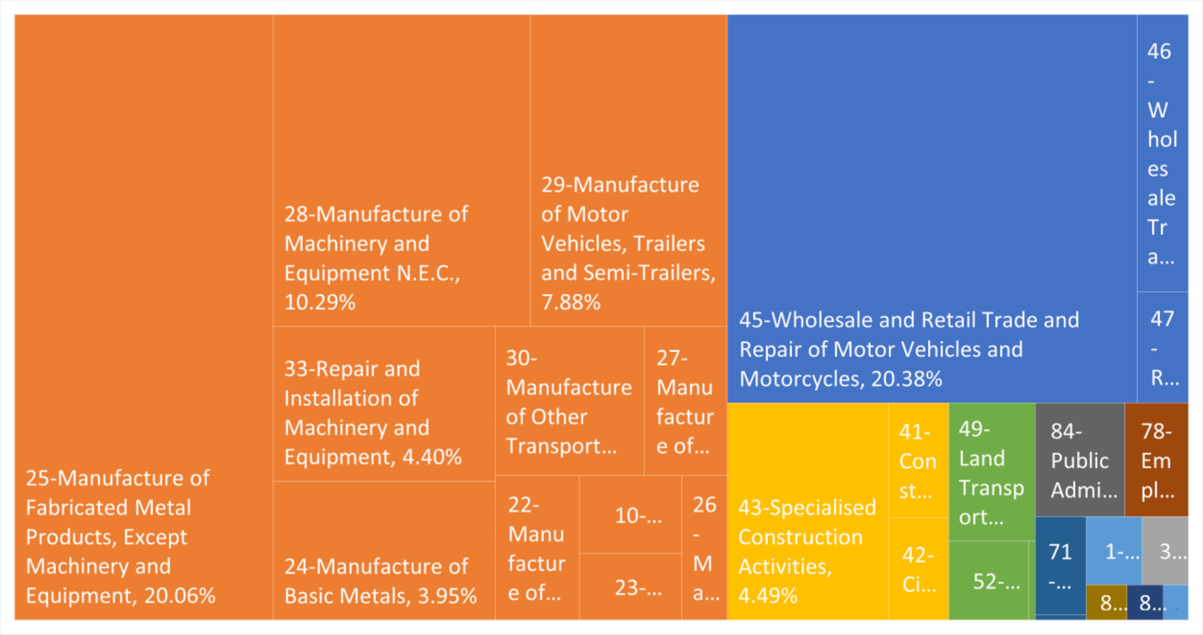
The share of ICT professional amount to 0.52% in land transport (NACE 49) and 0.26% in wholesale and retail trade and repair of motor vehicles and motorcycles (NACE 45) sector (see Figure 23). This highlights the low current presence of personnel able to understand and control this new technology and also suggests the current lack of ICT usage in both sectors.

Figure 21. Distribution of drivers and mobile plant operators (ISCO 83) in sectors (NACE Rev. 2) EU-15 (2012)



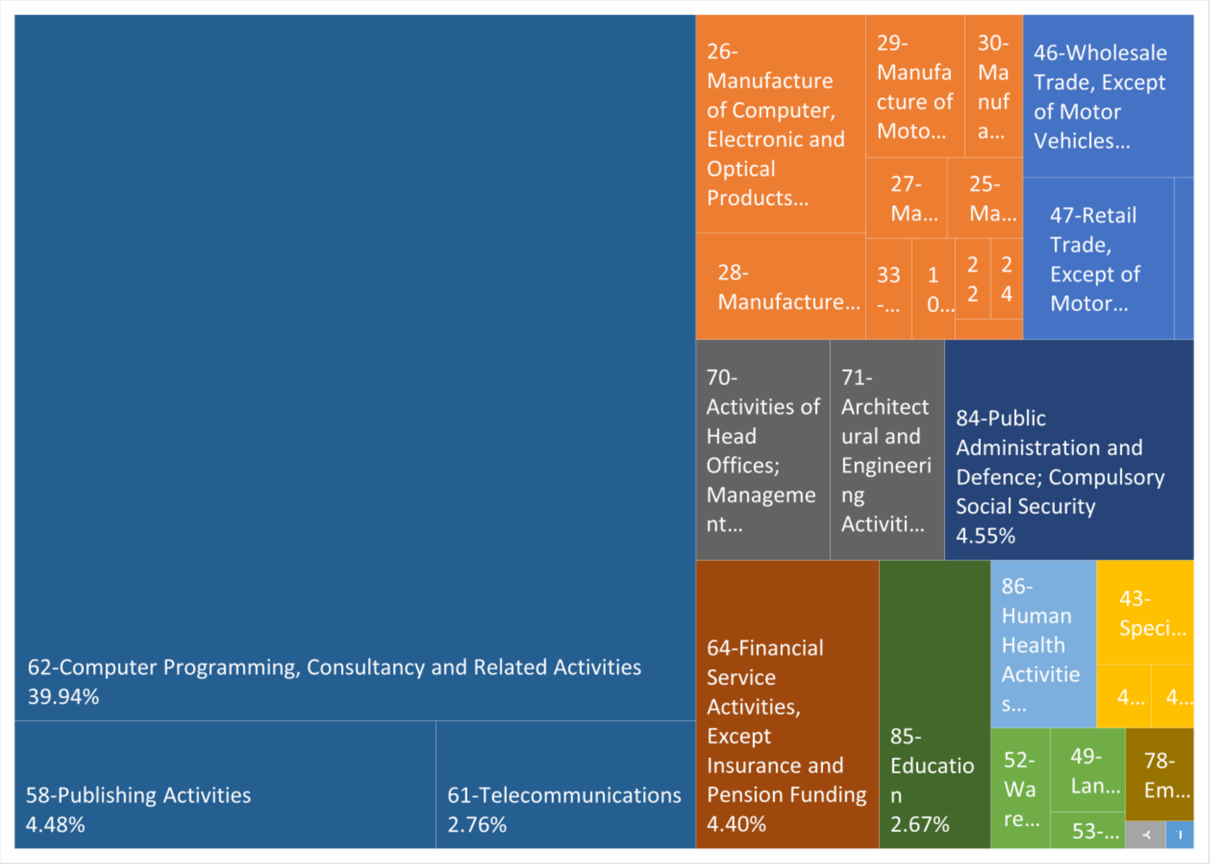
Source: Own elaborations.

Figure 22. Distribution of metal and machinery trades (ISCO 72) in sectors (NACE Rev. 2) EU-15 (2012)



Source: Own elaborations.

Figure 23. Distribution of ICT professionals (ISCO 25) in sectors (NACE Rev. 2) EU-15 (2012)



Source: Own elaborations.

Table 43. Economic activities classification (NACE Rev. 2)

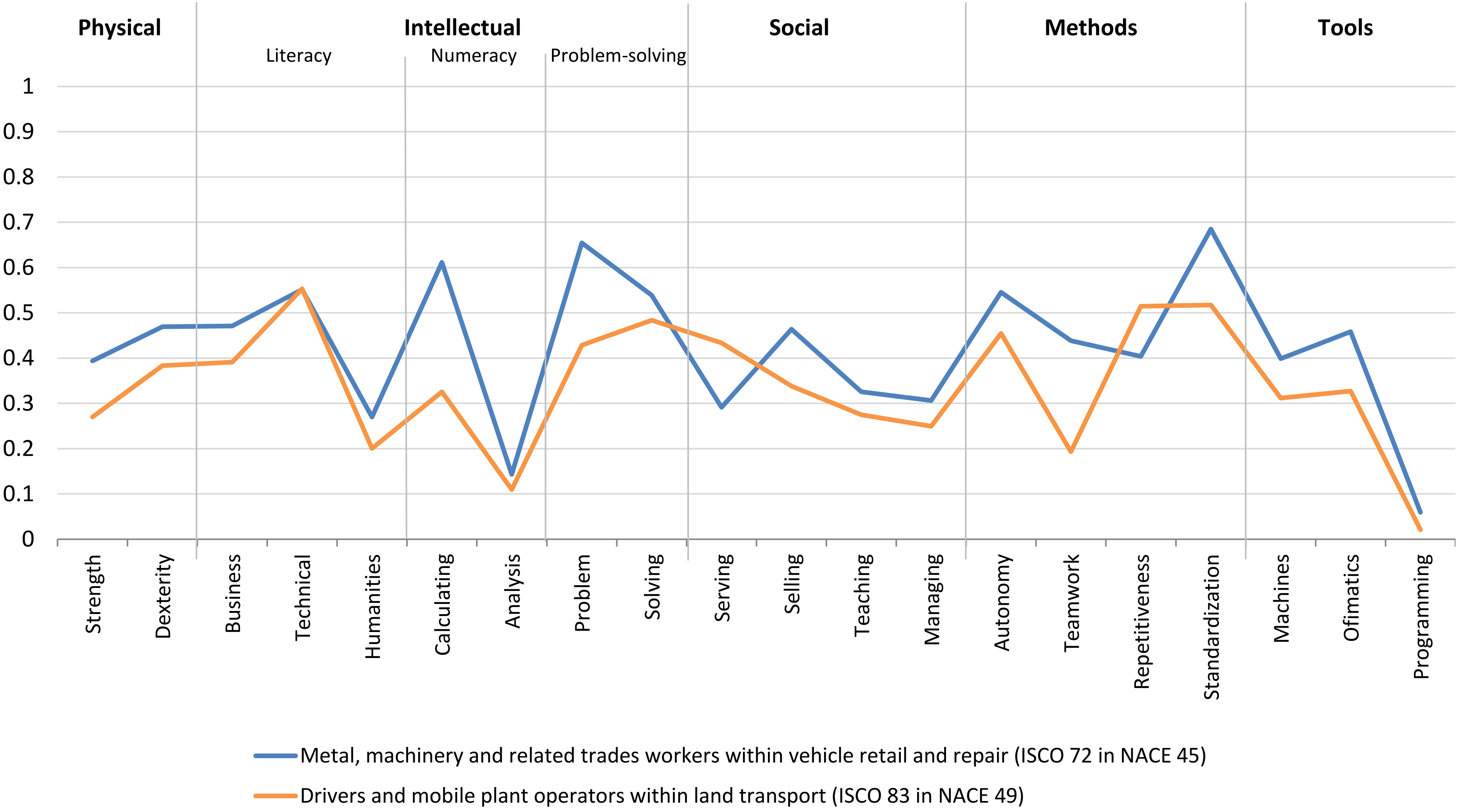
Economic activities classification (NACE Rev.2)	
Agriculture, forestry and fishing	
1	Crop and Animal Production, Hunting and Related Service Activities
Manufacturing	
10	Manufacture of Food Products
22	Manufacture of Rubber and Plastic Products
23	Manufacture of Other Non-Metallic Mineral Products
24	Manufacture of Basic Metals
25	Manufacture of Fabricated Metal Products, Except Machinery and Equipment
26	Manufacture of Computer, Electronic and Optical Products
27	Manufacture of Electrical Equipment
28	Manufacture of Machinery and Equipment N.E.C.
29	Manufacture of Motor Vehicles, Trailers and Semi-Trailers
30	Manufacture of Other Transport Equipment
33	Repair and Installation of Machinery and Equipment
Water supply; sewerage, waste management and remediation activities	
38	Waste Collection, Treatment and Disposal Activities; Materials Recovery
Construction	

Economic activities classification (NACE Rev.2)	
41	Construction of Buildings
42	Civil Engineering
43	Specialised Construction Activities
Wholesale and retail trade; repair of motor vehicles and motorcycles	
45	Wholesale and Retail Trade and Repair of Motor Vehicles and Motorcycles
46	Wholesale Trade, Except of Motor Vehicles and Motorcycles
47	Retail Trade, Except of Motor Vehicles and Motorcycles
Transportation and storage	
49	Land Transport and Transport Via Pipelines
52	Warehousing and Support Activities for Transportation
53	Postal and Courier Activities
Information and communication	
58	Publishing Activities
61	Telecommunications
62	Computer Programming, Consultancy and Related Activities
Financial and insurance activities	
64	Financial Service Activities, Except Insurance and Pension Funding
Professional, scientific and technical activities	
70	Activities of Head Offices; Management Consultancy Activities
71	Architectural and Engineering Activities; Technical Testing and Analysis
Administrative and support service activities	
78	Employment Activities
Public administration and defence; compulsory social security	
84	Public Administration and Defence; Compulsory Social Security
Education	
85	Education
Human health and social work activities	
86	Human Health Activities

Source: Eurostat (2008).

If the future occupations in driving and vehicle maintenance will change the task structure, it is useful to identify the skillset required to master the new job. The following graph (Figure 24) plots the skills level of both occupations.

Figure 24. Skill levels in ISCO 72 and ISCO 83 occupations



Source: Own elaborations.

The work of drivers, represented with orange line, generally involves limited information processing tasks if compared to other occupations. The repetitiveness of the job is high and the teamwork capabilities are low. This might be a problem if managing a fleet of vehicles will be the responsibility of an entire group or if the new logistics of AVs will require mind flexibility. However, technical literacy tasks is moderately high and this might help drivers in building knowledge upon this skill.

Vehicle mechanics and repairers, represented with a black line, have slightly more physical tasks, but also more numeracy, problem-solving, teamwork and standardization.

Both occupations have low levels of social tasks and relatively low levels of ICT use that could make them struggle finding another job in the future labour market demand across all sectors.

Concerns on inequality

The major danger we incur is consolidating the rising economic inequality trend in Europe (Autor, 2015; Brynjolfsson and McAfee, 2014; The White House, 2016; ITF, 2017; Mokyr et al., 2015). The returns on high skilled labour increases over the lower skilled counterpart, as the former is able to generate more value added for firms because they need an even better training to either design, repair the vehicles and working while commuting. The effect on the aggregate society is contentious because housing prices and transport costs decline due to cheaper and more efficient transport (Moavenzadeh, 2016). This may allow low-income households to save a large share of their expenses. Return to capital also increases but firms necessitate a high initial investment cost to buy expensive AVs and hire qualified staff together with a substantial trade volume so to make this investment paying out. This necessarily will put higher pressure on small enterprises which will face competitive disadvantages to bigger competitors. The effect on the number of firms present in the market is uncertain but policymakers can expect it to decrease in the short-medium term. The lack of employers reduce employees bargaining power because the labour market is less competitive for the formers, allowing them to charge lower wages. The lower-skilled workers will be impacted the most, as their market is more competitive.

The decrease in transport cost may also have a redistribution effect on employment across European countries. There are regions where production input factors might be less expensive (i.e. lower tax rate and lower wages) but with higher contracting and transport costs for firms that want to offshore. Such regions suffer from a market access penalty on their sales due to their geographical distance to bigger markets such as western-northern Europe which will be reduced by the implementation of AVs which can cut costs and time of transport. The implementation will increase Southern and Eastern Europe economic competitiveness, which results in higher salaries and levels of employment. European industries intensive in routine tasks have already seen a larger decline in their service costs over the period 1993-2010, they gained competitiveness due to labour-saving technologies and faced an increased product demand (Goos et al., 2014).

Firms will now have higher tendency to relocate factories in those regions where production costs are lower. Offshoring represented for German and Austrian firms respectively almost 47% and 17% of foreign direct investments in Eastern Europe during the period 1990-2001 (Marin, 2006). In particular, 38% of European firms who back-shored in their home country reported in 2012 they did it because of transport costs (Dachs and Zanker, 2015) and also Marin (2006) found a negative distance effect on intrafirm trade between Eastern Europe and Germany which penalizes relocating production activities but found no clear evidence for Austria.

It must be taken into account that EU countries endowed with lower human capital are endangered by the rising production automation trend for some firms, especially in the sector of manufacturing. Under this consideration, the cost savings in cheaper labour are likely not to be substantial if most of the firms off-shored do not require much labour input in the first place due to predominance of autonomous production. Firstly, off-shoring becomes less profitable even after accounting for risks and secondly, entrepreneurs and high-skilled workforce will reap all the benefits from this investments.

The resulting inequality will increase within countries but should decrease across countries (see Olsen, 2006 for a review on the topic and Herzer and Nunnenkamp, 2011). On one hand, offshoring harms the low percentile (lower skilled segment) of the richer countries population for the classical concept of factor price equalization (unskilled-non-differentiable labour price tends to equilibrium in all countries). Many manufacturing firms off-shore in countries where labour is cheap. This way, low skilled wages are pressured downward but the rewards for capital-owners increase since capital can be moved where it makes more profitable for them. On the other hand, Foreign Direct Investments (FDIs) make firms within a country to get to a critical mass enough for them to be globally competitive and bring profits in the country to be taxed and redistributed. Evidence from Germany also suggest firms are more likely to outsource rather than offshore if the production is capital-intensive, if transport cost are higher and R&D activities lower (Marin, 2006) so that more profits will be retained in the host countries for firms of these characteristics. If companies devote greater attention to production quality with tighter production control, they will instead locate to higher wages countries where human capital is possibly higher to offset the labour cost. Distance to markets grants firms a geographical market power: inefficient firms can charge lower price than efficient competitors because of the lower transport costs they face when they sell products in nearby marketplaces. This power prevents them from exiting the market (Brynjolfsson and McAfee, 2014) and leads to inefficient factor utilization. Therefore, AVs can bring fiercer competition in all countries and thus increase the whole EU productivity. While the European aggregate employment balance will be positive (not in driving-related activities, where the conclusions are uncertain instead), the levels of employment differ in individual countries because it favours highly skilled labour in countries with higher human capital dependence and lower skilled labour in countries where they are less human capital dependent.

Some think there will be tendency for city to segregate higher income people in extra-urban areas in larger houses (McLaughlin, 2017). The time cost paid by people commuting to work by car is the impossibility of performing any other activity. Therefore, autonomous cars advantage white-collar workers who perform knowledge work that can be performed while enjoying the ride and have higher opportunity cost because they earn more. Cities will have to expand in the extra-urban area if they wanted to provide larger accommodation for high income people which will be segregated.

A detailed analysis by sector is provided next.

Automotive (vehicle manufacturing and distribution)

In the ranking of most important changes upcoming in the automotive sector skills demand, European Automotive Skills Council (EASC) partners placed automation at the fourth place, below advanced manufacturing, advanced materials knowledge, and understanding of consumers preferences (European Sector Skills Council, 2016). Additionally, EASC partners proposed a number of occupations that are emerging to reflect the changes taking place in the automotive sector.

Currently manufacture of motor vehicles accounts for around 3.1 million jobs and 2.2 million jobs in sales.

CEDEFOP (2014) estimates that 213,000 new high-skilled jobs will be created from 2014 to 2025 in R&D, design and senior roles in the manufacturing process.

Employment in the sector is predicted to grow by 3.2% to 2025, roughly equivalent to the economy as a whole (see Table 1). Taking into account of a substantial need to replace employees leaving the sector due to retirement or for other reasons, an estimated 888,000 automotive jobs will need to be filled from 2013 to 2025 which counts as 3.2% growth per year.

The forecasts for the vehicle manufacturing sector vary significantly by country. The largest expansion in automotive employment is expected in Romania (an additional 48,040 jobs, representing a 38% increase in sector employment by 2025) and the United Kingdom (an additional 33,050 jobs, representing a 25.8% increase). Other countries anticipated to have an above-average employment growth include Finland, Spain and Hungary. The small Latvian automotive sector is also expected to grow considerably. Germany dominates automotive employment in the EU. Its 850,650 automotive workers in 2013 represented 37.9% of the total automotive industry in the EU. While Germany is only anticipated to have a small net increase in the number of automotive jobs (1.8%), this still represents an additional 15,160 jobs. Accounting the need to replace existing staff, it is forecast that 35.8% of all automotive job openings in the EU up to 2025 while be in Germany (341,590 job openings). In other countries, such as Poland, France and Italy, employment in the sector is expected to decline.

If AVs are introduced, the technical requirements to build vehicles will increase and sectorial skills will need to shift, most notably, in the software development more than in the car structural development. Firms might re-locate back to countries with high human capital, thus, boosting employment in those regions. Back-shoring is proved in Europe to be most frequent in high technology sectors (Dachs and Zanker, 2015). Although the automotive manufacture sector will experience the larger shift in the skill demand, also the wholesale and retail vehicle distribution sector will require workers capable of understanding and communicating specific knowledge to their customers. If AVs demand increases then it leaves room for car manufacturers to make higher profits and employ a larger number of workers in aggregate.

Manyika et al. (2017) estimates that from 60 to 70 million potential worldwide jobs will be demanded in the automotive industry from the increase in total disposable income over the period 2016-2030.

The European Tyre & Rubber Manufacturers' Association (ETRMA) has made a projection for the tyre industry. "If we consider an average growth or GDP of 2% and a normal fluctuation of only 3% to 4% the industry has to hire each year up to 15,000 employees. This is not considering an increased fluctuation due to the demographics of our workforce".

Electronics and software

The employment effects for the sector are predicted to be positive. CEDEFOP (2016) already highlights the increasing land transport sector dependency on ICT-based and specialized equipment and products. As the transport sector becomes more profitable and productive, firms that offer complementary services (like IT support or staff at transport control centres) will react to the same increase in demand and will experience both higher profits and employment. In fact, autonomous driving technology requires advanced software and monitoring systems for what reason electronics and software sector plays a crucial part in the further development of the automated technology.

Thierer and Hagemann (2015) emphasize the need for ICT skills in addition to the traditional vehicle repair skills because they predict the electronics and software components of vehicles will increase. In this context, a shortage of ICT professionals has been identified for 2020 (European Commission, 2016b). Already firms face significant difficulties in recruiting ICT specialists: in 2015, 41% of EU enterprises claimed to struggle in filling the vacancies (133). In such environment, some firms might not be demand autonomous technology because of their lack of qualified personnel available to handle complex informatics systems for vehicles navigation. Inefficient utilization capabilities will in general hinder the sector growth.

Telecommunication, data services and digital media

AVs increase the time for people to spend on digital entertainment. An increase in demand for this services directly translates into higher labour demand for designers of those products. With increasing vehicle connectivity, companies will request expertise in data management to handle the big supply of data collected and exchanged between different devices and infrastructure. Altogether, CAVs are expected to increase the demand for

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(133) As 2015 data from Eurostat Digital Economy and Society (ISOC) Database shows, available at: http://ec.europa.eu/eurostat/data/database?node_code=isoc_ske_itrcrn2 (last accessed 20 March 2018).

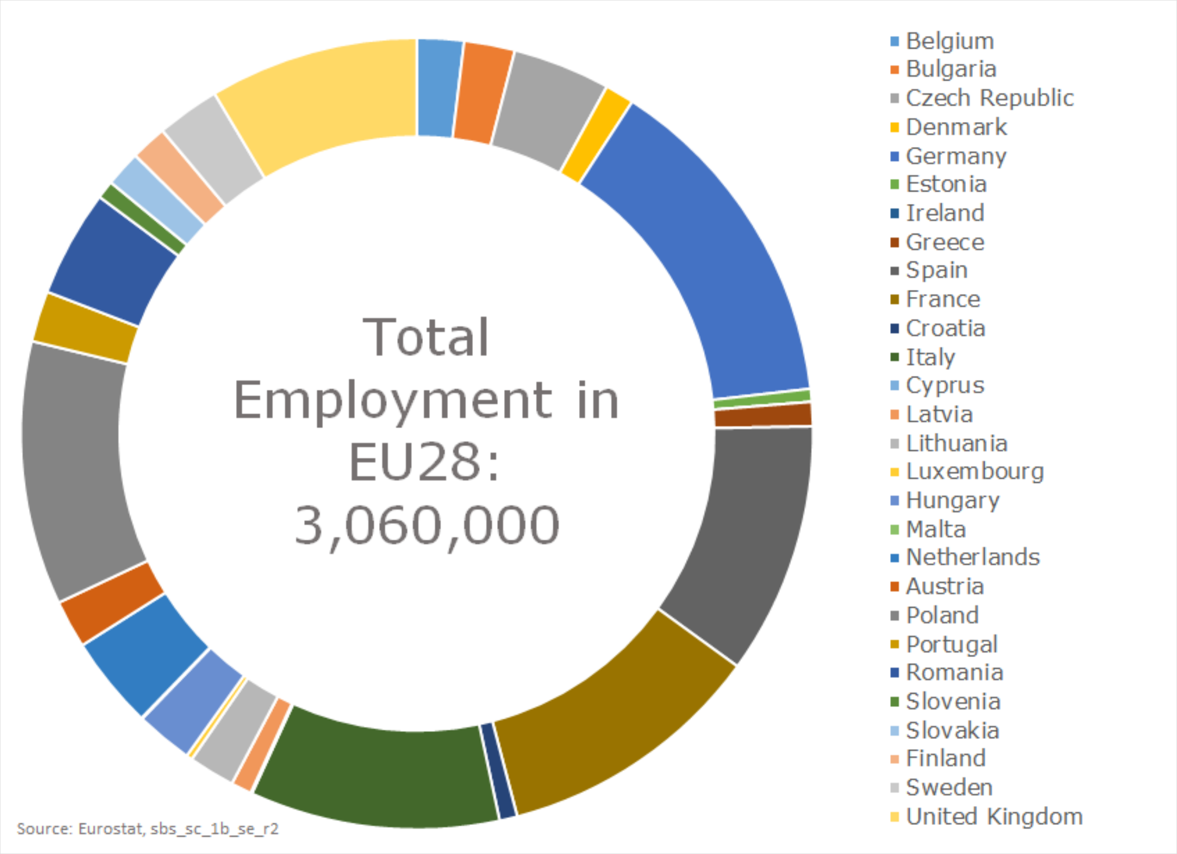
creative creation of original digital content, telecommunication, and data management and thus, increasing the labour demand in these sectors.

Freight transport

Freight transport is the sector more likely to experience adverse effects on its employment because the majority of the employees are *drivers* (workers of which primary activity is driving and are substituted by AV). However, the sector will experience major gains due to increasing efficiency, which may boost employment in logistic/management occupations within the industry. For instance, they will maybe shift labour demand to urban drivers or logistic managers due to higher workload requested on highways that necessarily leads to higher urban workload. Similarly, freight industries that are closely related to the land transport, such as air and maritime, will react to the same increase in demand and will experience both higher profits and employment.

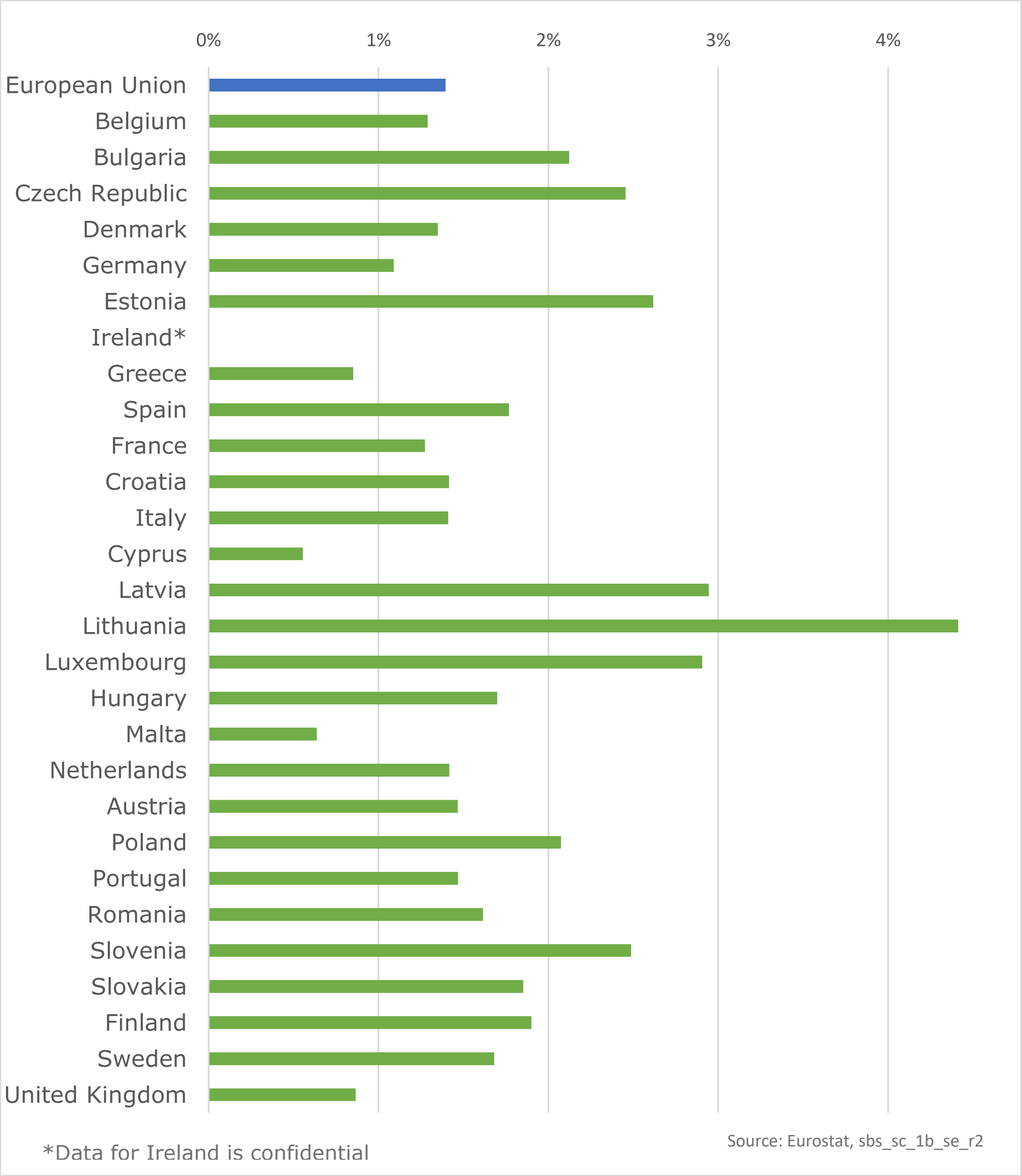
3 million European people were employed in the freight transport by road and removal services sector (NACE Rev. 2 H49.4) in 2015. Employment distribution differs among member states: large and continental countries (e.g. Germany, Poland, France) employ a larger amount of workers compared to small and insular countries (e.g. Greece, Cyprus, United Kingdom). In Figure 25, it is represented the share of employment in the sector on the total EU-28 employment. The employment figure in freight transport for Ireland is confidential so it was not possible to report it. In Figure 26, it is represented the internal share of employment in the sector on the total employment within that country.

Figure 25. Distribution of people employed in the EU - freight transport by road and removal services (2015)



Source: Own elaborations.

Figure 26. Percentage of total employment working in freight transport by road and removal services



Source: Own elaborations.

Figure 26 shows that the relative employment of freight transport sector is mainly higher in countries located in Continental Europe, probably due to better geographical location. Moreover, a large share of countries where the percentage share of employment in freight transport sector is higher than the European average are located in Eastern Europe (e.g. Poland, Lithuania, Latvia, Slovenia and Estonia). In order to draw conclusions about the effects of CAVs on local labour markets, the average level of education, taxation and other country-specific characteristics should be taken into account. However, Figure 26 indicates that workers in Eastern Europe are likely to be most affected by the automated driving technology.

Transport companies will increase productivity because autonomous trucks will be able to deliver freight 24 hours a day, seven days a week (Lanctot, 2017). *Drivers* in the occupation will be substituted by the new efficient technology. For illustrative purpose, a freight company that must ship 10 trucks a day will hire 15 full-time drivers that will work 7 days out of 10. If truck platooning enables one person to drive 5 trucks, then the company needs now only 3 full-time employees that work 7 days out of 10. Effective labour market policies can affect the market outcomes through a planned system of incentives for firms to reduce individual employees' working hours instead of displacing them and keep the same working hours for the remaining employees. This makes it possible to equally share the productivity gains within the society, leading to shorter workweek and increased living standards (Center for Global Policy Solutions, 2017). Firms can in fact hire 7 part-time employees that work 3 days out of 10 instead, which minimizes the social loss and makes the occupation attractive to women and older people as well. Even though productivity went up 5 times, flexible labour policies can make firms retain half of their workforce instead of one fifth.

Hosts in the occupations will probably increase in number. The International Transport Forum (ITF, 2017) thinks that remote control rooms will be installed for fall-back driving performance (take control of an autonomous vehicle in emergency situations) or other fleet monitoring tasks. Similar centres are currently used to monitor driverless mining vehicles in Australia's northwest (Somers and Weeratunga, 2015 as cited in ITF, 2017). Skilled and experienced drivers might change their occupations and become employed into monitoring and control rooms. The demand for these occupations will likely depend on the level of correlation between accidents (for example, a series of emergency situations originated from a snowfall) that will determine the simultaneous necessity of multiple operators at the control rooms (ITF, 2017). ICT professionals will also be demanded in the design and maintenance of these new tools.

Within the period 2011-2015, the drivers employed in land transport had a negative employment growth of -0.7% (Fernández-Macías et al., 2016). The job is in the medium quantile with respect to hourly wages, in the medium-low quantile with respect to average educational level of job-holders and in the lowest quantile with respect to non-pecuniary job quality.

ITF (2017) eventually estimates that the current 3.2 million truck-driving jobs in Europe may decrease to 2.3 or even up to 0.5 million by 2040 according to different scenarios. The market will have a mis-match between labour demand and supply increasing in the speed of technology uptake, ranging between 0.25 and 2.5 million of people.

The White House (2016) place 1.35 to 1.7 million US heavy truck divers at risk from automation.

For the scope of our analysis, we collected labour data of the EU from the LFS for the freight transport by road and removal services sector (NACE Rev. 2 H49.4) in 2015 (second quarter, Q2) within the current member states composition (28 countries). Below, the first graph (Figure 27) represents the relative age distribution of people working in the freight transport sector and educational distribution within the same age group. The second graph (Figure 28) represents instead the educational distribution in the sector among all age groups. The third graph (Figure 29) shows a comparison of relative age and education structure between 2008 (on the left side of the graph) and 2015 (on the right side) in percentage of the extracted sample within the same sector (134). These three types of graphs are also included for passenger transport and maintenance and repair sectors.

The data extracted presents however a low level of reliability. Therefore, the elaboration serves only as indication and needs to be interpreted with caution.

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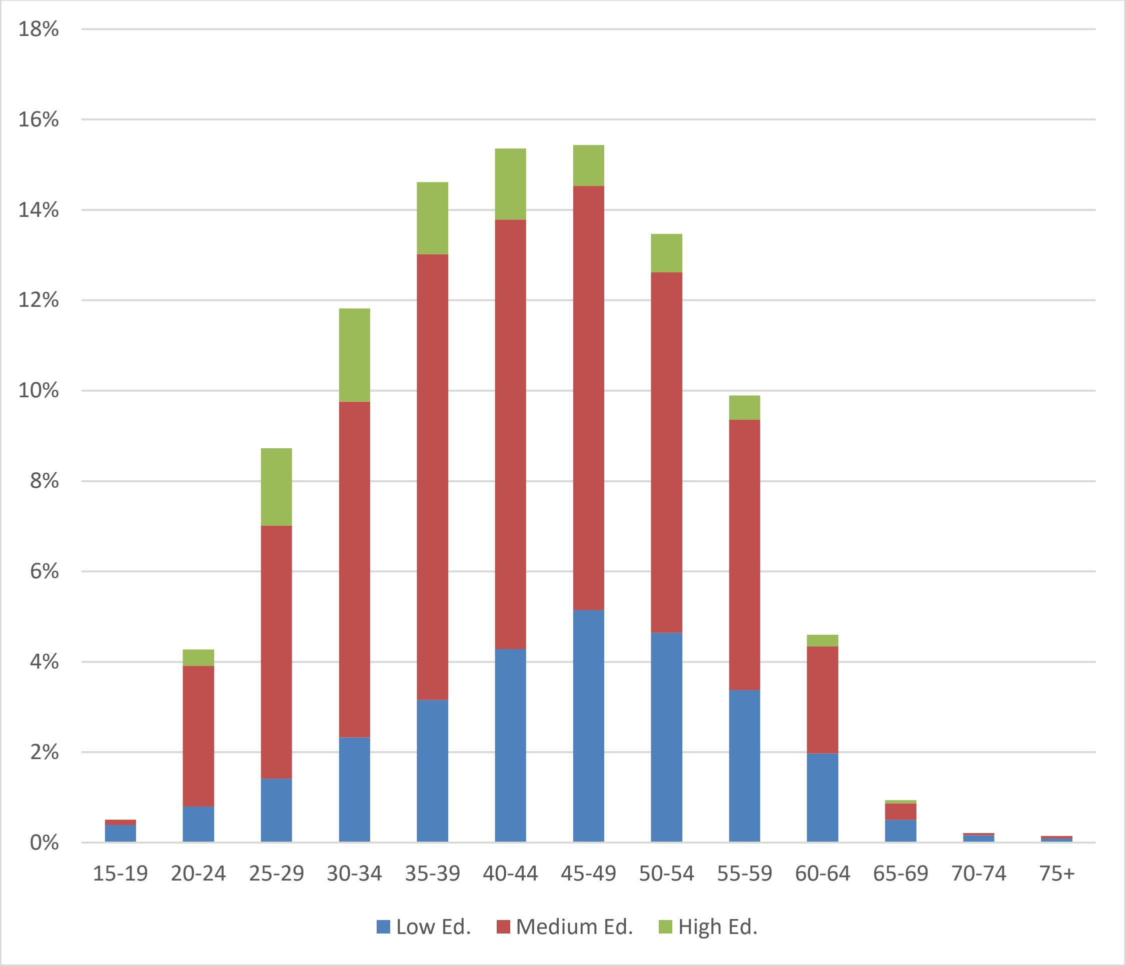
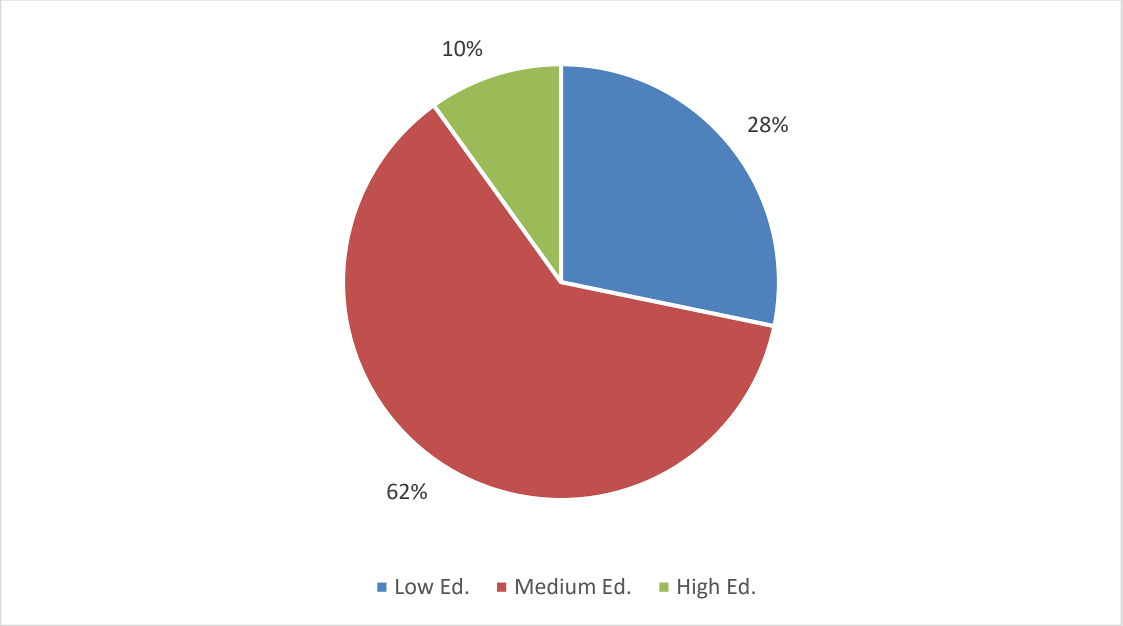
(134) The extraction comprises 22 European countries. Data for Belgium, Bulgaria, Denmark, Ireland, Latvia, and Slovenia is not available for both years' data. Data for 2008 does not include Italy, United Kingdom and Cyprus. The data undisclosed due to confidentiality reasons accounts approximately to 3.5% of the population.

Figure 27. Age distribution – freight transport EU-28 (2015)



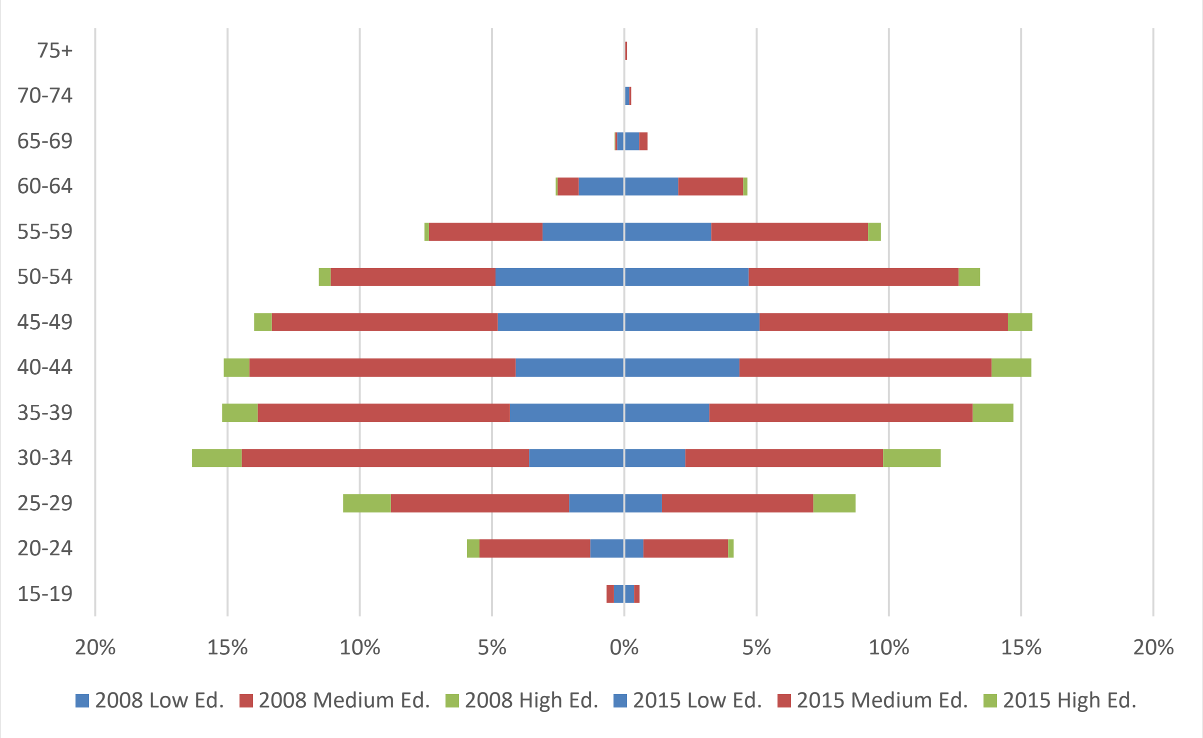
Source: Own elaborations.

Figure 28. Education distribution – freight transport EU-28 (2015)



Source: Own elaborations.

Figure 29. Age-education distribution – freight transport EU-22 (2008-2015)

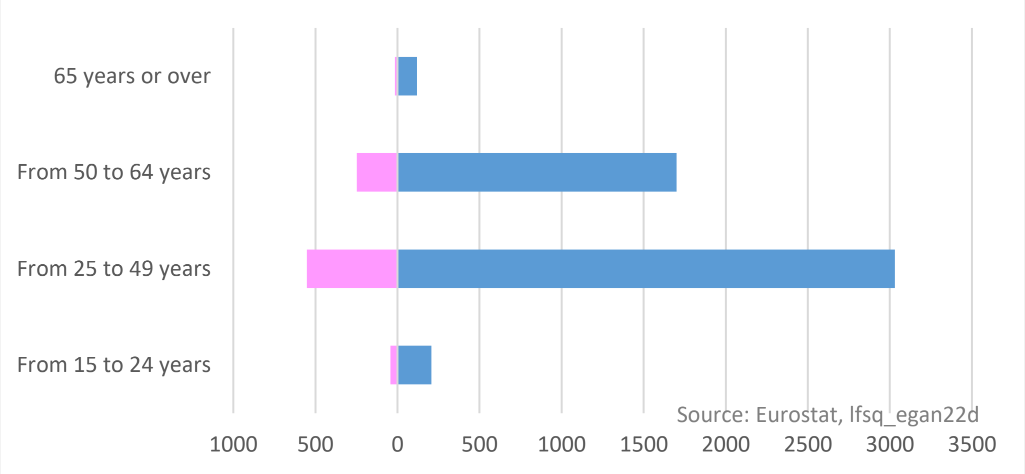


Source: Own elaborations.

Employment in freight transport shows an aging trend. Most notably, the age group 20-24 and 25-29 lost around 5% of representation in seven years and many studies (Christidis et al., 2014 among the others) predict the trend to continue in the future. This puts the occupation at risk of labour supply shortage and lower adaptability.

Most workers in the freight transport sector range between 35 and 50 years old and the age distribution is slightly skewed on the left. This might suggest working in the sector is strenuous and therefore, not suitable for aged workers. A 90% of the workers does not have a high education level (ISCED <4: Post-secondary non-tertiary education) and 28% of the total amount of workers have low education level (ISCED <2: less than lower secondary education). The proportion of highly educated workers is higher (more than 10%) in the three youngest age groups and diminishes with age.

Figure 30. Age-gender distribution in EU-28 land transport (Q2 2015), in thousands



Source: Own elaborations.

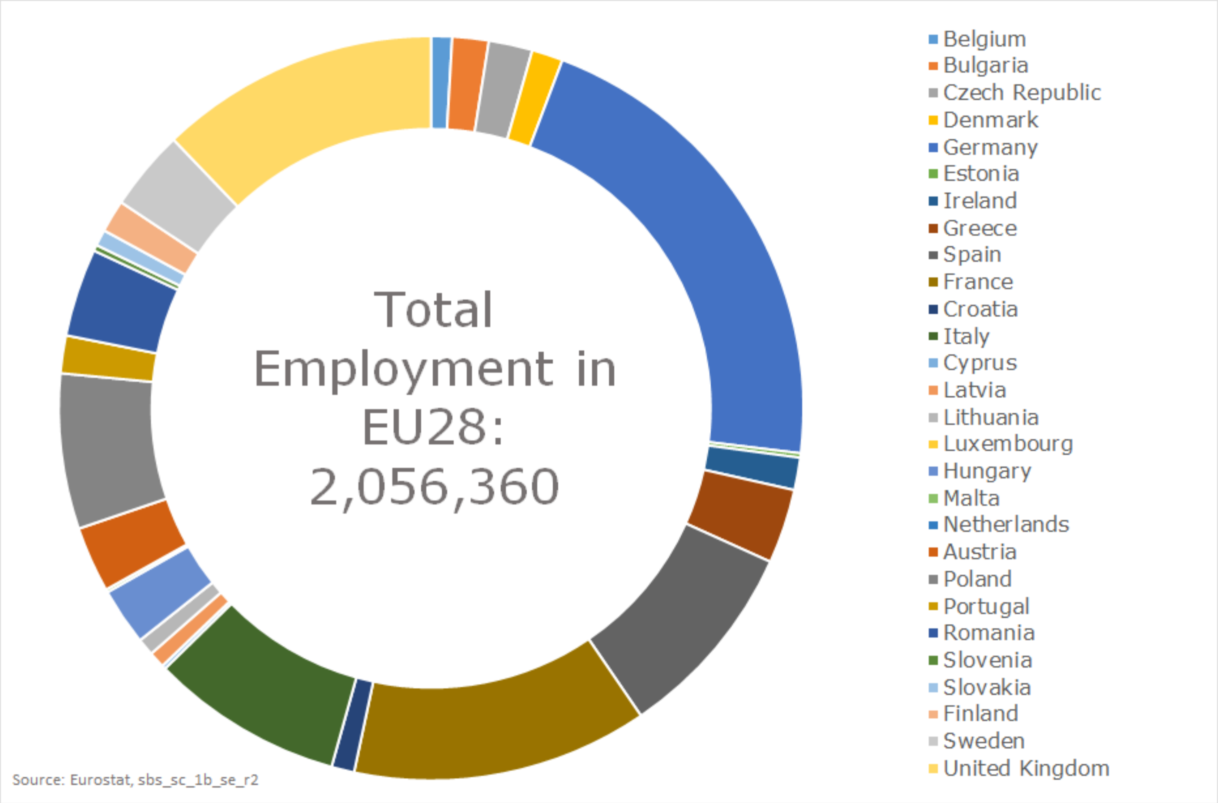
Within the land transport sector, there is a great gender imbalance towards males, which comprises more than 85% of the employment in the sector (see Figure 30). Within different age groups, men are 82.7% in the 15-24 age range, 84.6% in the 25-49, 87.2% in 50-64, and 88.8% in 65+. This might suggest the gender employment gap is closing with generations but this is not particularly impressive after taking into account the higher fertility of women in older age groups.

Altogether, the sector is notoriously at aging risk (ITF, 2017) and the workers employed typically have an educational attainment below average if compared to other sectors. Even if the sectors will probably experience productivity gains, if the technology will eventually substitute more than half of the workers in the sector, the incapability of these people to requalify accordingly will put them at risk.

Passenger transport

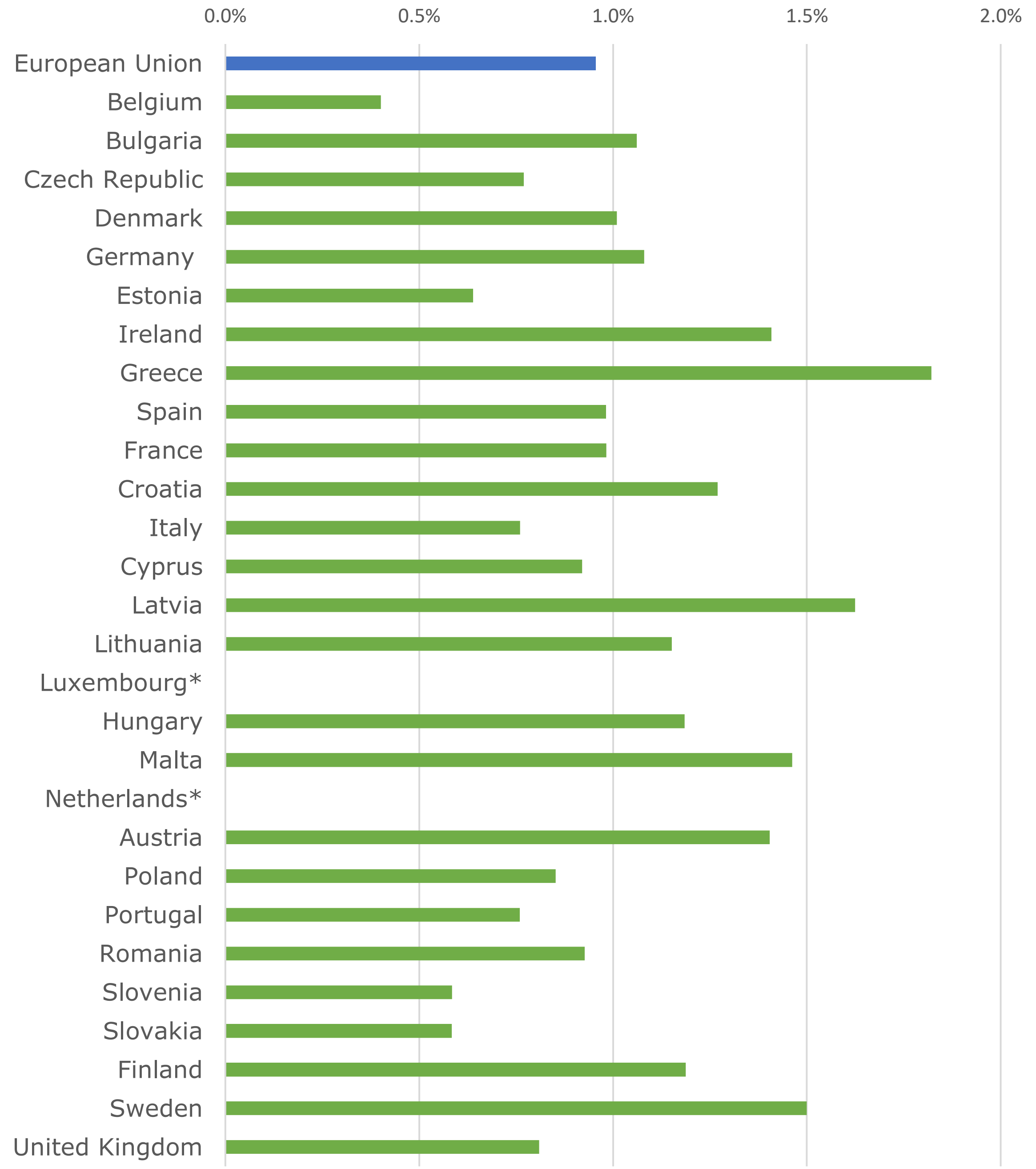
In 2015, 2 million European people were totally employed in the passenger transport sector, which is include the urban and suburban passenger land transport sector (NACE Rev. 2 H49.31), in the taxi operation sector (NACE Rev. 2 H49.32), and in the other passenger land transport n.e.c. sector (NACE Rev.2 H49.39). Figure 31 represents the share of employment in the passenger transport sector of the EU-28 total employment. The employment figure for the United Kingdom refers to 2014, the figure for Spain and France to 2013 and the figure for Finland to 2008 due to missing data for 2015. Data for Luxembourg and the Netherlands is confidential so it was not possible to report it. Figure 32 represents the internal share of employment in the sector of the total employment within that country.

Figure 31. Distribution of people employed in the EU taxi operation and urban, suburban, and other passenger land transport (2015)



Source: Own elaborations.

Figure 32. Percentage of total employment working in taxi operation and urban, suburban, and other passenger land transport (2015)



Source: Eurostat, sbs_sc_1b_se_r2

*Data for Luxembourg and the Netherlands is confidential

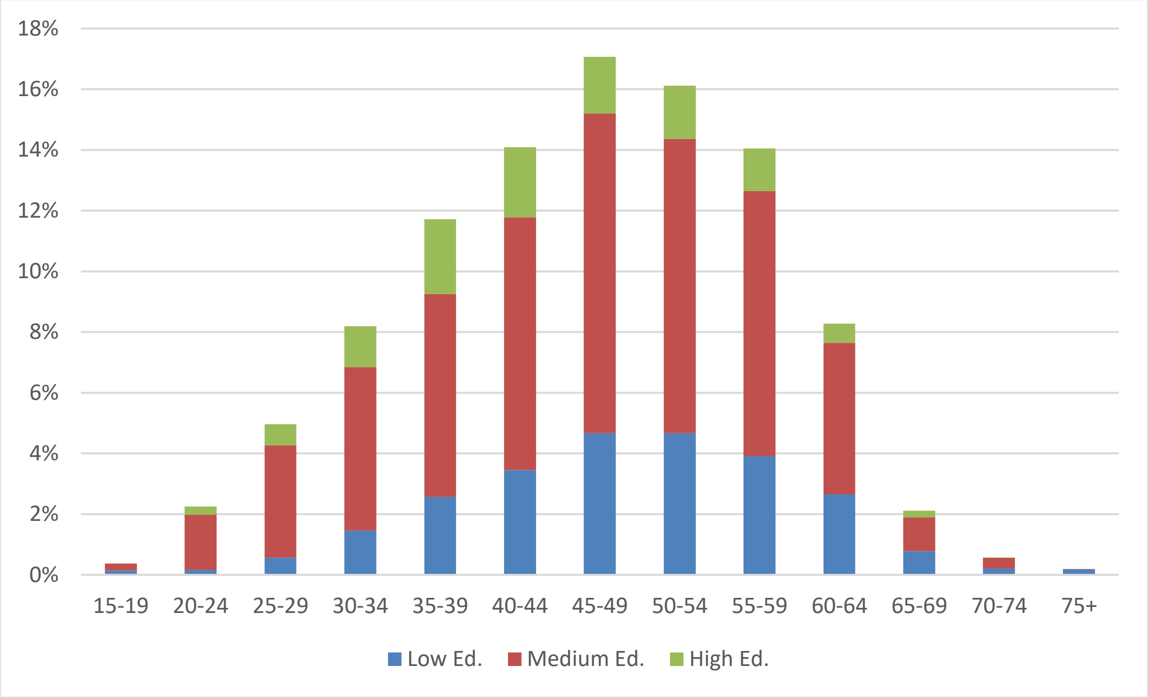
Source: Own elaborations.

Compared to Figure 26 (Percentage of total employment working in freight transport by road and removal services), the relative employment in the passenger transport sector (Figure 31) is more equally divided across countries in the EU. No clear pattern based on geography can be found. Factors that may affect the size of the passenger transport sector and the employment in that sector are for example degree of privatization, legislation, size of the country and population density.

For the scope of our analysis, we have collected labour data of the EU from the LFS for the passenger transport sector (NACE Rev. 2 H49.3) in 2015 (Q2) within the current member states composition (28 countries). Figure 33 represents the relative age distribution of people working in the sector and educational distribution within the same age group. Figure 34 represents instead the educational distribution among all age groups. As done for the freight transport sector, a comparison of relative age and education structure between 2008 and 2015 is given in Figure 35.

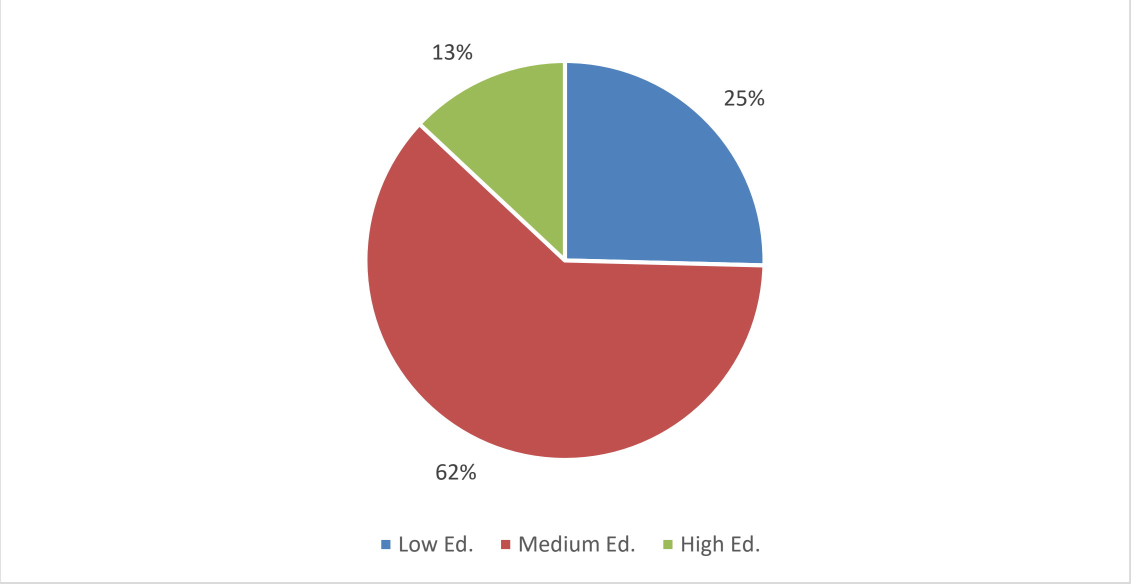
The data extracted presents however a low level of reliability. Therefore, the elaboration serves only as indication and needs to be interpreted with caution.

Figure 33. Age distribution – passenger transport EU-28 (2015)



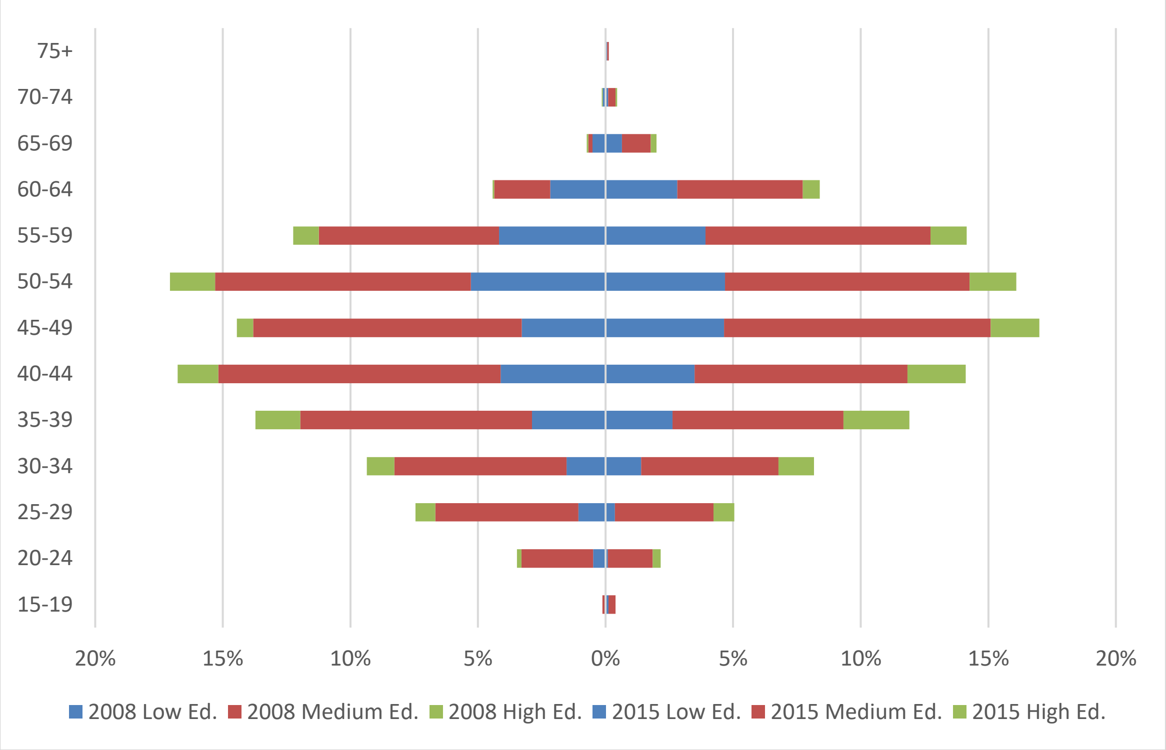
Source: Own elaborations.

Figure 34. Education distribution – passenger transport EU-28 (2015)



Source: Own elaborations.

Figure 35. Age-education distribution – passenger transport EU-22 (2008-2015)



Source: Own elaborations.

Employment in passenger transport presents an older age structure compared to freight transport but evidence the same aging trend. Similarly, this puts the sector into an even higher shortage risk and lower degree of adaptability.

Most workers in the passenger transport sector range between 40 and 60 years old and the age distribution is slightly skewed to the right. This puts the labour in the sector at risk of driver shortages after many will soon retire. Specifically, 87% of the workers do not have a high education level (ISCED <4: Post-secondary non-tertiary education) and 25% of the total amount of workers have low education level (ISCED <2: less than lower secondary education).

The proportion of highly educated workers is highest in the five youngest age groups, ranging from 12% (in the 20-24 age range) to 21% (in the 35-39 age range). Conversely, the proportion of lower educated people increases with age.

Altogether, the sector is prospected to have a lack of young labour supply to replace older workers once retired if the supply and demand of labour for different age groups will remain the same of 2015. For this reason, automation might come in help to bring equilibrium in the sector. However, the final employment balance might as well likely to be negative as much as AVs will be deployed.

Insurance

Vehicle insurance it is already legally mandatory so that the increasing value of vehicles will not have impacts on insurance demand. Little predictions can be made without knowing how the traffic legislation will evolve. To give an example, the legal responsibility of traffic accidents determine who will buy related insurance products. The demand for insurance is related both to consumers' wealth and risk aversion. The reducing rate of incidents will affect the profitability of the sector depending on both wealth and the risk perception of autonomous driving. In other words, if consumers will overestimate the accident risk entailed in the new vehicles driving, then insurance companies have room to exploit people's risk aversion and be able to sell insurance contracts with higher premiums.

Otherwise, if society will trust these vehicles, they might request insurance products less, reducing profits in the industry and consequently, decreasing labour demand and supply. It is possible to assume car manufacturers are risk-neutral and wealthy enough to pool risks and use the reducing rate of accidents to boost their profitability and reducing the one of insurances companies.

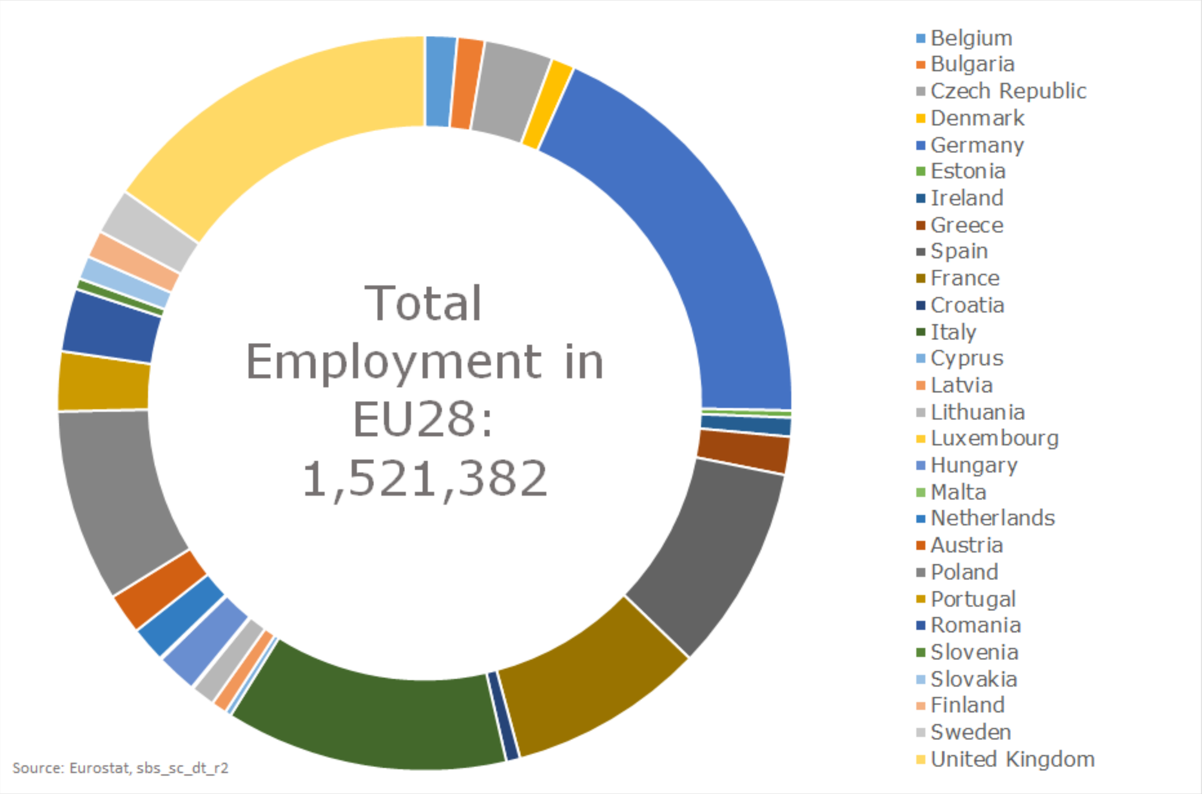
There will be a shift in demand for skills than those currently requested. Insurance companies need to cooperate with government and car manufacturers so to have access to big data quantities coming from vehicle information or, otherwise, third parties might offer the insurance service. This may include navigator apps with much traffic data like Google Maps or Waze and car manufacturer themselves (Tesla is for example currently selling car insurance with their products) (Canaan, 2017). This way, insurance companies will increasingly demand workers with high data analytics skills so to ensure returns on the investment done. As cars will also be more endangered by informatics attacks and software failure, insurance firms will find themselves in need of ICT experts which can help designing relevant actuarial framework and models.

Typically, jobs in insurance sector require high level of education and strong qualifications, both in ICT use and numeracy. Potential displaced employees might have not difficulties in re-qualify and change working sector.

Maintenance and repair

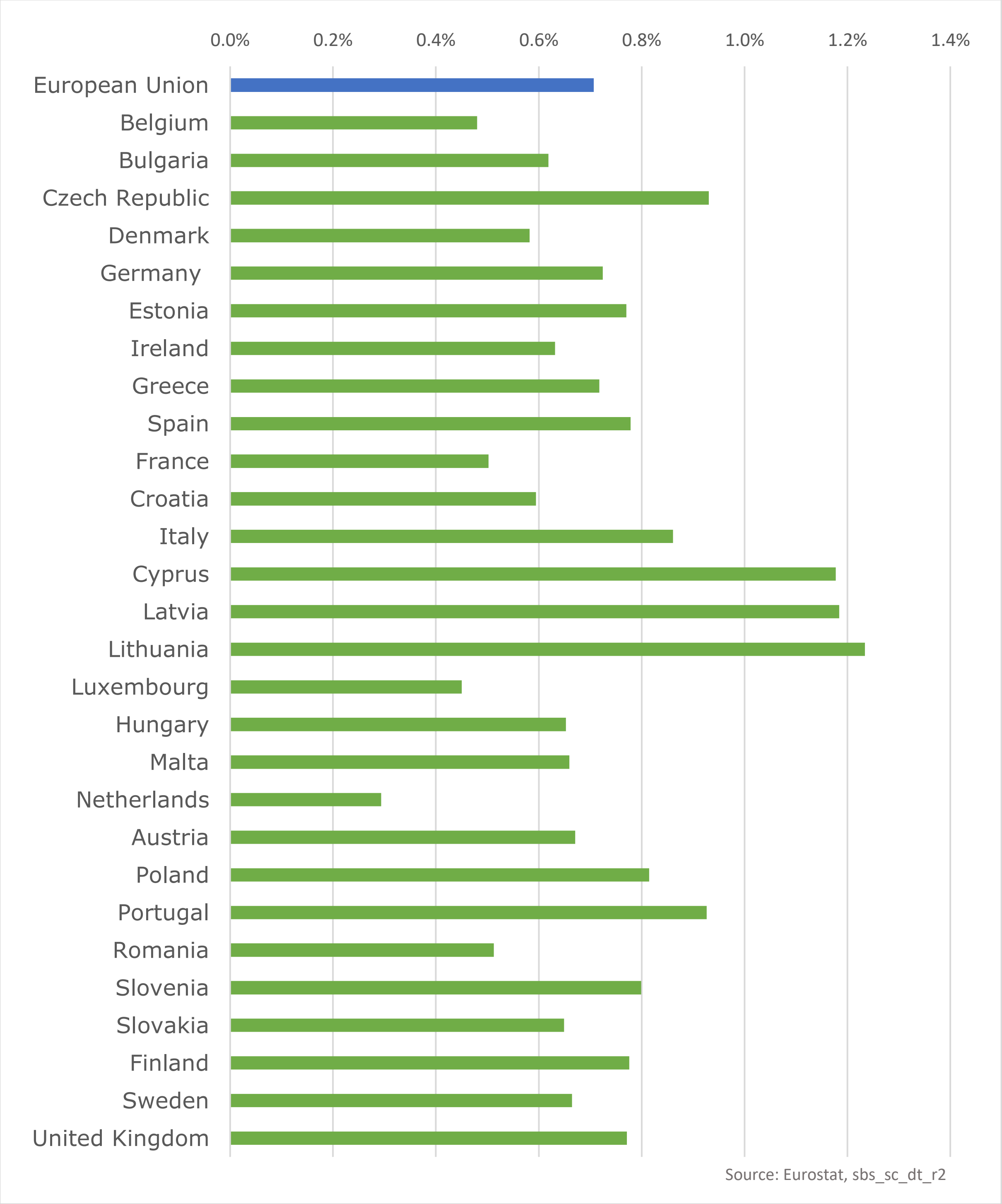
Currently 1.5 million people are employed in repair and maintenance of vehicles sector (NACE Rev. 2 G45.2) in 2015. Figure 36 represents the share of employment in the sector on the total EU-28 employment. Figure 37 represents the internal share of employment in the sector on the total employment within that country. The total amount of employment in Bosnia and Herzegovina is not available in Eurostat, thus, the percentage figure is missing.

Figure 36. Distribution of people employed in the EU maintenance and repair of motor vehicles (2015)



Source: Own elaborations.

Figure 37. Percentage of total employment working in maintenance and repair of motor vehicles (2015)



Source: Own elaborations.

The relative share of total employment working in maintenance and repair of motor vehicles is highest in Lithuania, followed by Latvia and Cyprus. Countries' average level of education, average size of the companies and capability to adjust new technologies affects the further development of the maintenance and repair of motor vehicles sector. Often maintenance and repair firms operate locally. However, deployment of automated driving technology may create global maintenance and repair firms that conquer markets from the local companies by providing standardized services.

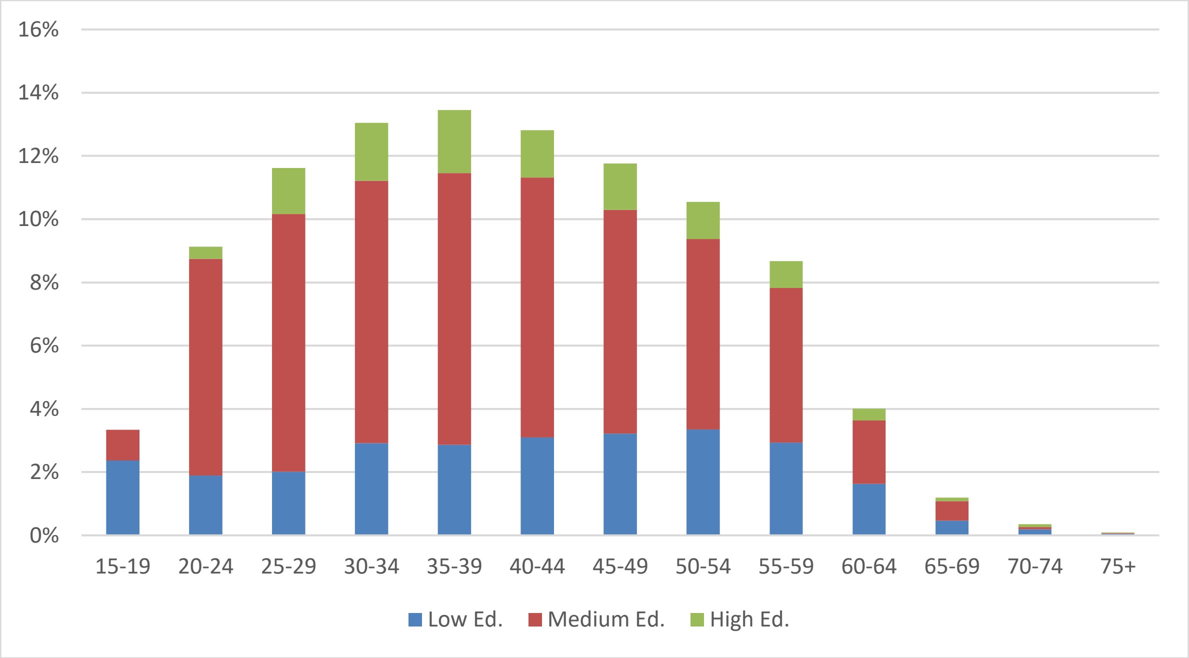
If autonomous cars will lower crash rate, then the demand for repair services will decline. Similarly, if autonomous cars will keep an optimal driving style (so without brusque breaks or with careful parking or keeping optimal engine rpm) that extends the lifetime of the vehicle, then the demand for maintenance services will decline. The maintenance and repair sector heavily rely on labour and part of the resulting employment decline will come from reduced demand and part from inability of certain workers to learn appropriate methods to deal with the new, complicated type of cars. However, the price of the service might increase because of the lower supply of qualified workforce, which would then receive a wage premium for their services over the unqualified mechanics, which goes along the inequality trend Europe is experiencing. Another dimension in which inequality will probably increase is in the profit share between car manufacturers and mechanics. If the large quantity of car data will end up in the hands of the car manufacturers, they can elaborate algorithms able to calculate the individual best moment to begin a pre-emptive maintenance procedure and communicate this to the driver. These procedures are likely carried out by mechanical centres under the supervision of the car manufacturer which will retain higher profits from the service offered due to their algorithm ownership and will leave workers with lower wages. Independent mechanics will experience then a lower demand and thus, lower salaries. Both channels improve market- and labour negotiation power of large car manufacturers firms, which necessarily increase inequality.

Overall, Manyika et al. (2017) predicted a decline of minimum 25% of developed countries general mechanics in 2030 but a slight increase of maximum 5% of specialized mechanics and repair.

For the scope of our analysis, we collected labour data of the European Union from the LFS for the repair and maintenance of vehicles sector (NACE Rev. 2 G45.2) in 2015 (Q2) within the current member states composition (28 countries). The first graph (Figure 38) represents the relative age distribution of people working in the sector and educational distribution within the same age group. The second graph (Figure 39) represents instead the educational distribution among all age groups. The third graph (Figure 40) shows the 2008-2015 comparison of age-education distribution in the sector.

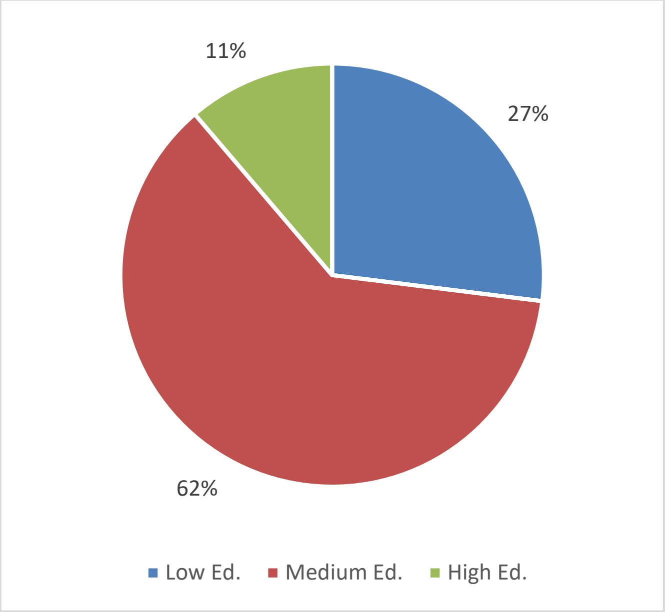
The data extracted presents however a low level of reliability. Therefore, the elaboration serves only as indication and needs to be interpreted with caution.

Figure 38. Age distribution in maintenance and repair, EU-28 (2015)



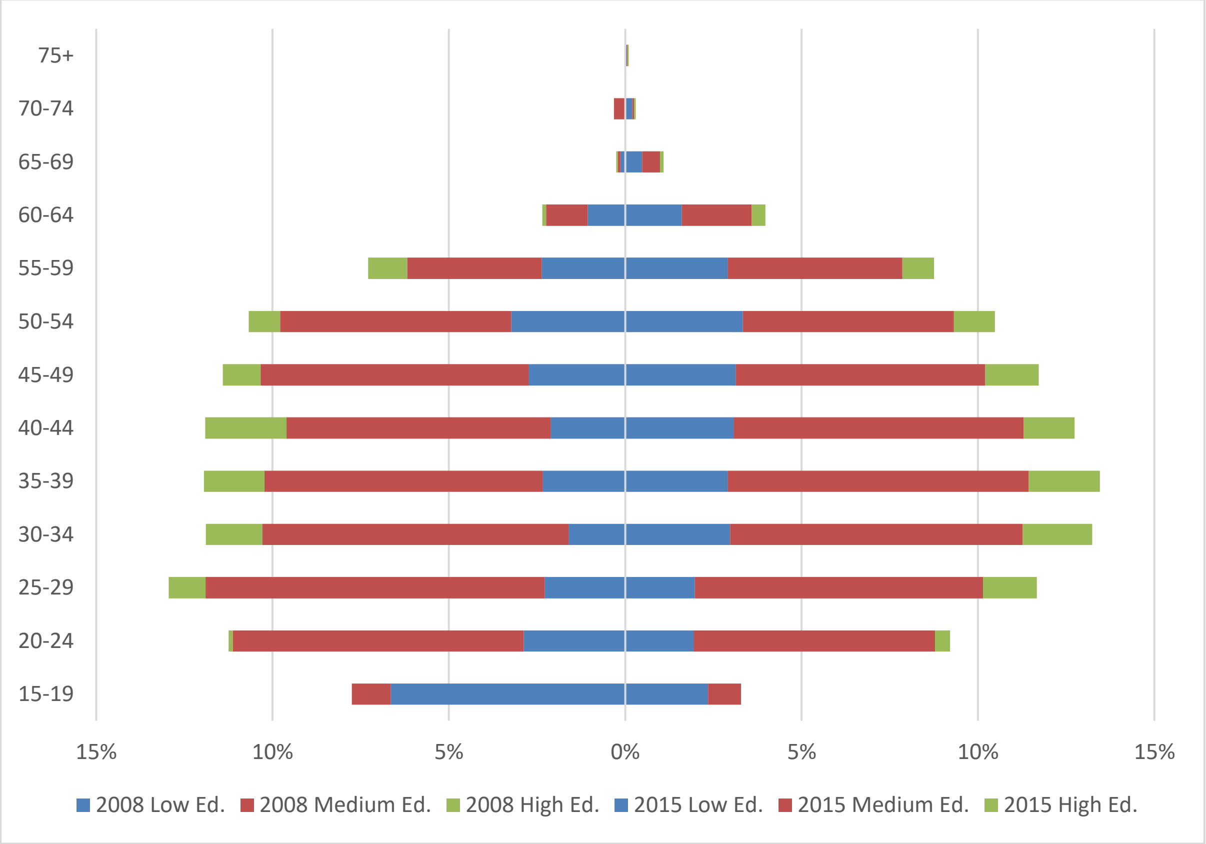
Source: Own elaborations.

Figure 39. Education distribution – maintenance and repair EU-25 (2015)



Source: Own elaborations.

Figure 40. Age-education distribution – maintenance and repair EU-22 (2008-2015)



Source: Own elaborations.

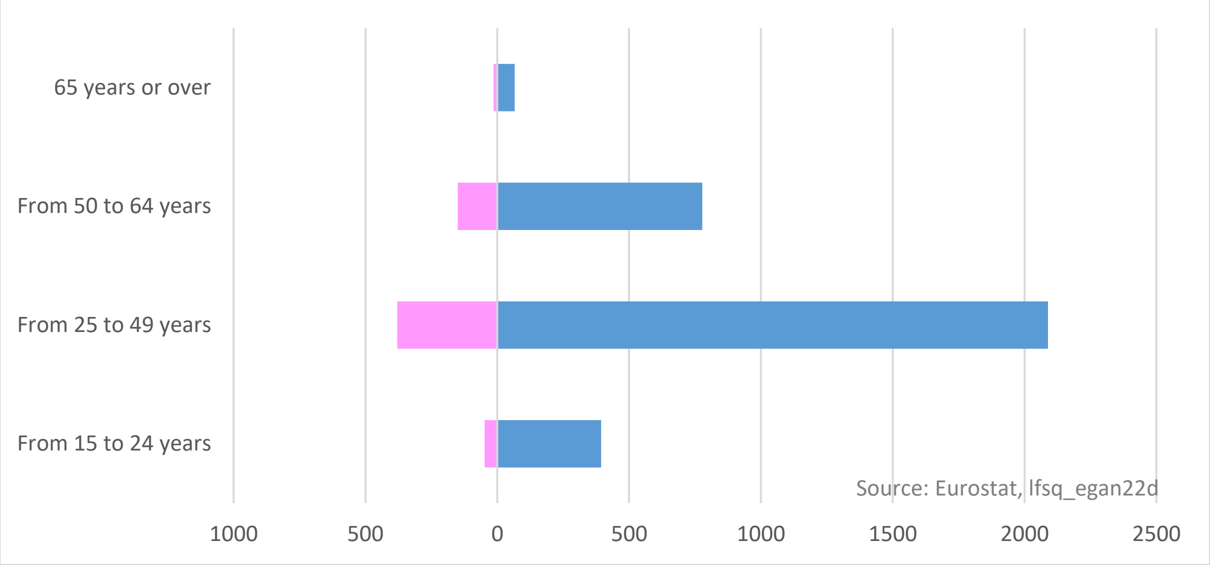
The aging trend in the maintenance and repair sector is more moderate than in the transport sector. This might evidence a comparatively higher attraction to the sector for the younger generations.

Most workers in the maintenance and repair sector range between 30 and 45 years old but the age distribution is balanced. This puts the labour in the sector safe from aging trend if there will be perfect generation replacement, so, if the job will keep the same attractiveness to young people and if the work conditions will not worsen for elder professionals. An 89% of the workers do not have a high education level (ISCED <4: Post-secondary non-tertiary education) and 27% of the total amount of workers have low education level (ISCED <2: less than lower secondary education).

The proportion of highly educated workers is higher (more than 12%) in the five youngest age groups and diminishes with age.

Within the wholesale and retail trade and repair of motor vehicles and motorcycles sector, there is a great gender imbalance towards males, which comprises 85% of the employment in the sector (see Figure 41). Within different age groups, men are 89.2% in the 15-24 age range, 84.6% in the 25-49, 83.8% in 50-64, and 82.6% in 65+.

Figure 41. Age-gender distribution in EU-25 Wholesale and retail trade, and EU-25 Repair of motor vehicles and motorcycles (Q2 2015), in thousands



Source: Own elaborations.

Altogether, workers in this sector will require new training to keep performing the job after AVs deployment. The innovations will likely generate new professional figures who will team with traditional mechanics as long as the AVs will not be predominant. The internal competition in the sector will increase with time for those who will not stay updated with the new maintenance procedures. The young age profile in the sector employment is promising with respect to the learning capabilities of the workers.

Others

AVs are likely to be used more in road freight, which is an intermediate input to other goods. In general, a cheaper service will generate a positive employment effect coming in the reduction of production costs for downstream firms and increase in demand for services offered by road transport companies, for upstream firms, and those that offer complementary services.

Summary

Economic effects of CAVs will affect in the same direction employment in different sectors. However, there might be an opposite (and negative) impact in sectors where labour might be substituted or where task changes in the occupation will be so drastic that workers unable to requalify will not find a market for their abilities and might eventually exit the profession. This might be the case of drivers and mechanics. According to the descriptive statistics and studies presented in the earlier chapters, the two occupations are at risk of automation or technology unemployment, which are made more severe by the relatively lower level of education among employees and older age structure in those sectors. The upcoming technological advancement in the transport sector is estimated to benefit high-skilled workers. Not only high-skilled workers in the transport sector will profit from the adaption of new technologies, but also workers in the other sectors, such as IT and telecommunication, are predicted to face an upward shift in labour demand. Moreover, the boundaries between sectors that demand higher level of education may fade.

Technological development and digitalisation tend to create more jobs than are lost due to the labour substitution effect (ITF, 2017). However, the reconstruction of labour markets may create structural unemployment, particularly harming lower-educated workers that in turn, can lead to increased inequality.

In order to provide a comprehensive picture of the possible effects on different sectors, more specific data and complex modelling would be required, but still this would include the difficult task of projecting the future social structure, both in terms of acceptance and uptake of the new technology.

Moreover, in our analysis we have disregarded the impact of legislation and policies on the adaption of automated driving technology. For this reason, the time frame for technological adaption is hard to predict. The faster the changes are the larger are the labour market disruptions.

Nonetheless, the rough estimations of the sectors' average age and level of education can provide information about the possible development paths. In general, knowledge-based sectors and occupations are predicted to gain comparative advantage whereas sectors with manual tasks are in danger to face labour market disruptions. Aging population and decreasing population growth may stabilize the labour market effects of CAVs in Europe but the impacts of the aging population as a stabilizing factor should be interpreted cautiously.

3.3.2 Impact of AV technologies on skills

On the basis of the employment effects identified in this study, an analysis of gaps and needs in relation to the skills that will be associated to the future employment is made.

As our previous employment analysis has revealed, the freight transport sector has been identified as the one where the most significant labour changes may take place as a result of automation. Also, sectors where new jobs may be created are mostly those related to ICT, jointly with digital services, electronics and robotics (the latter ones are coming from an EESC opinion, European Economic and Social Committee, 2017). In such a changing workforce landscape, the demand for skills will evolve significantly. It will require an increased investment in education and skills to support people in their adaptation to technological change along their careers (Hawksworth et al., 2018).

It is expected that physical and routine tasks will be reduced, whereas problem-solving and creative tasks are likely to increase (European Economic and Social Committee, 2017). Broad-based competencies will be increasingly demanded (European Economic and Social Committee, 2017). A Commission communication from 2017 (European Commission, 2017c) has evidenced the increasing demand for ICT skills in particular for vehicle manufacturing and maintenance workers.

Reskilling will also be needed for professional drivers (European Commission, 2017c). Specifically, drivers in the freight sector will be increasingly faced to new and expanded responsibilities, like potentially the management, operation and maintenance of fleets of AVs (Rea et al., 2017). Such new roles would require new competences. For instance, fleet monitors would need to know how to operate tracking systems, dynamic routing and AV technologies. In a recent survey conducted by CEDEFOP (European Skills and Jobs Survey, ESJ ([135])), five main skills have been identified for drivers and mobile plant operators (ISCO 83). These are: problem solving, job-specific skills, teamwork, communication and learning. An increasing dependence on ICT-based and specialised equipment is also highlighted, in particular for those workers in the land transport sector (NACE H49). Consequently, future occupations will demand new and more advanced skills in engineering and ICT, together with knowledge on how to use specific software and novel technologies like AVs or platooning.

Similarly, mechanics in the maintenance and repair sector would need to learn how to repair CAV systems of increasing complexity (Rea et al., 2017). Other occupations, like police officers, would also need to know how CAV technologies work and the underlying regulations (Rea et al., 2017).

In the future, there will be an increasing demand for high-skilled professionals (such as software developers, European Economic and Social Committee, 2017). Almost half of all job offerings by 2025 will demand higher qualifications, which are generally linked to academic and professional programmes at tertiary level (European Commission, 2016b). Increases in skills and education are associated to a growth in productivity and GDP per capita (European Commission, 2016b). Acknowledging the need to adapt, among the ten actions identified in the New Skills Agenda for Europe adopted in June 2016, the 'Digital Skills and Jobs Coalition' action is aimed at improving the digital skills of the wider population, and not just addressed to IT professionals.

In this context, a shortage of ICT professionals has been identified for 2020 (European Commission, 2016b). Such estimate urges on the necessity to face future skills by adapting education and training programs. The OECD Survey of Adult Skills (OECD, 2016) has revealed that higher proficiency in literacy, numeracy and problem solving in technology-rick environments usually leads to better labour market outcomes (getting an employment and earning higher salaries), compared to adults with lower skills. A more intense use of information-processing skills tends to be associated to higher salaries. At work, the most frequently used skills are writing and problem solving, followed by reading skills, whereas numeracy and ICT skills are the least used ones. In some countries/economies, adults with poor literacy and numeracy skills may have difficulties in the use of information technologies, which could hinder their labour market outcomes. Thus, policies targeting an improvement in adults' ICT competences should cover both the enhancement of literacy and numeracy skills and the access to technology. Two important perspectives are given: the need to have an education and training system that matches the skills required in the labour market, and the need to ensure that the labour market matches employees to jobs where they can put their human capital to the best use. These are crucial aspects if a strong and inclusive growth is to be promoted, being equally important for individuals and society as for the economy.

A forward-thinking talent model that is able to attract, retain and develop a new digital labour force in accordance to the evolving needs is identified as a likely challenge in (Rea et al., 2017). Though some degree of mismatch of qualifications and skills is unavoidable in a dynamic economy, as jobs gradually change in relation to technological and organisational development, customers' demand and changes in labour supply (OECD, 2015 as cited in OECD, 2016). Currently, 30% of higher education graduates in Europe are working in jobs that actually require a lower qualification while at the same time 40% of employers cannot find workers with the right set of skills as required for the open positions ([136]). Although education and training is the competence of EU Member States, the fact that they face similar challenges and opportunities makes it relevant to have initiatives for skills at European level, like the New Skills Agenda for Europe (European Commission, 2016c).

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[135] CEDEFOP European skills and jobs (ESJ) survey, available at: http://www.cedefop.europa.eu/en/events-and-projects/projects/european-skills-and-jobs-esj-survey (last accessed 5 April 2018).

[136] European Commission Employment, Social Affairs & Inclusion (section on skills) website, available at: http://ec.europa.eu/social/main.jsp?catId=1146 (last accessed 5 April 2018).

Future growth and jobs will depend on the reskilling and upskilling of European citizens and workforce as well as on the awareness raising and support initiatives offered to users in response to the transformation of businesses brought in by CCAM. EU countries, employers' associations, trade unions, industry and other stakeholders are called on to face these challenges. In this context, legacy industries facing automation would be particularly challenged, such as the land transport sector.

For the broader drivers' population, it is evident that the driving activity will be gradually changing as more automation is introduced into the vehicles. These changing circumstances will require different skills, especially to monitor the normal functioning of the automated driving systems (i.e. supervision and selective intervention skills against manual control and manoeuvring skills; as described in Spulber and Wallace, 2016), up to the point where no human intervention will be required with fully automated driving systems. As automation gradually takes over vehicle control, the lack of frequent driving can create the risk that drivers no longer possess the skills required to safely regain vehicle control in handover situations (Meschtscherjakov et al., 2018). Understanding the automated driving systems functioning will be essential for the safe operation of AVs, for which the highly heterogeneous vehicle systems could represent a challenge (Spulber and Wallace, 2016). As automation is gradually deployed, progressive and continuous training could become more relevant than the current one-off initial training (Spulber and Wallace, 2016). This will have an effect on the training provided through driving schools for obtaining a driving license.

3.3.3 Concluding remarks on employment and skills

The concerns on job destruction by machines can be dated back to the first industrial revolution. The short run effects of effective technologies implementation negatively impacted workers (The White House, 2016) but on the long run, technology advancements eventually led to higher job creation (ITF, 2017). In general, estimating the **number of jobs at risk of automation** has been proved difficult and can lead to completely different results depending on minor changes applied in the approach used. Frey and Osborne (2017) find for example that 47% of US jobs are at risk of computerisation but Arntz et al. (2016) find that only 9% of jobs in OECD countries is at risk instead. The former study estimates the share of jobs threatened by automation based on experts opinion over specific occupations while the latter uses the same methodology but with a task-based approach, so based on the same experts predictions but estimating the degree of their automation-risk predictions on the proportion of automatable task within each occupation.

At the present state of art, AVs cannot perform all the tasks required in most driving-related jobs and there is much uncertainty if they will ever do (Litman, 2018). However, a partial tasks substitution (e.g. platooning substitutes the tasks that now strictly require a second driver to perform) will increase competition in the lower-skills labour market. Firstly, because the tasks substitution by AVs will make the job appealing for more people that previously had a dislike for driving (Miller, J., 2015). Secondly, because lower demand for drivers will make the transport sector less accessible. The competition effect will not only be restricted to the transport sector but to all the other lower-skilled occupations where displaced drivers will apply (The White House, 2016).

According to our estimations, workers endangered of technological substitution (drivers and mobile plant operators, ISCO 83, International Labour Organization) working in land transport (NACE 49) amount to approximately 1.5% of total EU-15 employment in 2012 and those who require new training to keep performing the job (metal, machinery and related trades, ISCO 72) in wholesale, retail and repair of motor vehicles (NACE 45) amount to 0.7% of total EU-15 employment in 2012. It also seems evident that employment effects will not only be restricted to the land transport sector but will impact all sectors that employ drivers such as warehousing and support, wholesale trade or postal and courier activities. ITF (2017) estimates that the current 3.2 million truck-driving jobs in Europe may decrease to 2.3 or even up to 0.5 million by 2040 according to different scenarios. A slow CAV uptake or an informative awareness campaign can lead workers to qualify on time and mitigate the transition costs for them (ITF, 2017). Retraining or income assistance programs are mechanisms that can support the transition (Rea et al., 2017).

It is relevant to note that both occupations under study (ISCO 72 and 83) have low levels of ICT use, whereas **ICT skills** will be increasingly demanded in the future. CEDEFOP (2016) highlights the increasing land transport sector dependency on ICT-based and specialized equipment and products. Thierer and Hagemann (2015) also emphasize the need for ICT skills in addition to the traditional vehicle repair skills. In this context, a shortage of ICT professionals has been identified for 2020 (European Commission, 2016b). If the demanded skills can be matched in the future, there could be opportunities for reallocation of employees. For instance, Thierer and Hagemann (2015) claim that in the future some highly qualified mechanics might move over to higher-paying jobs in the information sector. ITF (2017) also postulates that skilled and experienced drivers could be demanded in the case that remote control rooms are installed for CAVs monitoring.

Inequality between low-skilled and high-skilled workers will widen. AVs can make some sectors more profitable but most of the benefits will be reaped by those highly skilled workers who can either produce and repair the new vehicles or those who get more productive with the additional time previously spent in transport activities. This has been proved to be the case in other non-transport-related sectors (as stated in e.g. ITF, 2017; The White House, 2016; Arntz et al., 2016; Frey and Osborne, 2017; OECD, 2016). The European Commission highlights that by 2025, about 50% of EU’s jobs offerings will target highly qualified people (European Commission, 2016c). However, another aspect to consider is the easier geographical connectivity facilitated by CAV technologies, which could enable workers to accept jobs from firms previously rejected due to distance to the workplace or because less accessible in general (Litman, 2018). This effect is likely to be positive on labour market participation and on skills match between employers-employees.

Another challenge is predicting what kind of **new occupations** will be created in the future. Even though recent labour market experiences suggest that those will be mostly skewed on the higher part of the skill distribution (ITF, 2017), it is very difficult to determine the qualifications and characteristics of the future jobs demanded by the economy.

At the level of **skills required for driving a CAV**, the automation of the driving task will increasingly require supervision and selective intervention skills in opposition to manual control and manoeuvring skills (Spulber and Wallace, 2016). Understanding the automated driving systems functioning will also be essential for a safe operation of AVs for which the highly heterogeneous vehicle systems could represent a challenge (Spulber and Wallace, 2016). As automation is gradually deployed, progressive and continuous training could become more relevant than the current one-off initial training (Spulber and Wallace, 2016).

The impacts of CCAM on employment are largely influenced by the speed of introduction of the new technologies and mobility changes. The more gradual the introduction will be the higher the probability that the negative implications on employment will be absorbed by the economic system of the European society.

4 Limitations of the study and future lines of work

4.1 Limitations of the study

Along the study, some simplifying assumptions have been adopted given the uncertainty and complexity of the topic under study, as well as the lack of data. These should be relaxed in the future, accounting for additional insights onto CAVs behaviour and effects in different areas. Although it is implicitly considered in the narrative used to define the different scenarios, the study does not consider interaction effects among sectors and complexity causal loops. Substitution effects are not considered neither. The estimations may therefore suffer from some double counting and from non-linear effects that cannot be properly addressed in the present work.

In addition, the economic impacts have to be seen as the global impacts of the introduction of CAVs to the European case. How much of these impacts will contribute to the European economy has still to be seen. Much will depend on the capability of the European industry to keep the pace of new competitors especially from the communication and IT sectors, as well as on the ability of education stakeholders to take anticipatory actions that address the skills needed in the future. It is also worth mentioning that the indicator to measure the economic impacts are the potential revenues. The impact on the future European Value Added has not been considered at this stage.

The reader is invited to consider the estimations presented in this study as indications of future trends and not in absolute terms.

4.2 Methodological approach for future studies

The present JRC study stands as a preliminary exploratory research activity that will feed into a larger project whose aim is to go deeper into the analysis of the possible impacts of future mobility scenarios on EU employment and the macro-economic changes connected to the mobility revolution. The project's goal is to support the social dimension of impact assessments dealing with European transport strategies. For that purpose, different units from the JRC are collaborating, cross-cutting and combining social sciences, economics and engineering, on the basis of robust science. The approach and ambition of this project go well beyond the state of the art of current studies in the field. Overall, efforts will be placed in capturing the dynamics and causal loops intrinsic to the European economic sector, addressing the limitations of the present study.

A first research line will analyse the job impact and employment intensity of all segments of the transport sector (manufacturing, maintenance services, as well as transport services) with a bottom-up data driven assessment approach. It will combine various statistical resources from Eurostat with other data (including business data and big data) to derive a detailed and complete picture of the EU transport sector with Member State detail. The bottom-up approach will also include, to the extent possible, the socio-economic stratification and skills of workforce. An important step forward will be the analysis of the occupational distribution within each analysed sector, aiming at understanding how the existing occupational breakdown of each sector will evolve in different possible future scenarios. For that purpose, the task contents of occupations can be used to predict the potential impact of automation at an occupational level. This methodology will be partially based on previous pioneering JRC work to assess job impacts of new transport regulation and transport workers' skills, renewable electricity deployment, of the deployment of alternative fuels infrastructure and future car CO_2 regulation.

The second research line will build on the previous one and integrate (to the extent possible) the detailed bottom-up employment data, combined with an improved and extended technological representation of the transport sector, into the global macro-economic, JRC's General Equilibrium Model for Economy-Energy-Environment, JRC-GEM-

E3 model (137). This model will also allow to analyse the macro-economic impacts of different mobility scenarios, various low-carbon policies, shifts in global value chains, trade and tax policies, energy security issues (like the Iran oil embargo of 2012). The JRC-GEM-E3 model has been used intensively by DG CLIMA and DG ENER over the last 10 years for their impact assessments and has a proven policy and academic track record (138).

Besides supporting the assessment of employment impacts of future Commission proposals (in transport and beyond), this project will provide support to policy development for inclusive growth in the context of the *Low-Emission Mobility Strategy* as well as *Agenda for Jobs, Growth and Investment*, and allow the Commission to better assess policy initiatives to foster employment and foresee and mitigate any possible negative social impacts. Better analytical capabilities of JRC-GEM-E3 model may benefit other activities under the Energy Union (and beyond) such as the macro-economic scenarios in support to POTEnCIA (Policy Oriented Tool for Energy and Climate Change Impact Assessment) analyses, and GECO (Global Energy and Climate Outlook) reports in context of the international climate negotiations (in combination with the POLES model).

A first overview to the activities that will form the basis of this future project is given below:

1. **Project coordination** to ensure the proper progress of the different tasks and adopt the necessary adjustments to guarantee that project deadlines are met in a timely manner.
2. Establishment of a **bottom-up methodology** to analyse job impacts and job shifts in the transport sector; extend the **JRC-GEM-E3 model** with a much better representation of the transport sector (both technologies and in employment).
3. Identification of yet realistic (possibly disruptive) **mobility scenarios** for a transition towards highly automated and electrified road transport by or beyond 2050.
4. Exploration of **policy options and strategies** for enhancing positive job impacts and mitigating negative job impacts caused by a smart mobility revolution combining the various developed and improved tools in the project with a qualitative framing of possible barriers and other social dimensions.
5. **Policy user group** establishment, to profit from further collaboration opportunities.

Other future and on-going activities could also benefit from the outcomes of the present study, helping to understand the relative importance of each of the sectors of the EU economy that will most likely be affected by CCAM, as well as potential effects on the workforce and skills. As an example, the following on-going project has been identified as relevant to the cope of this study (among the recent projects funded with Horizon 2020 calls (139)):

— **Piloting Automated Driving on European Roads - L3Pilot** (140)

L3Pilot belongs to the ART-02-2016 H2020 call and is an innovation action with a budget of roughly 47 million euros coordinated by Volkswagen AG and joining efforts of 34 partners. 11 European countries, 100 vehicles and 1000 test drivers. The tested functions cover a wide range from parking to urban and highway driving, which will

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(137) European Commission EU Science Hub General Equilibrium Model for Economy-Energy-Environment (JRC-GEM-E3) description website, available at: https://ec.europa.eu/jrc/en/gem-e3/model?search (last accessed 5 April 2018).

(138) JRC-GEM-E3 list of related publications available at: https://ec.europa.eu/jrc/en/gem-e3/publications (last accessed 5 April 2018).

(139) European Commission Innovation and Networks Executive Agency (INEA) H2020 Automated Road Transport list of related projects available at: https://ec.europa.eu/inea/en/horizon-2020/h2020-transport/projects-by-field/automated-road-transport (last accessed 5 April 2018).

(140) L3Pilot project website available at: http://www.l3pilot.eu/home/ (last accessed 5 April 2018).

provide valuable data for evaluation of technical aspects, user acceptance, driving and travel behaviour as well as on the impact on traffic and society.

- **Trilateral Working Group on Automation in Road Transportation** (Innamaa et al., 2017)

  A framework for assessing the impacts of AVs is under preparation within the Trilateral Working Group on Automation in Road Transportation among EU, US and Japan stakeholders. In it, direct and indirect impacts are identified, the latter representing broader effects resulting from a chain of direct impacts ("ripple effect") (Innamaa et al., 2017). Socio-economic effects belong to this category of indirect impacts. For instance, improvements in safety, use of driving time, or emissions will have long-term economic impacts. Some possible KPIs in this area are: GDP, productivity estimates, work time lost from traffic crashes, work time gained due to multitask while travelling, labour force participation rate.

Other currently on-going Horizon 2020 calls of relevance to this field are the following, especially the ones highlighted in bold (European Commission, 2017n):

- Call 'Digitising and Transforming European Industry and Services: Automated Road Transport' H2020-DT-ART-2018-2020, under the Smart, green and integrated transport workprogramme:
    - DT-ART-01-2018: Testing, validation and certification procedures for highly automated driving functions under various traffic scenarios based on pilot test data
    - **DT-ART-02-2018: Support for networking activities and impact assessment for road automation**
    - DT-ART-03-2019: Human centred design for the new driver role in highly automated vehicles
    - DT-ART-04-2019: Developing and testing shared, connected and cooperative automated vehicle fleets in urban areas for the mobility of all
    - DT-ART-05-2020: Efficient and safe connected and automated heavy-duty vehicles in real logistics operations (forthcoming)
    - DT-ART-06-2020: Large-scale, cross-border demonstration of highly automated driving functions for passenger cars (forthcoming)
- **Public Procurement along 2018-2019 - Exploring the possible employment implications of connected and automated driving.**

5 Conclusions

The present study has evidenced some main challenges and opportunities linked to the transition towards a future CCAM mobility, which will need to be faced in order to unlock the unprecedented benefits that CAV technologies could bring to our society and economy.

In particular, the study has evidenced the following key conclusions:

- In economic terms, it is expected that CCAM provides profitable opportunities for sectors like automotive, electronics and software, telecommunication, data services, digital media and freight transport; mostly as a consequence of increased vehicle sales, data exchanges and services, and more efficient transport operations.
- Sectors like insurance and maintenance and repair are however identified as businesses that might suffer important decreases in revenues in the future, especially as a result of decreased accidents. Although new revenue opportunities are also expected to appear, the overall long-term effect is expected to be negative.
- The economic impacts of CCAM will reach other sectors like construction of roads, land development, or health, especially in the long-term.
- At a societal level, a CCAM mobility could bring important safety and productivity gains. Nevertheless, some important concerns exist, such as users' acceptance, ethics, social inclusion, or labour.
- Specifically, important labour changes lie ahead for professional drivers, decreasing driving responsibilities towards the acquisition of new and more technical roles. Some of these jobs will disappear in the long-term and anticipatory actions remain a crucial mechanism to ensure that workers receive support and retraining opportunities. Concerns around inequality might also exist.
- At the level of skills, ICT competences will be increasingly demanded in the future, e.g. in manufacturing, maintenance and transport-related jobs. The skills required for driving a vehicle will also change as automation gains full control of the vehicle, e.g. requiring more supervision and selective skills.

Overall, the impacts of CCAM on the economy and society are expected to be positive. It is nevertheless highly important to emphasise the great transformational power that CCAM entails and the fact that there will be both losers and winners in the mobility transition. It becomes then crucial to anticipate the needs that come along the new business opportunities and workforce evolution.

Although the scenarios analysed in this study do not represent a forecast of impacts, they help to illustrate a set of possible effects that will drive fundamental changes in different sectors of our economy. The specific calculations are subject to a great uncertainty though, as the evolution of prices of technologies and market penetration rates are still highly unknown. Also, little is known about the long-term effects of a CCAM mobility in terms of traffic flows, travel and vehicle use patterns, among other impacts. Thus, the focus shall not be paid on the precise estimations given in this study, if not as qualitative indications of possible future evolution paths. More studies are needed to explore the range of potential impacts and build knowledge in this area.

In particular, the outcomes of this initial assessment will be used as an input to a more thorough study where the different elements identified at this stage will be integrated in a modelling framework able to handle the dynamics and the causal loops intrinsic of the European economic sector.

Policymakers, industry and education players in Europe shall then seize the opportunity of capturing the indicated benefits within the EU by adopting broad sets of measures, especially given the relevance of sectors like automotive, electronics and software or freight transport in Europe. The same holds true for the minimisation of the potential negative implications. This study does not claim to be the final word, rather to provide input to current discussions and research efforts through an exploration of possible socio-economic changes and preparatory actions, which could contribute to shape the future mobility in compliance of specified policy targets. We are confident that the findings presented in this study will contribute to the ongoing debate on the type and magnitude of potential impacts of CCAM in the European economy and society.

References

Abraham, H., Lee, C., Brady, S., Fitzgerald, C., Mehler, B., Reimer, B., and Coughlin, J.F., 'Autonomous Vehicles, Trust, and Driving Alternatives: A survey of consumer preferences', White Paper, 2016.

Abraham, H., Reimer, B., Seppelt, B., and Fitzgerald, C., 'Consumer Interest in Automation: Preliminary Observations Exploring a Year's Change', White Paper, 2017.

ACEA, *37 leading companies join forces in European Automotive-Telecom Alliance,* 30 September 2016a, available at: http://www.acea.be/press-releases/article/37-leading-companies-join-forces-in-european-automotive-telecom-alliance (last accessed 5 February 2018).

ACEA, *The Automobile industry Pocket guide 2016/2017,* 2016b, available at: http://www.acea.be/publications/article/acea-pocket-guide (last accessed 26 April 2018).

ACEA, *Strategy Paper on Connectivity,* 2016c, available at: http://www.acea.be/uploads/publications/ACEA_Strategy_Paper_on_Connectivity.pdf (last accessed 12 April 2018).

ACEA, *Connected and automated driving: EATA presents deployment roadmap, submits proposal for EU project,* 27 February 2017a, available at: http://www.acea.be/press-releases/article/connected-and-automated-driving-eata-presents-deployment-roadmap-submits-pr (last accessed 5 February 2018).

ACEA, *Report Vehicles in use-Europe 2017,* 2017b, available at: http://www.acea.be/statistics/article/vehicles-in-use-europe-2017 (last accessed 6 February 2018).

Acemoglu, D., and Robinson, J., *Why Nations Fail: The Origins of Power, Prosperity, and Poverty*, Random House Digital, 2012.

Aghion, P., and Howitt, P., 'Growth and Unemployment', *The Review of Economic Studies*, Vol. 61, No 3, 1994, pp. 477-494.

Albright, J., Schneider, J., and Nyce, C., *The chaotic middle: The Autonomous Vehicle and Disruption in Automobile Insurance,* KPMG, White Paper, 2017, available at: https://home.kpmg.com/us/en/home/insights/2017/05/the-chaotic-middle-autonomous-vehicle-disruption-automobile-insurance.html (last accessed 13 April 2018).

Alonso Raposo, M., Ciuffo, B., Makridis, M., and Thiel, C., *From Connected Vehicles to a Coordinated Automated Road Transport (C-ART) system,* Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria.

Andersson, P., and Ivehammar, P.A., *Cost-Benefit Analysis of self-driving vehicles on the road*, Proceedings of 7th Transport Research Arena TRA 2018, 16-19 April 2018, Vienna, Austria.

Arbib, J., and Seba, T., *Rethinking Transportation 2020-2030: The Disruption of Transportation and the Collapse of the Internal-Combustion Vehicle and Oil Industries,* RethinkX, 2017.

Arntz, M., Gregory, T., and Zierahn, U., *The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis,* No 189, OECD Publishing, 2016, available at: https://www.oecd-ilibrary.org/social-issues-migration-health/the-risk-of-automation-for-jobs-in-oecdcountries_5jlz9h56dvq7-en (last accessed 12 April 2018).

Asselin-Miller, N., Horton, G., Amaral, S., Figg, H., Sheldon, D., Lutz, Ch., Flaute, M., and Wells, P., *GEAR 2030 Strategy 2015-2017 - Comparative analysis of the competitive position of the EU automotive industry and the impact of the introduction of autonomous vehicles: final report*, 2017, available at: https://publications.europa.eu/en/publication-detail/-/publication/24c9ad0e-da38-11e7-a506-01aa75ed71a1/language-en/formatPDF /source-52926290 (last accessed 12 April 2018).

Autor, D.H., Levy, F., and Murnane, R.J., 'The skill content of recent technological change: An empirical exploration*', The Quarterly journal of economics*, Vol. 118, No 4, 2003, pp. 1279-1333.

Autor, D.H., 'Why Are There Still So Many Jobs? The History and Future of Workplace Automation', *Journal of Economic Perspectives*, Vol. 29, No 3, 2015, pp. 3-30.

Babrowski, S., Heinrichs, H., Jochem, P., and Fichtner, W., 'Load shift potential of electric vehicles in Europe', *Journal of Power Sources*, Vol. 255, 2014, pp. 283-293.

Baker, E.H., Crusius, D., Fischer, M., Gerling, W., Gnanaserakan, K., Kerstan, H., Kuhnert, F., Kusber, J., Mohs, J., Schulte, M., Seyfferth, J., Stephan, J., and Warnke, T., *Connected car report 2016: Opportunities, risk, and turmoil on the road to autonomous vehicles,* PwC strategy&, 2016, available at: https://www.strategyand.pwc.com/reports/connected-car-2016-study (last accessed 16 January 2018).

Bansal, P., and Kockelman, K.M., 'Forecasting Americans' long-term adoption of connected and autonomous vehicle technologies', *Transportation Research Part A: Policy and Practice*, Vol. 95, 2017, pp. 49-63.

Beede, D., Powers, R., and Ingram, C., *The Employment Impact of Autonomous Vehicles*, SSRN Electronic Journal, 2017, available at: https://www.ssrn.com/abstract=1969462 (last accessed 12 April 2018).

Bernhart, W., Winterhoff, M., Hoyes, C., Chivukula, V., Garrelfs, J., Jung, S., and Galander, S., *Autonomous driving: Disruptive innovation that promises to change the automotive industry as we know it-it's time for every player to think: act!*, Roland Berger Strategy Consultants, 2014, available at: https://www.rolandberger.com/publications/publication_pdf/roland_berger_tab_autonomous_driving.pdf (last accessed 12 April 2018).

Bertoncello, M., Camplone, G., Gao, P., Kaas, H.W., Mohr, D., Moller, T., and Wee, D., *Monetizing car data. New service business opportunities to create new customer benefits,* Mckinsey&Company, 2016, available at: https://www.mckinsey.com/~/media/McKinsey /Industries/Automotive%20and%20Assembly/Our%20Insights/Monetizing%20car%20data/Monetizing-car-data.ashx (last accessed 12 April 2018).

Bessen, J., 'Toil and technology', *IMF Finance & Development*, Vol. 52, No 1, 2015, pp. 16-19, available at: http://www.imf.org/external/pubs/ft/fandd/2015/03/bessen.htm (last accessed 22 March 2018).

BI Intelligence, *The Top 5 Disruptive Trends Shaping Transportation and Logistics*, 2017.

Bischoff, J., and Maciejewski, M., 'Simulation of city-wide replacement of private cars with autonomous taxis in Berlin', *Procedia computer science*, Vol. 83, 2016, pp. 237-244.

Blanco, M., Atwood, J., Russell, S., Trimble, T., McClafferty, J., and Perez, M., *Automated vehicle crash rate comparison using naturalistic data*, Virginia Tech Transportation Institute, 2016, available at: https://www.vtti.vt.edu/PDFs/Automated%20Vehicle %20Crash%20Rate%20Comparison%20Using%20Naturalistic%20Data_Final%20Report_20160107.pdf (last accessed 12 April 2018).

Boeriu, H., *AUDI AG, BMW Group and Daimler AG officially purchase Nokia's HERE maps*, BMW BLOG, 4 December 2015, available at: http://www.bmwblog.com/2015/12/04/audi-ag-bmw-group-and-daimler-ag-officially-purchase-nokias-here-maps/ (last accessed 26 April 2018).

Boogar, L., *German Taxi app MyTaxi acquired by Daimler*, RUDE BAGUETTE, 3 September 2014, available at: http://www.rudebaguette.com/2014/09/03/german-taxi-app-mytaxi-acquired-daimler/ (last accessed 26 April 2018).

Bösch, P.M., Becker, F., Becker, H., and Axhausen, K.W., 'Cost-based Analysis of Autonomous Mobility Services', *Transport Policy,* Vol. 64, 2018, pp. 76-91.

Boucherat, X., 'Absolutely indispensable: future of AVs hinges on AI', *Automotive Megatrends Magazine*, Q1 2018, pp. 40-43, available at: https://automotivemegatrends.com/automotive-megatrends-magazine-q1-2018/ (last accessed 12 April 2018).

Bowles, J., *The Computerization of European Jobs*, Bruegel, Brussels, 2014, available at: http://bruegel.org/2014/07/the-computerisation-of-european-jobs (last accessed 15 February 2018).

Brandmayr, C., Benton, D., George, A., and Kumar, C., *People power; How consumer choice is changing the UK energy system,* Green Alliance, 2017, available at: https://www.green-alliance.org.uk/people_power_consumer_choice.php (last accessed 12 April 2018).

Briggs, M., *Future of Mobility: Corporate Carsharing. Continued Growth in Traditional Carsharing & Fleet Markets Leading to Convergence & New Mobility Business Models such as Corporate Carsharing,* Frost and Sullivan, 2014, available at: https://www.slideshare.net/FrostandSullivan/corporate-carsharing-3-1814 (last accessed 4 April 2018).

Brown, A., Gonder, J., and Repac, B., 'An analysis of possible energy impacts of automated vehicles', In Meyer, G., Beiker, S., *Road Vehicle Automation,* Lecture Notes in Mobility, Springer International Publishing, 2014, pp. 137-153.

Brynjolfsson, E., and McAfee, A., *The second machine age: work, progress, and prosperity in a time of brilliant technologies,* W.W. Norton & Company, 2014.

Burghout, W., Rigole, P.J., and Andreasson, I., 'Impacts of shared autonomous taxis in a metropolitan area', *Transportation Research Board 94th Annual Meeting*, 2015, available at: http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A912176&dswid=30546355 (last accessed 12 April 2018).

Burianski, M., and Theissen, C., *Germany Permits Automated Vehicles,* White & Case Technology Newsflash, 23 Jun 2017, available at: https://www.whitecase.com/publications/article/germany-permits-automated-vehicles (last accessed 5 February 2018).

Burke, K., *Automakers see high-stakes mobility as an opportunity*, Automotive News, 29 September 2016, available at: http://www.autonews.com/article/20160929/OEM06/160929767/automakers-see-high-stakes-mobility-as-an-opportunity (last accessed 7 February 2018).

Burns, L., Jordan, W., and Scarborough, B., *Transforming Personal Mobility*, The Earth Institute, Columbia University, 2013, available at: http://sustainablemobility.ei.columbia.edu/files/2012/12/Transforming-Personal-Mobility-Jan-27-20132.pdf (last accessed 15 February 2018).

Canaan, M., *"To be or not to be" is no longer the question: Insurers confront the "when" and "how" of uneven transition as mobility preferences and capabilities evolve,* Deloitte, 2017, available at: https://www2.deloitte.com/content/dam/Deloitte/us/Documents/financial-services/us-dcfs-ins-autonomous-vehicles-insurers-confront-when-and-how-of-self-driving-cars.pdf (last accessed 12 April 2018).

Cavoli, C., Phillips, B., Cohen, T., and Jones, P., *Social and Behavioural Questions Associated with Automated Vehicles: A Literature Review,* UCL Transport Institute, 2017, available at: https://trid.trb.org/view.aspx?id=1457834 (last accessed 15 February 2018).

CEDEFOP, *Automotive sector and clean vehicles, Analytical Highlight, EU Skills Panorama 2014*, 2014, available at: http://skillspanorama.cedefop.europa.eu/sites/default/files/EUSP_AH_Automotive_0.pdf (last accessed 12 April 2018).

CEDEFOP, *Drivers and mobile plant operators: skills opportunities and challenges, Analytical Highlights, Skills Panorama,* 2016, available at: http://skillspanorama.cedefop.europa.eu/en/printpdf/analytical_highlights/drivers-and-mobile-plant-operators-skills-opportunities-and-challenges (last accessed 6 March 2018).

Center for Global Policy Solutions, *Stick Shift: Autonomous Vehicles, Driving Jobs, and the Future of Work,* Washington, DC, 2017, available at: http://globalpolicysolutions.org/report/stick-shift-autonomous-vehicles-driving-jobs-and-the-future-of-work/ (last accessed 12 April 2018).

Christidis, P., Navajas E., Brons M., Schade B., Mongeli I., and Soria A., *Future employment in transport– Analysis of labour supply and demand,* Publications Office, 2014, available at: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC93302/move%20jobs%20%20jrc%20final%20report%20final%2020150113.pdf (last accessed 6 March 2018).

Chu, J., *Driverless platoons: Analysis finds autonomous trucks that drive in packs could save time and fuel,* MIT News Office, 20 December 2016, available at: http://news.mit.edu/2016/driverless-truck-platoons-save-time-fuel-1221 (last accessed 6 February 2018).

Clements, L.M., and Kockelman, K.M., 'Economic Effects of Automated Vehicles', *Transportation Research Record: Journal of the Transportation Research Board*, No 2606, 2017, pp. 106-114.

CLEPA, *Truck platooning: Smart mobility through intelligent transport systems and automated & connected driving,* 2017, available at: https://clepa.eu/wp-content/uploads/2017/10/CLEPA-Platooning-Panel-A4-V4-HD.pdf (last accessed 6 March 2018).

Cohen, T., and Cavoli, C., *Automation of the Driving Task: Some possible consequences and governance challenges,* ITF Discussion Paper, OECD/ITF, Paris, 2017, available at: https://www.itf-oecd.org/automation-driving-task-possible-consequences-governance-challenges (last accessed 12 April 2018).

Cookson, G., and Pishue, B., *INRIX Connected and Autonomous Vehicle Consumer Survey*, 2017.

Corwin, S., Vitale, J., Kelly, E., and Cathles, E., *The future of mobility: How transportation technology and social trends are creating a new business ecosystem,* Deloitte LLP, 2015, available at: https://www2.deloitte.com/insights/us/en/focus/future-of-mobility/transportation-technology.html (last accessed 12 April 2018).

Council of the European Union, *Council conclusions on the digitalisation of transport*, Brussels 2017.

Cyganski, R., 'Autonome Fahrzeuge und autonomes Fahren aus Sicht der Nachfragemodellierung', in *Autonomes Fahren: Technische, rechtliche und gesellschaftliche Aspekte,* Springer, 2015, pp. 241-263.

Dachs, B., and Zanker, C., *Backshoring of production activities in European manufacturing*, European Manufacturing Survey, 2015.

De Gennaro, M., Paffumi, E., Scholz, H., and Martini, G., 'GIS-driven analysis of e-mobility in urban areas: An evaluation of the impact on the electric energy grid', *Applied Energy*, 124, 2014, pp. 94-116.

De Jong, G.C., and Gunn, H.F., 'Recent Evidence on Car Cost and Time Elasticities of Travel Demand in Europe', *Journal of Transport Economics and Policy*, Vol. 35, No 2, 2001, pp. 137-160.

DHL Trend Research, *Self-driving vehicles in logistics: A DHL perspective on implications and use cases for the logistics industry*, 2014, available at: http://www.dhl.com/content/dam/downloads/g0/about_us/logistics_insights/dhl_self_driving_vehicles.pdf (last accessed 12 April 2018).

Dungs, J., Herrmann, F., Duwe, D., Schmidt, A., Stegmüller, S., Gaydoul, R., Peters, P.L., and Sohl, M., *The Value of Time, Potential for user-centered services offered by autonomous driving*, Fraunhofer IAO and Horváth & Partners, Stuttgart, 2016, available at: https://blog.iao.fraunhofer.de/images/blog/studie-value_of_time.pdf (last accessed 12 April 2018).

ERTRAC, *Automated Driving Roadmap,* 2017, available at: http://www.ertrac.org/uploads/documentsearch/id38/ERTRAC_Automated-Driving-2015.pdf (last accessed 12 April 2018).

European Commission, *EU Commissioner Oettinger holds Roundtable on Automated Driving in Frankfurt,* 2015, available at: https://ec.europa.eu/digital-single-market/en/news/eu-commissioner-oettinger-holds-roundtable-automated-driving-frankfurt (last accessed 13 April 2018).

European Commission, *EU Reference Scenario 2016: Energy, transport and GHG emissions - Trends to 2050*, Office for official publications of the European communities, Luxembourg, 2016a, available at: https://ec.europa.eu/energy/sites/ener/files/documents/20160713%20draft_publication_REF2016_v13.pdf (last accessed 12 April 2018).

European Commission, *Analytical underpinning for a New Skills Agenda for Europe,* COMMISSION STAFF WORKING DOCUMENT, SWD(2016), 195 final, Accompanying the communication document A NEW SKILLS AGENDA FOR EUROPE: Working together to strengthen human capital, employability and competitiveness COM (2016) 381 final, 2016b, available at: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A52016SC0195 (last accessed 12 April 2018).

European Commission, A NEW SKILLS AGENDA FOR EUROPE, Working together to strengthen human capital, employability and competitiveness COM(2016) 381 final, 2016c, available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016DC0381 (last accessed 12 April 2018).

European Commission, *A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility.* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2016) 766 final, 2016d, available at: https://ec.europa.eu/energy/sites/ener/files/documents/1_en_act_part1_v5.pdf (last accessed 12 April 2018).

European Commission, *5G for Europe Action Plan*, DG CONNECT, 2016e, available at: https://ec.europa.eu/digital-single-market/en/5g-europe-action-plan (last accessed February 2018).

European Commission, *Proposed Directive establishing the European Electronic Communications Code*, 2016f, available at: https://ec.europa.eu/digital-single-market/en/news/proposed-directive-establishing-european-electronic-communications-code (last accessed February 2018).

European Commission, *EU Transport in figures*, Statistical Pocketbook, 2017a, available at: https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2017_en (last accessed 5 March 2018).

European Commission, *Autonomous cars: A big opportunity for European industry*, Digital Transformation Monitor, 2017b, available at: https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Autonomous%20cars%20v1_1.pdf (last accessed 12 April 2018).

European Commission, *Europe on the Move: An agenda for a socially fair transition towards clean, competitive and connected mobility for all,* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2017) 283, 2017c, available at: https://ec.europa.eu/transport/sites/transport/files/com20170283-europe-on-the-move.pdf (last accessed 12 April 2018).

European Commission, *GEAR 2030, High Level Group on the Competitiveness and Sustainable Growth of the Automotive Industry in the European Union: final report,* 2017d, available at: https://ec.europa.eu/docsroom/documents/26081/attachments/1/translations/en/renditions/native (last accessed 12 April 2018).

European Commission, *EU and EEA Member States sign up for cross border experiments on cooperative, connected and automated mobility,* 2017e, available at: https://ec.europa.eu/digital-single-market/en/news/eu-and-eea-member-states-sign-cross-border-experiments-cooperative-connected-and-automated (last accessed 13 April 2018).

European Commission, *C-ITS platform PHASE II-Cooperative Intelligent Transport Systems towards Cooperative, Connected and Automated Mobility,* Final Report, 2017f, available at: https://ec.europa.eu/transport/sites/transport/files/2017-09-c-its-platform-final-report.pdf (last accessed 12 April 2018).

European Commission, *Joint statement by Commissioners Oettinger, Bulc and Gabriel, on cooperative, connected and automated mobility,* Statement, 15 September 2017g, Frankfurt, available at: http://europa.eu/rapid/press-release_STATEMENT-17-3272_en.htm (last accessed 6 February 2018).

European Commission, *Blueprint for Sectoral Cooperation on Skills: Responding to Skills Mismatches at Sectoral Level: A Key Action of the New Skills Agenda for Europe*, 2017h, available at: http://bookshop.europa.eu/uri?target=EUB:NOTICE:KE0716170:EN:HTML (last accessed 12 April 2018).

European Commission, *CALL FOR PROPOSAL under "ERASMUS+" PROGRAMME-a new strategic approach (Blueprint) to sectoral cooperation on skills,* 10 April 2017i, available at: https://ec.europa.eu/growth/content/call-proposal-under-erasmus-programme-new-strategic-approach-blueprint-sectoral-0_en (last accessed 12 April 2018).

European Commission, *Driving Clean Mobility: Questions & Answers on the initiatives that protect the planet, empower its consumers, and defend its industry and workers,* Fact Sheet, 8 November 2017j, available at: http://europa.eu/rapid/press-release_MEMO-17-4243_en.htm (last accessed 12 April 2018).

European Commission, *Specifications for the provision of cooperative intelligent transport systems (C-ITS),* DG Mobility and Transport, 2017k, available at: https://ec.europa.eu/info/law/better-regulation/initiatives/ares-2017-2592333_en (last accessed 12 February 2018).

European Commission, *The race for automotive data,* Digital Transformation Monitor, 2017l, available at: https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_The%20race%20for%20automotive%20data%20v1.pdf (last accessed 11 April 2018).

European Commission, *Adoption of novel technologies across the automotive value chain,* Digital Transformation Monitor, 2017m, available at: https://ec.europa.eu/growth/tools-databases/dem/monitor/content/adoption-novel-technologies-across-automative-value-chain (last accessed 12 April 2018).

European Commission, *Smart, green and integrated transport*, EN Horizon 2020, Work Programme 2018-2020, 2017n, available at: http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-transport_en.pdf (last accessed 12 April 2018).

European Economic and Social Committee, *Implications of the digitalisation and robotisation of transport for EU policy-making*, TEN/632, 2017, available at: https://www.eesc.europa.eu/en/our-work/opinions-information-reports/opinions/implications-digitalisation-and-robotisation-transport-eu-policy-making (last accessed 12 April 2018).

European Sector Skills Council, *Automotive Industry Report,* 2016, available at: http://www.etrma.org/uploads/Modules/Documentsmanager/skill-council-automotive-report-2016---stampa4.pdf (last accessed 12 April 2018).

European Union, *Declaration of Amsterdam on cooperation in the field of connected and automated driving,* 14-15 April 2016, available at: https://www.regjeringen.no/contentassets/ba7ab6e2a0e14e39baa77f5b76f59d14/2016-04-08-declaration-of-amsterdam---final1400661.pdf (last accessed 13 April 2018).

Eurostat, *NACE Rev.2-Statistical Classification of Economic Activities in the European Community,* 2008, available at: http://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF (last accessed 2 April 2018).

Fagnant, D., and Kockelman, K., 'Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations', *Transportation Research Part A: Policy and Practice,* Vol. 77, 2015, pp. 164-181.

Fagnant, D., and Kockelman, K., 'The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios', *Transportation Research Part C: Emerging Technologies,* Vol. 40, 2014, pp. 1-13.

Fernández-Macías, E., *Automation, digitisation and platforms: implications for work and employment,* Concept Paper, Eurofound, 2017, available at: https://www.eurofound.europa.eu/sites/default/files/wpef17035.pdf (last accessed 12 April 2018).

Fernández-Macías, E., Hurley, J., and Bisello, M., *What do Europeans do at work? A task-based analysis: European Jobs Monitor 2016*, Eurofound, 2016, available at: https://www.researchgate.net/publication/304246760_What_do_Europeans_do_at_work_A_task-based_analysis (last accessed 12 April 2018).

Fildes, N., and Campbell, P., *Telecoms versus carmakers in race to get connected,* Financial Times, 13 November 2017, available at: https://www.ft.com/content/6c1b7f60-a9d3-11e7-93c5-648314d2c72c (last accessed 9 February 2018).

Fingas, J., *Mercedes and Bosch will test self-driving taxis in a few months*, engadget, 4 February 2018, https://www.engadget.com/2018/02/04/mercedes-and-bosch-will-test-self-driving-taxis-in-months/ (last accessed 26 April 2018).

Firnkorn, J., and Müller, M., 'Free-Floating Electric Carsharing-Fleets in Smart Cities: The Dawning of a Post-Private Car Era in Urban Environments?*', Environmental Science & Policy*, Vol. 45, 2015, pp. 30-40.

Fraedrich, E., Cyganski, R., Wolf, I., and Lenz, B., *User perspectives on autonomous driving. A Use-Case-Driven Study in Germany*, Geographisches Institut, Humboldt-Universität zu Berlin, 2016, available at: https://www.geographie.hu-berlin.de/de/institut/publikationsreihen/arbeitsberichte/download/Arbeitsberichte_Heft_187.pdf (last accessed 12 April 2018).

Frey, C.B., and Osborne, M.A., 'The future of employment: How susceptible are jobs to computerisation?', *Technological Forecasting and Social Change*, Vol. 114, Issue C, Oxford Martin, 2017, pp. 254-280.

Ford, M., *Rise of the Robots: Technology and the Threat of a Jobless Future*, Basic Books, New York, 2015.

Gamio, L., Rich, G., and McCabe, D., *Here's where jobs will be lost when robots drive trucks,* AXIOS, 22 February 2017, available at: https://www.axios.com/heres-where-jobs-will-be-lost-when-robots-drive-trucks-1513300554-58297c36-0cfb-4675-b3cd-9454d932ebbb.html (last accessed 6 March 2018).

Ganguli, N., Burns C., and Goldsberry R., *Supplying the future of mobility. Automotive suppliers in the evolving transportation ecosystem*, Deloitte University Press, 2016, available at: https://www2.deloitte.com/cn/en/pages/consumer-industrial-products/articles/supplying-the-future-of-mobility.html (last accessed 12 April 2018).

German Federal Ministry of Transport and Digital Infrastructure, *Action plan automated and connected driving,* 2nd High Level Structural Dialogue on 14th-15th September 2017 in Frankfurt/M., German Federal Ministry of Transport and Digital Infrastructure, 2017, available at: https://www.bmvi.de/SharedDocs/EN/Documents/DG/action-plan-automated-and-connected-driving.pdf?__blob=publicationFile (last accessed 12 April 2018).

German Federal Ministry of Transport and Digital Infrastructure, *Ethics Commission-Automated and Connected Driving,* 2017, available at: https://www.bmvi.de/SharedDocs/EN/publications/report-ethics-commission.pdf?__blob=publicationFile (last accessed 12 April 2018).

Gibbons, S. and Machin, S., *Transport and Labour Market Linkages: Empirical Evidence, Implications for Policy and Scope for Further UK Research,* Department of Transport, 2006, available at: http://bit.ly/bflHzU (last accessed 12 April 2018).

Gibson, G., Löhr, E., Hughes, D., Levin, S., Windisch, E., de Stasio, C., Fermi, F., Bielanska, D., Fiorello, D., Martino, A., Jégou, L., Grandserre, E., Skinner, I., and Glencross, R., *Support Study for the Impact Assessment Accompanying the Revision of the Eurovignette Directive (1999/62/EC),* Final Report, No MOVE/A3/119-2013, European Commission, 2017, available at: https://ec.europa.eu/transport/sites/transport/files/docs/2017-05-support-study-ia-revision-eurovignette-dir.pdf (last accessed 12 April 2018).

Gillespie, G., *Connected & Autonomous Vehicles: Developing the UK Supply Chain*, 2016, available at: https://www.drivemidlands.co.uk/wp-content/uploads/2016/03/Dr-George-Gillespie.pdf (last accessed 12 April 2018).

Goodall, W., Fishman, T.D., Bornstein, J., and Bonthron, B., *The rise of mobility as a service: Reshaping how urbanites get around*, Deloitte 2017, available at: https://www2.deloitte.com/nl/nl/pages/consumer-industrial-products/articles/the-rise-of-mobility-as-a-service.html (last accessed 13 April 2018).

Goos, M., Manning, A., and Salomons, A., 'Explaining job polarization: Routine-biased technological change and offshoring', *American Economic Review*, Vol. 104, No 8, 2014, pp. 2509-2526.

Goos, M., Manning, A., and Salomons, A., 'Job polarization in Europe', *American economic review*, Vol. 99, No 2, 2009, pp. 58-63.

Gordon, R.J., 'Does the "New Economy" Measure Up to the Great Inventions of the Past?*', Journal of Economic Perspectives, Vol.* 14, No 4, 2000, pp. 49-74.

Graetz, G., and Michaels, G., *Robots and Work*, IZA Discussion Paper, No 8938, 2015, available at: https://www.iza.org/en/publications/dp/8938/robots-at-work (last accessed 12 April 2018).

Gregory, T., Salomons, A., and Zierahn, U., *Racing with or against the machine? Evidence from Europe*, ZEW Discussion Papers, No 16-053, 2016.

Gruel, W., and Stanford J.M., 'Assessing the Long-term Effects of Autonomous Vehicles: A Speculative Approach', *Transportation Research Procedia*, Vol. 13, 2016, pp. 18-29.

Gundermann, S., Dressler, N., Winterhoff, M., Aulbur, W., and Bernhart, W., *On the road toward the autonomous truck: Opportunities for OEMs and suppliers*, 2015, available at: https://www.rolandberger.com/en/Publications/pub_autonomous_truck.html (last accessed 21 February 2018).

Haboucha, C.J., Ishaq, R., and Shiftan, Y., 'User preferences regarding autonomous vehicles', *Transportation Research Part C: Emerging Technologies*, Vol. 78, 2017, pp. 37-49.

Harper, C.D., Hendrickson, C.T., Mangones, S. and Samaras, C., 'Estimating potential increases in travel with autonomous vehicles for the non-driving, elderly and people with travel-restrictive medical conditions', *Transportation Research: Part C,* 2016.

Hawkins, A., *Volvo is reportedly scaling back its ambitious self-driving car experiment: The automaker had planned to deliver 100 autonomous SUVs to families in Sweden, China, and the UK,* The Verge, 14 December 2017, available at: https://www.theverge.com/

2017/12/14/16776466/volvo-drive-me-self-driving-car-sweden-delay (last accessed 5 February 2018).

Hawksworth, J., Berriman, R., and Goel, S., *Will robots really steal our jobs?: An international analysis of the potential long term impact of automation,* PwC, 2018, available at: https://www.pwc.com/hu/hu/kiadvanyok/assets/pdf/impact_of_automation_on_jobs.pdf (last accessed 12 April 2018).

Heinrichs, D., 'Autonomes Fahren und Stadtstruktur' in *Autonomes Fahren: Technische, rechtliche und gesellschaftliche Aspekte,* Springer, 2015, pp. 219-239.

Herzer, D., and Nunnenkamp, P., *FDI and income inequality: Evidence from Europe*, 2011.

Hill, N., Skinner, I., Zazias, G., Siskos, P., Petropoulos, A., Fragkiadakis, K., and Paroussos, L., *Assessing the impacts of selected options for regulating CO_2 emissions from new passenger cars and vans after 2020,* Final report for the European Commission, DG Climate Action, (forthcoming 2018).

Hohenberger, C., Spörrle, M., and Welpe, I.M., 'How and why do men and women differ in their willingness to use automated cars? The influence of emotions across different age groups'. *Transportation Research Part A: Policy and Practice,* Vol. 94, 2016, pp. 374-385.

Hollis, D., *U.S. not alone with driver shortage; it's a global issue,* Truckers News, 2016, available at: https://www.truckersnews.com/trucker-shortage-global-issue/ (last accessed March 2018).

Ibison, D., *Volvo Cars and Uber join forces to develop autonomous driving cars*, VOLVO CAR GROUP, 18 August 2016, available at: https://www.media.volvocars.com/global/en-gb/media/pressreleases/194795/volvo-cars-and-uber-join-forces-to-develop-autonomous-driving-cars (last accessed 26 April 2018).

Industry today, *What are the driving factors behind the driver shortage?,* Vol. 11, 2013, available at: https://industrytoday.com/article/what-are-the-driving-factors-behind-the-driver-shortage/ (last accessed 5 April 2018).

Innamaa, S., Smith, S., Barnard, Y., Rainville, L., Rakoff, H., Horiguchi, R., and Gellerma, H., *Trilateral Impact Assessment Framework for Automation in Road Transportation,* Draft Version 1.0, Trilateral Impact Assessment Sub-Group for Automation in Road Transportation, 2017, available at: https://connectedautomateddriving.eu/wp-content/uploads/2017/05/Trilateral_IA_Framework_Draft_v1.0.pdf (last accessed 11 April 2018).

Insurance Europe, *European Insurance in Figures: 2015 data,* available at: https://www.insuranceeurope.eu/european-insurance-figures-2015-data (last accessed 12 April 2018).

International Labour Organization, *ISCO-08, International standard classification of occupations 2008: structure, group definitions and correspondence tables*, International Labour Office, 2012, available at: http://www.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_172572.pdf (last accessed 12 April 2018).

ITF, *Urban Mobility System Upgrade-How shared self-driving cars could change city traffic,* International Transport Forum, OECD Publishing, 2015, available at: http://www.internationaltransportforum.org/Pub/pdf/15CPB_Self-drivingcars.pdf (last accessed 11 April 2018).

ITF, *Shared Mobility: Innovation for Liveable Cities,* International Transport Forum Policy Papers, No 21, OECD Publishing, 2016, available at: http://dx.doi.org/10.1787/5jlwvz8bd4mx-en (last accessed 12 April 2018).

ITF, *Managing the Transition to Driverless Road Freight Transport,* International Transport Forum Policy Papers, No 32, OECD Publishing, 2017, available at: http://dx.doi.org/10.1787/0f240722-en (last accessed 12 April 2018).

Janssen, R., Zwijnenberg, H., Blankers, I., and de Kruijff, J., *Truck Platooning. Driving the future of transportation,* TNO, 2015, available at: https://publications.tno.nl/publication/34616035/dLIjFM/janssen-2015-truck.pdf (last accessed 12 April 2018).

Karp, L., Kim, R., Liu, C., and Liu, B., *Insuring Autonomous Vehicles. An $81 Billion Opportunity between now and 2025,* Accenture and Stevens Institute of Technology, 2017, available at: https://www.accenture.com/t20170530T040532__w__/pl-en/_acnmedia/PDF-53/Accenture-Autonomous_Vehicles.pdf (last accessed 12 April 2018).

Kaviraj, K., *Jobs & Opportunities In The Driver-Less Vehicles Space,* LEVEL 10, 24 July 2017, available at: https://levelten.org/jobs-opportunities-driverless-vehicles/ (last accessed 5 March 2018).

KIA, *Listino prezzi 2018: Niro,* available at: https://www.kia.com/api/bin/docDownload?program=brochure&path=%2Fcontent%2Fdam%2Fkwcms%2Fkme%2Fit%2Fit%2Fassets%2Fcontents%2Futility%2Fprice-list%2F2018%2Faprile%2FListino_Kia_Niro_HEV-PHEV_Pubblico_08_01_2018.pdf (last accessed 16 April 2018).

Kilcarr, S., *The price tag for autonomous trucks still unclear,* FleetOwner, 9 December 2015, available at: http://www.fleetowner.com/technology/price-tag-autonomous-trucks-still-unclear (last accessed 5 March 2018).

Krause, J., et al., *EU Road Vehicle Energy Consumption and CO_2 emissions by 2050 – Expert-Based Scenarios,* forthcoming 2018.

Kyriakidis, M., Happee, R., and de Winter, J.C., 'Public opinion on automated driving: Results of an international questionnaire among 5000 respondents', *Transportation research part F: traffic psychology and behaviour,* Vol. 32, 2015a, pp. 127-140.

Kyriakidis, M., van de Weijer, C., van Arem, B., and Happee, R., *The Deployment of Advanced Driver Assistance Systems in Europe*, SSRN Electronic Journal, 2015b, available at: http://www.ssrn.com/abstract=2559034 (last accessed 11 April 2018).

Lallemand, T., and Rycx, F., *Are Young and Old Workers Harmful for Firm Productivity?*, IZA Discussion Paper, No 3938, 2009, available at: https://www.iza.org/publications/dp/3938 (last accessed 12 April 2018).

Lanctot R., *Accelerating the Future: The Economic Impact of the Emerging Passenger Economy*, Strategy Analytics, 2017, available at: https://newsroom.intel.com/newsroom/wp-content/uploads/sites/11/2017/05/passenger-economy.pdf (last accessed 11 April 2018).

Landau, D.M., *5G: The Communications Key to Autonomous Driving,* IQ, 2 January 2017, available at: https://iq.intel.com/5g-communications-key-autonomous-driving/ (last accessed 6 February 2018).

Lastauto Omnibus-Katalog, ISBN-10: 361330824X, ISBN-13: 978-3613308244, 2017.

Leech, J., Whelan, G., Bhaiji, M., Hawes, M., and Scharring, K., *Connected and Autonomous Vehicles - The UK Economic Opportunity*, KPMG and SMMT DRIVING THE MOTOR

INDUSTRY, 2015, available at: https://home.kpmg.com/content/dam/kpmg/pdf/2015/04/connected-and-autonomous-vehicles.pdf (last accessed 12 April 2018).

Levin, M.W., and Boyles, S.D., 'Effects of Autonomous Vehicle Ownership on Trip, Mode, and Route Choice', *Transportation Research Record: Journal of the Transportation Research Board,* Vol. 2493, 2015, pp. 29-38.

Lienert, P., *Self-driving cars could generate billions in revenue-U.S. study,* REUTERS, 5 March 2015, available at: https://www.reuters.com/article/usa-autos-autonomous/self-driving-cars-could-generate-billions-in-revenue-u-s-study-idUSL1N0W52CQ20150305 (last accessed 3 April 2018).

Litman, T., *Understanding transport demands and elasticities,* Victoria Transport Policy Institute, 2017, available at: http://www.vtpi.org/elasticities.pdf (last accessed 12 April 2018).

Litman, T., *Autonomous vehicle implementation predictions*, Victoria Transport Policy Institute, 2018, available at: https://www.vtpi.org/avip.pdf (last accessed 12 April 2018).

Manyika, J., Chui, M., Bughin, J., Dobbs, R., Bisson, P., and Marrs, A., *Disruptive technologies: Advances that will transform life, business and the global economy,* McKinsey&Company, 2013, available at: https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Disruptive%20technologies/MGI_Disruptive_technologies_Full_report_May2013.ashx (last accessed 12 April 2018).

Manyika, J., Lund, S., Chui, M., Bughin, J., Woetzel, J., Batra, P., and Sanghvi, S., *Jobs Lost, Jobs Gained: Workforce Transitions in a Time of Automation*, McKinsey&Company, 2017, available at: https://www.mckinsey.com/~/media/McKinsey/Global%20Themes/Future%20of%20Organizations/What%20the%20future%20of%20work%20will%20mean%20for%20jobs%20skills%20and%20wages/MGI-Jobs-Lost-Jobs-Gained-Report-December-6-2017.ashx (last accessed 12 April 2018).

Marchetti, C., 'Anthropological Invariants in Travel Behavior', *Technological Forecasting and Social Change*, Internal Publication, International Institute for Applied Systems Analysis, Vol. 47, No 1, 1994, pp. 75-88.

Marin, D., 'A New International Division of Labor in Europe: Outsourcing and Offshoring to Eastern Europe*', Journal of the European Economic Association*, Vol. 4, No 2/3, 2006, pp. 612-622.

Marshall, A., *After Peak Hype, Self-Driving Cars enter the Trough of Disillusionment*, Transportation, 29 December 2017, available at: https://www.wired.com/story/self-driving-cars-challenges/ (last accessed 14 February 2018).

Martens, B., and Müller-Langer F., *Multi-sided markets in digital car data*, Preliminary draft, European Commission, (forthcoming 2018).

McCarthy, M., Seidl, M., Mohan, S., Hopkin, J., Stevens, A., and Ognissanto, F., *Access to In-vehicle Data and Resources*, Final report, European Commission, 2017, available at: https://ec.europa.eu/transport/sites/transport/files/2017-05-access-to-in-vehicle-data-and-resources.pdf (last accessed 12 April 2018).

McCarthy, J., *Volkswagen invests $300m in Gett accounting for more than half of its fundraiser*, THE DRUM, 24 May 2016, available at: http://www.thedrum.com/news/2016/05/24/volkswagen-invests-300m-gett-accounting-more-half-its-fundraiser (last accessed 26 April 2018).

McCauley, R., *Why Autonomous and Electric Vehicles Are Inextricably Linked: The future of autonomous vehicles is directly tied to the cost-effectiveness of electric vehicles,* 15 March 2017, available at: http://www.govtech.com/fs/why-autonomous-and-electric-vehicles-are-inextricably-linked.html (last accessed 5 February 2018).

McFarland, M., *How free self-driving car rides could change everything,* 1 September 2017, available at: http://money.cnn.com/2017/09/01/technology/future/free-transportation-self-driving-cars/index.html (last accessed 5 February 2018).

McLaughlin, R., *How Driverless Cars Could Drive Even Deeper Economic Inequality*, FASTCOMPANY, 11 Jun 2017, available at: https://www.fastcompany.com/40490471/how-driverless-cars-could-drive-even-deeper-economic-inequality (last accessed 7 March 2018).

Meschtscherjakov, A., Trösterer, S., Mirnig, A.G., McCall, R., McGee, F., and Tscheligi, M., *Driver De-Skilling and its Effect for Safety in Autonomous Driving*, Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria.

Milakis, D., Snelder, M., van Arem, B., van Wee, G.P., and Correia, G.H.D.A., 'Development and Transport Implications of Automated Vehicles in the Netherlands: Scenarios for 2030 and 2050', *European Journal of Transport and Infrastructure Research*, Vol. 17, Issue 1, 2017.

Miller, A., *The road to autonomy: driverless cars and the implications for insurance*, Thinkpiece 118, Thatcham research, 2015, available at: http://www.cii.co.uk/media/6321203/tp118_miller_thatcham_driverless_cars_vf_july2015.pdf (last accessed 2 May 2018).

Miller, J., 'Autonomous Vehicles: Implications for Employment Demand', *The Bridge*, Vol. 45, No 3, 2015, pp. 5-11.

Moavenzadeh, J., *How Driverless Cars Can Shrink America's Income Gap,* FORTUNE, 22 May 2016, available at: http://fortune.com/2016/05/22/driverless-cars-income-gap/ (last accessed 9 March 2018).

Mohr, D., Kaas, H.W., Gao, P., Cornet, A., Wee, D., Inampudl, S., Krieger, A., Richter, G., Habeck, A., and Newman, J., *Connected car, automotive value chain unbound,* McKinsey&Company, 2014, available at: https://www.mckinsey.de/files/mck_connected_car_report.pdf (last accessed 12 April 2018).

Mokyr, J., Vickers, C., and Ziebarth, N.L., 'The history of technological anxiety and the future of economic growth: Is this time different?', *Journal of Economic Perspectives*, Vol. 29, No 3, 2015, pp. 31-50.

Mosquet, X., Dauner, T., Lang, N., Rubmann, N., Mei-Pochtler, A., Agrawal, R., and Schmieg, F., *Revolution in the Driver's Seat: The Road to Autonomous Vehicles*, Boston Consulting Group*,* 2015, available at: https://www.bcg.com/it-it/publications/2015/automotive-consumer-insight-revolution-drivers-seat-road-autonomous-vehicles.aspx (last accessed 12 April 2018).

Nash, M., 'Training, not tech, is slowing AV development', *Automotive Megatrends Magazine*, Q1 2018, pp. 53-55, available at: https://automotivemegatrends.com/automotive-megatrends-magazine-q1-2018/ (last accessed 12 April 2018).

Naughton, K., *Volvo Plans to Offer Fully Self-Driving Car to Luxury Buyers,* Bloomberg, 29 September 2016, available at: https://www.bloomberg.com/news/articles/2016-09-

29/volvo-plans-to-offer-fully-self-driving-car-to-luxury-buyers (last accessed 4 April 2018).

Nica, G., *BMW, Audi and Daimler Join Forces to form 5G Automotive Association,* BMWBLOG, 28 September 2016, available at: http://www.bmwblog.com/2016/09/28/bmw-audi-daimler-join-forces-form-5g-automotive-association/ (last accessed 13 April 2018).

Nieuwenhuijsen, J., Correia, G.H. de Almeida, Milakis, D., van Arem, B., and van Daalen, E., 'Towards a Quantitative Method to Analyze the Long-Term Innovation Diffusion of Automated vehicles Technology Using System Dynamics', *Transportation Research Part C: Emerging Technologies,* Vol. 86, 2018, pp. 300-327.

Nijland, H., and van Meerkerk, J., 'Mobility and environmental impacts of car sharing in the Netherlands', *Environmental Innovation and Societal Transitions,* Vol. 23, 2017, pp. 84-91.

Nowak, G., Maluck, J., Stürmer, C., and Pasemann, J., *The era of digitized trucking: Transforming the logistics value chain*, PwC strategy&, 2016, available at: https://www.strategyand.pwc.com/reports/era-of-digitized-trucking (last accessed 7 April 2018).

OECD, *Adults, Computers and Problem Solving: What's the Problem?,* OECD Skills Studies, OECD Publishing, 2015, available at: http://www.oecd.org/education/adults-computers-and-problem-solving-9789264236844-en.htm (last accessed 5 April 2018).

OECD, *Skills Matter: Further Results from the Survey of Adult Skills*, OECD Skills Studies, OECD Publishing, 2016, available at: http://www.oecd-ilibrary.org/education/skills-matter_9789264258051-en (last accessed 11 April 2018).

Olsen, K.B., *Productivity Impacts of Offshoring and Outsourcing: A Review,* Working Paper 2006/1, OECD Directorate for Science, Technology and Industry (STI), 2006, available at: https://www.oecd-ilibrary.org/docserver/685237388034.pdf?expires=1523622582&id=id&accname=guest&checksum=B4D24455718035B2619599D0CF90576C (last accessed 12 April 2018).

Pakusch, C., and Bossauer, P., 'User acceptance of fully autonomous public transport', In *Proceedings of the 14th international joint conference on e-business and telecommunications*, Vol. 4, 2017, pp. 52-60.

Palmer, K., *Driverless cars will shave '£265' off insurance premiums in five years,* The Telegraph, 23 May 2015, available at: http://www.telegraph.co.uk/finance/personalfinance/insurance/motorinsurance/11623218/Driverless-cars-will-shave-265-off-insurance-premiums-in-five-years.html (last accessed March 2018).

Panetta, K., *Top Trends in the Gartner Hype Cycle for Emerging Technologies,* Gartner, 15 August 2017, available at: https://www.gartner.com/smarterwithgartner/top-trends-in-the-gartner-hype-cycle-for-emerging-technologies-2017/ (last accessed 6 April 2018).

Peters, A., *The Grocery Store Of The Future Is Mobile, Self-Driving, And Run By AI,* FASTCOMPANY, 13 Jun 2017, available at: https://www.fastcompany.com/40429419/this-tiny-grocery-store-is-mobile-self-driving-and-run-by-ai (last accessed 5 February 2018).

Peterson, B., 'The Vision of Automated Driving: What is it good for? Answers from Society with Economical and Organizational Perspectives', *44th European Microwave Conference*, IEEE, Rome, 2014, pp. 1723-1729, available at: http://ieeexplore.ieee.org/document/6986789/ (last accessed 12 April 2018).

Poletti, T., *Want to invest in self-driving cars? Check out the chips,* MarketWatch, 27 August 2016, available at: https://www.marketwatch.com/story/want-to-invest-in-self-driving-cars-check-out-the-chips-2016-08-26 (last accessed at 4 April 2018).

POLIS, *Road Vehicle Automation and Cities and Regions,* Polis-European Cities and Regions Networking for Innovative Transport Solutions, 2018, available at: https://www.polisnetwork.eu/uploads/Modules/PublicDocuments/polis_discussion_paper_automated_vehicles.pdf (last accessed 6 March 2018).

Prieto, M., Baltas, G., and Stan, V., 'Car Sharing Adoption Intention in Urban Areas: What Are the Key Sociodemographic Drivers?', *Transportation Research Part A: Policy and Practice,* Vol. 101, 2017, pp. 218-227.

Razin, E., *How Driverless Cars Could Disrupt The Real Estate Industry,* Forbes, 11 March 2018, available at: https://www.forbes.com/sites/elyrazin/2018/03/11/how-driverless-cars-could-disrupt-the-real-estate-industry/#366d3cab13c1 (last accessed 13 March 2018).

Rea, B., Stachura, S., Wallace, L., and Pankratz, D.M., *Making the Future of Mobility Work: How the New Transportation Ecosystem Could Reshape Jobs and Employment*, Deloitte Review, 2017, available at: https://www2.deloitte.com/content/dam/insights/us/articles/3876_Making-the-FoM-work/DUP_Making-FoM-work-reprint.pdf (last accessed 12 April 2018).

Renda, A., *Ethics, algorithms and self-driving cars-a CSI of the 'trolley problem',* No 2018/02, 2018, available at: https://www.ceps.eu/system/files/PI%202018-02_Renda_TrolleyProblem.pdf (last accessed 12 April 2018).

Römer, M., Gaentzle, S., and Wess, C., *How Automakers Can Survive the Self-Driving Era,* ATKearney, 2016, available at: https://www.atkearney.com/automotive/article?/a/how-automakers-can-survive-the-self-driving-era (last accessed 4 February 2018).

Saam, M., Niebel, T., and Schulte, P., *The Sectoral Impact of the Digitalisation of the Economy,* Results of The Study Smart 2016/0054 for DG Connect, forthcoming 2018.

SAE International, *J3016 Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles,* Surface vehicle recommended practice, 2016.

SAE International, *Automated driving, levels of driving automation are defined in new SAE international standard J3016,* 2014, available at: http://www.sae.org/misc/pdfs/automated_driving.pdf (last accessed 12 April 2018).

Salvetti, S., *Trasporto pesante, la sostenibilità è l'orizzonte di Scania,* LIFEGATE, 5 April 2017, available at: https://www.lifegate.it/persone/stile-di-vita/trasporto-sostenibilita-scania (last accessed 6 March 2018).

SARTRE, D4.3, *Report on fuel consumption*, APPLUS+IDIADA, 2014.

Schaeller, B., *Unsustainable? The Growth of App-Based Ride Services and Traffic, Travel and the Future of New York City*, Schaller Consulting, 2017, available at: http://schallerconsult.com/rideservices/unsustainable.htm (last accessed 12 April 2018).

Schiebe, S., *With the aim of increasing safety in road traffic, Volkswagen will enable vehicles to communicate with each other as from 2019,* Volkswagen, 28 June 2017, available at: https://www.volkswagen-media-services.com/en/detailpage/-/detail/With-the-aim-of-increasing-safety-in-road-traffic-Volkswagen-will-enable-vehicles-to-commu nicate-with-each-other-as-from-2019/view/5234247/7a5bbec13158edd433c6630f5ac445da?p_p_auth=ugQ4cXwM (last accessed 12 February 2018).

Schoettle, B., and Sivak, M., *Potential Impact of Self-driving Vehicles on Household Vehicle Demand and Usage*, The University of Michigan Transportation Research Institute, 2015, available at: http://www.umtri.umich.edu/our-results/publications/potential-impact-self-driving-vehicles-household-vehicle-demand-and-usage (last accessed 12 April 2018).

Seba, T., *Stakeholders Workshop on Challenges & Opportunities of Automated Road Transport-13th of June 2017,* European Commission, 2017, available at: https://webcast.ec.europa.eu/stakeholders-workshop-on-challenges-opportunities-of-automated-road-transport-13th-of-june-2017 (last accessed 9 February 2018).

Securing America's Future Energy, Securing America's Future Energy: Quarterly Donor Update, Q1 2017, available at: http://secureenergy.org/q1-2017-update/ (last accessed 5 February 2018).

Shaheen, S., and Chan, N., *Mobility and the Sharing Economy: Impacts Synopsis,* Transportation Sustainability Research Center, University of California, 2015, available at: http://tsrc.berkeley.edu/node/850 (last accessed 12 April 2018).

Shirouzu, N., *Millennials are shifting car ownership model; ask Toyota*, REUTERS, 10 February 2016, available at: https://www.reuters.com/article/us-autos-toyota-millennials/millennials-are-shifting-car-ownership-model-ask-toyota-idUSKCN0VI295 (last accessed 5 February 2018).

Silberg, G., Mayor, T., Dubner, T., Anderson, J., and Shin, L., *The clockspeed dilemma,* KPMG, 2015, available at: https://home.kpmg.com/xx/en/home/insights/2015/12/the-clockspeed-dilemma-gary-silberg-head-of-automotive-kpmg-us.html (last accessed 12 April 2018).

Sivak, M., and Schoettle, B., *Recent Decreases in the Proportion of Persons with a Driver's License Across all Age Groups,* University of Michigan Transportation Research Institute, 2016, available at: https://trid.trb.org/view/1480411 (last accessed 12 April 2018).

Sivak, M., and Schoettle, B., *Road safety with self-driving vehicles: general limitations and road sharing with conventional vehicles,* University of Michigan Transportation Research Institute, 2015, available at: https://deepblue.lib.umich.edu/handle/2027.42/111735 (last accessed 12 April 2018).

Somers, A., and Weeratunga, K., *Automated vehicles: Are we ready?,* Report for Main Roads Western Australia, 2015.

Spulber, A., and Wallace, R., *Impact of Automated Vehicle Technologies on Driver Skills,* Transportation Systems Analysis Group, 2016, available at: http://www.cargroup.org/publication/impact-of-automated-vehicle-technologies-on-driver-skills/ (last accessed 12 April 2018).

Statista, *Global autonomous vehicle component market potential for automotive suppliers and semiconductor makers from 2015 to 2050 (in million U.S. dollars),* 2015a, available at: https://www.statista.com/statistics/677950/autonomous-vehicle-component-market-potential-worldwide/ (last accessed 6 February 2018).

Statista, *Projected size of the global market for V2X technologies in vehicles from 2020 to 2050* (in million U.S. dollars),* 2015b, available at: https://www.statista.com/statistics/565790/global-market-size-for-v2x-in-vehicles/ (last accessed 6 February 2018).

Statista, *Estimated shipments of connected cars globally from 2017 to 2020 (in million units),* 2017, available at: https://www.statista.com/statistics/743400/estimated-connected-car-shipments-globally/ (last accessed 6 February 2018).

Statista, *Dossier: Autonomous Vehicle Technology*, 2018, available at: https://www.statista.com/study/28221/driverless-cars-statista-dossier/ (last accessed 6 February 2018).

Sterman, J.D., *Business dynamics: systems thinking and 168odelling for a complex world*, New York, McGraw-Hill/Irwin, 2000, available at: https://www.researchgate.net/publication/44827001_Business_Dynamics_System_Thinking_and_Modeling_for_a_Complex_World (last accessed 12 April 2018).

Stone, P., Brooks, R., Brynjolfsson, E., Calo, R., Etzioni, O., Hager, G., Hirschberg, J., Kalyanakrishnan, S., Kamar, E., Kraus, S., Leyton-Brown, K., Parkes, D., Press, W., Saxenian, A., Shah, J., Tambe, M., and Teller, A., *Artificial intelligence and Life in 2030. One Hundred Year Study on Artificial Intelligence: Report of the 2015-2016 Study Panel,* Stanford University, 2016.

Takahashi, D., *Aimotive raises $38 million for self-driving car software,* VentureBeat, 4 January 2018, available at: https://venturebeat.com/2018/01/04/aimotive-raises-38-million-for-self-driving-car-software/ (last accessed 3 April 2018).

Tavasszy, L.A., and Janssen, R., *The value case for truck platooning,* 10.13140/RG.2.2.13325.54247, 2016, available at: https://www.researchgate.net/publication/312116529_The_value_case_for_truck_platooning (last accessed 12 April 2018).

The White House, *Artificial Intelligence, Automation, and the Economy*, 2016, available at: https://www.whitehouse.gov/sites/whitehouse.gov/files/images/EMBARGOED%20AI%20Economy%20Report.pdf (last accessed 12 April 2018).

Thiel, C., Drossinos, Y., Krause, J., Harrison, G., Gkatzoflias, D., and Donati, A.V., 'Modelling Electro-mobility: An Integrated Modelling Platform for Assessing European Policies', *Transportation Research Procedia,* Vol. 14, 2016, pp. 2544-2553.

Thierer, A.D., and Hagemann, R., 'Removing Roadblocks to Intelligent Vehicles and Driverless Cars', *Wake Forest Journal of Law & Policy*, Vol. 5, No 2, 2015, pp. 339-391, available at: https://www.mercatus.org/system/files/Thierer%26Hagemann-RoadblockstoDriverlessCars%28FINAL%29.pdf (last accessed 6 March 2018).

Todd, S., and Waters, W., *Europe's leading reefer haulier highlights driver shortage,* Lloyd's Loading List, 16 January 2018, available at: https://www.lloydsloadinglist.com/freight-directory/news/Europe%E2%80%99s-leading-reefer-haulier-highlights-driver-shortage/71128.htm?mc_cid=add6e41d60&mc_eid=f2d7fc2386#.WuHzz6JM2uP (last accessed 5 February 2018).

Transparency Market Research, *Connected Car Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast 2013-2019,* 2013, available at: https://www.transparencymarketresearch.com/connected-car.html (last accessed 12 February 2018).

UK Department for Transport, *National Travel Survey: Change in travel since 1965,* 2015, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/457732/nts2014-factsheet.pdf (last accessed 12 April 2018).

UNESCO Institute for Statistics, *International Standard Classification of education,* ISCED 2011, 2012, available at: http://uis.unesco.org/sites/default/files/documents/international-standard-classification-of-education-isced-2011-en.pdf (last accessed 12 April 2018).

Wadud, Z., 'Fully Automated Vehicles: A Cost of Ownership Analysis to Inform Early Adoption', *Transportation Research Part A: Policy and Practice,* Vol. 101, 2017, pp. 163-176.

Wadud, Z., MacKenzie, D., and Leiby, P., 'Help or hindrance? The Travel, Energy and Carbon Impacts of Highly Automated Vehicles', *Transportation Research Part A: Policy and Practice*, Vol. 86, 2016, pp. 1-18.

Wee, D., Kässer, M., Bertoncello, M., Heineke, K., Eckhard, G., Hölz, J., Saupe, F., and Müller, T., *Competing for the connected customer-perspectives on the opportunities created by car connectivity and automation*, McKinsey&Company, 2015, available at: https://www.mckinsey.com/~/media/mckinsey/industries/automotive%20and%20assembly/our%20insights/how%20carmakers%20can%20compete%20for%20the%20connected%20consumer/competing_for_the_connected_customer.ashx (last accessed 12 April 2018).

Weiss, J., Hledik, R., Lueken, R., Lee, T., and Gorman, W., 'The electrification accelerator: Understanding the implications of autonomous vehicles for electric utilities', *The Electricity Journal*, Vol. 30, No 10, 2017, pp. 50-57.

World Economic Forum, *Digital Transformation of Industries: Logistics Industry,* White Paper in collaboration with Accenture, 2016a, available at: http://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/digital-enterprise-narrative-final-january-2016.pdf (last accessed 12 April 2018).

World Economic Forum, *Digital Transformation of Industries: Automotive Industry,* White Paper in collaboration with Accenture, 2016b, available at: http://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/wef-dti-automotivewhitepaper-final-january-2016.v1.pdf (last accessed 12 April 2018).

Yano Research Institute, *Consumer Survey on Automated Driving Systems in Japan, US and Europe: Key Research Findings 2017,* 2018, available at: https://www.yanoresearch.com/press/press.php/001794 (last accessed 12 April 2018).

List of abbreviations

5G	5th Generation wireless systems
5GAA	5G Automotive Alliance
ACEA	European Automobile Manufacturers' Association
ADAS	Advanced Driver Assistance Systems
AI	Artificial Intelligence
AMT	Automated Mechanical Transmission
API	Application Programming Interface
ART	Automated Road Transport
ATM	Automatic Teller Machine
AV	Automated Vehicle
AVO	Average Vehicle Occupancy
B2B	Business-to-Business
BL	Baseline
ca.	circa
CAD	Connected and Automated Driving
CAGR	Compound Annual Growth Rate
CAV	Connected and Automated Vehicle
CCAM	Cooperative, Connected and Automated Mobility
CEDEFOP	Centre Européen pour le Développement de la Formation Professionnelle
C-ITS	Cooperative Intelligent Transport Systems
DDT	Dynamic Driving Task
DG CLIMA	Directorate-General for Climate Action
DG ENER	Directorate-General for Energy
DIONE	Fleet impact model
EASC	European Automotive Skills Council
EATA	European Automotive-Telecom Alliance
ECU	Electronic Control Unit
EESC	European Economic and Social Committee
EJM	European Jobs Monitor

ESC	Electronic Stability Control
EseG	European Socio-Economic Groups
ESJ	European Skills and Jobs Survey
ETRMA	The European Tyre & Rubber Manufacturers’ Association
ETSI	European Telecommunications Standards Institute
EU	European Union
EV	Electric Vehicle
FDI	Foreign Direct Investments
FT	Freight Transport
FTE	Full-Time Equivalent
G7	Group of Seven
GB	Gigabyte
GDP	Gross Domestic Product
GECO	Global Energy and Climate Outlook
GEM-E3	General Equilibrium Model for Economy-Energy-Environment
GVA	Gross Value Added
Gvkm	Billion vehicle kilometre
h	hours
H2020	Horizon 2020
HCV	Heavy Commercial Vehicle
HLG	High Level Group
HMI	Human-Machine Interface
ICE	Internal Combustion Engine
ICT	Information and Communications Technology
IO	Individually Owned
ISCED	International Standard Classification of Education
ISCO	International Standard Classification of Occupations
IT	Information Technology
ITF	International Transport Forum
ITS	Intelligent Transport System

JRC	Joint Research Centre
km	kilometre
KPI	Key Performance Indicator
ktoe	thousands of tonnes of oil equivalent
kW	kiloWatt
kWh	kiloWatt hour
L0-L5	Levels of automation 0 to 5
LCV	Light Commercial Vehicle
LFS	Labour Force Survey
LFS	Labour Force Survey
LTE	Long Term Evolution
MaaS	Mobility-as-a-Service
MID	Motor Insurance Directive
MWh	Megawatt hour
n.b	nota bene
n.e.c.	not elsewhere classified
NA	National Accounts
NACE	Nomenclature statistique des Activités économiques dans la Communauté Européenne
NUTS	Nomenclature des Unités Territoriales Statistiques
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
PAYD	Pay-As-You-Drive
pkm	passenger-kilometre
PLD	Product Liability Directive
PMT	Personal Miles Travelled
POTEnCIA	Policy Oriented Tool for Energy and Climate Change Impact Assessment
Q	Quarter
R&D	Research and Development
SAV	Shared Automated Vehicle
SBS	Structural Business Statistics

Sc1-Sc3	Scenario 1 to 3
SD	System Dynamics
StVG	Road Traffic Act, Strassenverkehrsgesetz
TCO	Total Cost of Ownership
tkm	tonne-kilometre
TWh	TeraWatt hour
UBI	Usage-Based Insurance
UNECE	United Nations Economic Commission for Europe
V2G	Vehicle-to-grid
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-Everything
VA	Value Added
VKT	Vehicle Kilometres Travelled
VMT	Vehicle Miles Travelled
VOT	Value-of-Time
VTTS	Value of Travel Time Saved
WEF	World Economic Forum

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Annexes

Annex 1. Definitions of economic sectors

Table 44 shows the sectors analysed in this study, based on the Nomenclature statistique des Activités économiques dans la Communauté Européenne (NACE) Rev. 2 classification of economic activities (Eurostat, 2008).

Table 44. Sectors analysed in the present study, combining relevant NACE Rev. 2 classes of economic activities

Sector	Code	Description	Detailed description
Automotive	C27.11	Manufacture of electric motors, generators and transformers	This class includes: — manufacture of electric motors (except internal combustion engine starting motors) — manufacture of distribution transformers, electric — manufacture of arc-welding transformers — manufacture of fluorescent ballasts (i.e. transformers) — manufacture of substation transformers for electric power distribution — manufacture of transmission and distribution voltage regulators — manufacture of power generators (except battery charging alternators for internal combustion engines) — manufacture of motor generator sets (except turbine generator set units) — rewinding of armatures on a factory basis This class excludes: — manufacture of electronic component-type transformers and switches, see 26.11 — manufacture of electric welding and soldering equipment, see 27.90 — manufacture of solid state inverters, rectifiers and converters, see 27.90 — manufacture of turbine-generator sets, see 28.11 — manufacture of starting motors and generators for internal combustion engines, see 29.31

Sector	Code	Description	Detailed description
Automotive *(continued)*	C27.40	Manufacture of electric lighting equipment	This class includes: — manufacture of discharge, incandescent, fluorescent, ultra-violet, infra-red etc. lamps, fixtures and bulbs — manufacture of ceiling lighting fixtures — manufacture of chandeliers — manufacture of table lamps (i.e. lighting fixture) — manufacture of Christmas tree lighting sets — manufacture of electric fireplace logs — manufacture of flashlights — manufacture of electric insect lamps — manufacture of lanterns (e.g. carbide, electric, gas, gasoline, kerosene) — manufacture of spotlights — manufacture of street lighting fixtures (except traffic signals) — manufacture of lighting equipment for transportation equipment (e.g. for motor vehicles, aircraft, boats) — manufacture of non-electrical lighting equipment This class excludes: — manufacture of glassware and glass parts for lighting fixtures, see 23.19 — manufacture of current-carrying wiring devices for lighting fixtures, see 27.33 — manufacture of ceiling fans or bath fans with integrated lighting fixtures, see 27.51 — manufacture of electrical signalling equipment such as traffic lights and pedestrian signalling equipment, see 27.90 — manufacture of electrical signs, see 27.90

Sector	**Code**	**Description**	**Detailed description**
Automotive *(continued)*	C28.11	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines	This class includes: — manufacture of internal combustion piston engines, except motor vehicle, aircraft and cycle propulsion engines: ○ marine engines ○ railway engines — manufacture of pistons, piston rings, carburettors and such for all internal combustion engines, diesel engines etc. — manufacture of inlet and exhaust valves of internal combustion engines — manufacture of turbines and parts thereof: ○ steam turbines and other vapour turbines ○ hydraulic turbines, waterwheels and regulators thereof ○ wind turbines ○ gas turbines, except turbojets or turbo propellers for aircraft propulsion — manufacture of boiler-turbine sets — manufacture of turbine-generator sets — manufacture of engines for industrial application This class excludes: — manufacture of electric generators (except turbine generator sets), see 27.11 — manufacture of prime mover generator sets (except turbine generator sets), see 27.11 — manufacture of electrical equipment and components of internal combustion engines, see 29.31 — manufacture of motor vehicle, aircraft or cycle propulsion engines, see 29.10, 30.30, 30.91 — manufacture of turbojets and turbo propellers, see 30.30

Sector	Code	Description	Detailed description
Automotive *(continued)*	C29	Manufacture of motor vehicles, trailers and semi-trailers	This division includes the manufacture of motor vehicles for transporting passengers or freight. The manufacture of various parts and accessories, as well as the manufacture of trailers and semi-trailers, is included here. The maintenance and repair of vehicles produced in this division are classified in 45.20.
	G45.1	Sale of cars and light motor vehicles	This class includes: — wholesale and retail sale of new and used vehicles: ○ passenger motor vehicles, including specialised passenger motor vehicles such as ambulances and minibuses, etc. (with a weight not exceeding 3,5 tons) — wholesale and retail sale of off-road motor vehicles (with a weight not exceeding 3,5 tons) This class excludes: — wholesale and retail sale of parts and accessories for motor vehicles, see 45.3 — renting of motor vehicles with driver, see 49.3 — renting of motor vehicles without driver, see 77.1
	G45.3	Sale of motor vehicle parts and accessories	This group includes wholesale and retail trade of all kinds of parts, components, supplies, tools and accessories for motor vehicles, such as: ○ rubber tyres and inner tubes for tyres ○ spark plugs, batteries, lighting equipment and electrical parts

Sector	Code	Description	Detailed description
Electronics and software	C26.20	Manufacture of computers and peripheral equipment	This class includes the manufacture and/or assembly of electronic computers, such as mainframes, desktop computers, laptops and computer servers; and computer peripheral equipment, such as storage devices and input/output devices (printers, monitors, keyboards). Computers can be analog, digital, or hybrid. Digital computers, the most common type, are devices that do all of the following: (1) store the processing program or programs and the data immediately necessary for the execution of the program, (2) can be freely programmed in accordance with the requirements of the user, (3) perform arithmetical computations specified by the user and (4) execute, without human intervention, a processing program that requires the computer to modify its execution by logical decision during the processing run. Analog computers are capable of simulating mathematical models and comprise at least analog control and programming elements. This class includes: — manufacture of desktop computers — manufacture of laptop computers — manufacture of main frame computers — manufacture of hand-held computers (e.g. PDA) — manufacture of magnetic disk drives, flash drives and other storage devices — manufacture of optical (e.g. CD-RW, CD-ROM, DVD-ROM, DVD-RW) disk drives — manufacture of printers — manufacture of monitors — manufacture of keyboards — manufacture of all types of mice, joysticks, and trackball accessories — manufacture of dedicated computer terminals — manufacture of computer servers — manufacture of scanners, including bar code scanners

Sector	Code	Description	Detailed description
Electronics and software *(continued)*	C26.20 *(conti-nued)*	Manufacture of computers and peripheral equipment *(continued)*	— manufacture of smart card readers — manufacture of virtual reality helmets — manufacture of computer projectors (video beamers) — manufacture of computer terminals, like automatic teller machines (ATM's), point-of-sale (POS) terminals, not mechanically operated — manufacture of multi-function office equipment performing two or more of following functions: printing, scanning, copying, faxing This class excludes: — reproduction of recorded media (computer media, sound, video, etc.), see 18.20 — manufacture of electronic components and electronic assemblies used in computers and peripherals, see 26.1 — manufacture of internal/external computer modems, see 26.12 — manufacture of interface cards, modules and assemblies, see 26.12 — manufacture of loaded electronic boards, see 26.12 — manufacture of modems, carrier equipment, see 26.30 — manufacture of digital communication switches, data communications equipment (e.g. bridges, routers, gateways), see 26.30 — manufacture of consumer electronic devices, such as CD players and DVD players, see 26.40 — manufacture of television monitors and displays, see 26.40 — manufacture of video game consoles, see 26.40 — manufacture of blank optical and magnetic media for use with computers or other devices, see 26.80

Sector	Code	Description	Detailed description
Electronics and software *(continued)*	C26.40	Manufacture of consumer electronics	This class includes the manufacture of electronic audio and video equipment for home entertainment, motor vehicle, public address systems and musical instrument amplification. This class includes: — manufacture of video cassette recorders and duplicating equipment — manufacture of televisions — manufacture of television monitors and displays — manufacture of audio recording and duplicating systems — manufacture of stereo equipment — manufacture of radio receivers — manufacture of speaker systems — manufacture of household-type video cameras — manufacture of jukeboxes — manufacture of amplifiers for musical instruments and public address systems — manufacture of microphones — manufacture of CD and DVD players — manufacture of karaoke machines — manufacture of headphones (e.g. radio, stereo, computer) — manufacture of video game consoles This class excludes: — reproduction of recorded media (computer media, sound, video, etc.), see 18.2 — manufacture of computer peripheral devices and computer monitors, see 26.20 — manufacture of telephone answering machines, see 26.30

Sector	Code	Description	Detailed description
Electronics and software *(continued)*	C26.40 *(continued)*	Manufacture of consumer electronics *(continued)*	— manufacture of paging equipment, see 26.30 — manufacture of remote control devices (radio and infrared), see 26.30 — manufacture of broadcast studio equipment such as reproduction equipment, transmitting and receiving antennas, commercial video cameras, see 26.30 — manufacture of antennas, see 26.30 — manufacture of digital cameras, see 26.70 — manufacture of electronic games with fixed (non-replaceable) software, see 32.40
	C26.51	Manufacture of instruments and appliances for measuring, testing and navigation	This class comprises manufacturing of search, detection, navigation, guidance, aeronautical, and nautical systems and instruments; automatic controls and regulators for applications, such as heating, air conditioning, refrigeration and appliances; instruments and devices for measuring, displaying, indicating, recording, transmitting, and controlling temperature, humidity, pressure, vacuum, combustion, flow, level, viscosity, density, acidity, concentration, and rotation; totalising (i.e., registering) fluid meters and counting devices; instruments for measuring and testing the characteristics of electricity and electrical signals; instruments and instrumentation systems for laboratory analysis of the chemical or physical composition or concentration of samples of solid, fluid, gaseous, or composite material; other measuring and testing instruments and parts thereof. The manufacture of non-electric measuring, testing and navigating equipment (except simple mechanical tools) is included here. This class includes: — manufacture of aircraft engine instruments — manufacture of automotive emissions testing equipment — manufacture of meteorological instruments — manufacture of physical properties testing and inspection equipment — manufacture of polygraph machines — manufacture of radiation detection and monitoring instruments

Sector	Code	Description	Detailed description
Electronics and software *(continued)*	C26.51 *(continued)*	Manufacture of instruments and appliances for measuring, testing and navigation *(continued)*	— manufacture of surveying instruments — manufacture of thermometers liquid-in-glass and bimetal types (except medical) — manufacture of humidistats — manufacture of hydronic limit controls — manufacture of flame and burner control — manufacture of spectrometers — manufacture of pneumatic gauges — manufacture of consumption meters (e.g., water, gas, electricity) — manufacture of flow meters and counting devices — manufacture of tally counters — manufacture of mine detectors, pulse (signal) generators; metal detectors — manufacture of search, detection, navigation, aeronautical, and nautical equipment, including sonobuoys — manufacture of radar equipment — manufacture of GPS devices — manufacture of environmental controls and automatic controls for appliances — manufacture of measuring and recording equipment (e.g. flight recorders) — manufacture of motion detectors — manufacture of radars — manufacture of laboratory analytical instruments (e.g. blood analysis equipment) — manufacture of laboratory scales, balances, incubators, and miscellaneous laboratory apparatus for measuring, testing, etc.

Sector	Code	Description	Detailed description
Electronics and software *(continued)*	C26.51 *(continued)*	Manufacture of instruments and appliances for measuring, testing and navigation *(continued)*	This class excludes: — manufacture of telephone answering machines, see 26.30 — manufacture of irradiation equipment, see 26.60 — manufacture of optical positioning equipment, see 26.70 — manufacture of dictating machines, see 28.23 — manufacture of weighing devices (other than laboratory balances), levels, tapemeasures etc., see 28.29 — manufacture of medical thermometers, see 32.50 — installation of industrial process control equipment, see 33.20 — manufacture of simple mechanical measuring tools (e.g. measuring tapes, calipers), see manufacturing class according to main material used
	J62	Computer programming, consultancy and related activities	This division includes the following activities of providing expertise in the field of information technologies: writing, modifying, testing and supporting software; planning and designing computer systems that integrate computer hardware, software and communication technologies; on-site management and operation of clients' computer systems and/or data processing facilities; and other professional and technical computer-related activities.
Telecommunication	F42.22	Construction of utility projects for electricity and telecommunications	This class includes the construction of distribution lines for electricity and telecommunications and related buildings and structures that are integral part of these systems. This class includes: — construction of civil engineering constructions for: ○ long-distance and urban communication and power lines ○ power plants This class excludes: — project management activities related to civil engineering works, see 71.12

Sector	Code	Description	Detailed description
Telecommunication *(continued)*	F43.21	Electrical installation	This class includes the installation of electrical systems in all kinds of buildings and civil engineering structures of electrical systems. This class includes: — installation of: ○ electrical wiring and fittings ○ telecommunications wiring ○ computer network and cable television wiring, including fibre optic ○ satellite dishes ○ lighting systems ○ fire alarms ○ burglar alarm systems ○ street lighting and electrical signals ○ airport runway lighting ○ electric solar energy collectors — connecting of electric appliances and household equipment, including baseboard heating This class excludes: — construction of communications and power transmission lines, see 42.22 — monitoring and remote monitoring of electronic security systems, such as burglar alarms and fire alarms, including their installation and maintenance, see 80.2

Sector	Code	Description	Detailed description
Telecommunication *(continued)*	J61	Telecommunications	This division includes the activities of providing telecommunications and related service activities, that is transmitting voice, data, text, sound and video. The transmission facilities that carry out these activities may be based on a single technology or a combination of technologies. The commonality of activities classified in this division is the transmission of content, without being involved in its creation. The breakdown in this division is based on the type of infrastructure operated. In the case of transmission of television signals this may include the bundling of complete programming channels (produced in division 60) in to programme packages for distribution.
Data services	J63	Information service activities	This division includes the activities of web search portals, data processing and hosting activities, as well as other activities that primarily supply information.
Digital Media	G47.91	Retail sale via mail order houses or via Internet	This class includes retail sale activities via mail order houses or via Internet, i.e. retail sale activities where the buyer makes his choice on the basis of advertisements, catalogues, information provided on a website, models or any other means of advertising and places his order by mail, phone or over the Internet (usually through special means provided by a website). The products purchased can be either directly downloaded from the Internet or physically delivered to the customer. This class includes: — retail sale of any kind of product by mail order — retail sale of any kind of product over the Internet — direct sale via television, radio and telephone — Internet retail auctions This class excludes: — retail sale of motor vehicles and motor vehicles parts and accessories over the Internet, see groups 45.1, 45.3 — retail sale of motorcycles and motorcycles parts and accessories over the Internet, see 45.40

Sector	Code	Description	Detailed description
Digital Media *(continued)*	J60.10	Radio broadcasting	This class includes: — activities of broadcasting audio signals through radio broadcasting studios and facilities for the transmission of aural programming to the public, to affiliates or to subscribers — activities of radio networks, i.e. assembling and transmitting aural programming to the affiliates or subscribers via over-the-air broadcasts, cable or satellite — radio broadcasting activities over the Internet (Internet radio stations) — data broadcasting integrated with radio broadcasting This class excludes: — the production of taped radio programming, see 59.20
	J60.20	Television programming and broadcasting activities	This class includes the creation of creating a complete television channel programme, from purchased programme components (e.g. movies, documentaries etc.), self produced programme components (e.g. local news, live reports) or a combination thereof. This complete television programme can be either broadcast by the producing unit or produced for transmission by a third party distributor, such as cable companies or satellite television providers. The programming may be of a general or specialised nature (e.g. limited formats such as news, sports, education or youth oriented programming). This class includes programming that is made freely available to users, as well as programming that is available only on a subscription basis. The programming of video-on-demand channels is also included here. This class also includes data broadcasting integrated with television broadcasting. This class excludes: — the production of television programme elements (movies, documentaries, talk shows, commercials etc.) not associated with broadcasting, see 59.11 — the assembly of a package of channels and distribution of that package, without programming, see division 61

Sector	Code	Description	Detailed description
Freight Transport	H49.2	Freight rail transport	This class includes: — freight transport on mainline rail networks as well as short line freight railroads This class excludes: — warehousing and storage, see 52.10 — freight terminal activities, see 52.21 — operation of railroad infrastructure; related activities such as switching and shunting, see 52.21 — cargo handling, see 52.24
	H49.41	Freight transport by road	This class includes: — all freight transport operations by road: ○ logging haulage ○ stock haulage ○ refrigerated haulage ○ heavy haulage ○ bulk haulage, including haulage in tanker trucks including milk collection at farms ○ haulage of automobiles ○ transport of waste and waste materials, without collection or disposal — renting of trucks with drive — freight transport by man or animal-drawn vehicles This class excludes: — log hauling within the forest, as part of logging operations, see 02.40 — distribution of water by trucks, see 36.00 — operation of terminal facilities for handling freight, see 52.21

Sector	Code	Description	Detailed description
Freight Transport *(continued)*	H49.41 *(continued)*	Freight transport by road *(continued)*	— crating and packing activities for transport, see 52.29 — post and courier activities, see 53.10, 53.20 — waste transport as integrated part of waste collection activities, see 38.11, 38.12
	H49.42	Removal services	This class includes: — removal (relocation) services to businesses and households by road transport
	H50.2	Sea and coastal freight water transport	This class includes: — transport of freight over seas and coastal waters, whether scheduled or not — transport by towing or pushing of barges, oil rigs etc. — renting of vessels with crew for sea and coastal freight water transport This class excludes: — storage of freight, see 52.10 — harbour operation and other auxiliary activities such as docking, pilotage, lighterage, vessel salvage, see 52.22 — cargo handling, see 52.24 — renting of commercial ships or boats without crew, see 77.34
	H50.4	Inland freight water transport	This class includes: — transport of freight via rivers, canals, lakes and other inland waterways, including inside harbours and ports — renting of vessels with crew for inland freight water transport This class excludes: — cargo handling, see 52.24 — renting of commercial ships or boats without crew, see 77.34

Sector	**Code**	**Description**	**Detailed description**
Freight Transport *(continued)*	N77.12	Renting and leasing of trucks	This class includes: — renting and operational leasing of the following types of vehicles: ○ trucks, utility trailers and heavy motor vehicles (with a weight exceeding 3,5 tons) ○ recreational vehicles This class excludes: — renting or leasing of heavy goods vehicles or trucks with driver, see 49.41
Passenger transport	H49.10	Passenger rail transport, interurban	This class includes: — rail transportation of passengers using railroad rolling stock on mainline networks, spread over an extensive geographic area — passenger transport by interurban railways — operation of sleeping cars or dining cars as an integrated operation of railway companies This class excludes: — passenger transport by urban and suburban transit systems, see 49.31 — passenger terminal activities, see 52.21 — operation of railroad infrastructure; related activities such as switching and shunting, see 52.21 — operation of sleeping cars or dining cars when operated by separate units, see 55.90, 56.10
	H49.31	Urban and suburban passenger land transport	This class includes: — land transport of passengers by urban or suburban transport systems. This may include different modes of land transport, such as by motor bus, tramway, streetcar, trolley bus, underground and elevated railways etc. The transport is carried out on scheduled routes normally following a fixed time schedule, entailing the picking up and setting down of passengers at normally fixed stops. — town-to-airport or town-to-station lines

Sector	**Code**	**Description**	**Detailed description**
Passenger transport *(continued)*	H49.31 *(continued)*	Urban and suburban passenger land transport *(continued)*	— operation of funicular railways, aerial cableways etc. if part of urban or suburban transit systems This class excludes: — passenger transport by interurban railways, see 49.10
	H49.32	Taxi operation	This class includes: — other renting of private cars with driver
	H49.39	Other passenger land transport n.e.c.	This class includes: — other passenger road transport: ○ scheduled long-distance bus services ○ charters, excursions and other occasional coach services ○ airport shuttles — operation of teleferics, funiculars, ski and cable lifts if not part of urban or suburban transit systems — operation of school buses and buses for transport of employees — passenger transport by man- or animal-drawn vehicles This class excludes: — ambulance transport, see 86.90
	H51.10	Passenger air transport	This class includes: — transport of passengers by air over regular routes and on regular schedules — charter flights for passengers — scenic and sightseeing flights — renting of air transport equipment with operator for the purpose of passenger transportation

Sector	Code	Description	Detailed description
Passenger transport *(continued)*	H51.10 *(conti-nued)*	Passenger air transport *(continued)*	— general aviation activities, such as: ○ transport of passengers by aero clubs for instruction or pleasure This class excludes: — renting of air transport equipment without operator, see 77.35
	N77.11	Renting and leasing of cars and light motor vehicles	This class includes: — renting and operational leasing of the following types of vehicles: ○ passenger cars and other light motor vehicles (with a weight not exceeding 3,5 tons) without driver This class excludes: — renting or leasing of cars or light motor vehicles with driver, see 49.32, 49.39
Insurance	K65.12	Non-life insurance	This class includes: — provision of insurance services other than life insurance: ○ accident and fire insurance ○ health insurance ○ travel insurance ○ property insurance ○ motor, marine, aviation and transport insurance ○ pecuniary loss and liability insurance
	K65.2	Reinsurance	This class includes: — activities of assuming all or part of the risk associated with existing insurance policies originally underwritten by other insurance carriers

Sector	Code	Description	Detailed description
Maintenance and repair	G45.20	Maintenance and repair of motor vehicles	This class includes: — maintenance and repair of motor vehicles: ○ mechanical repairs ○ electrical repairs ○ electronic injection systems repair ○ ordinary servicing ○ bodywork repair ○ repair of motor vehicle parts ○ washing, polishing, etc. ○ spraying and painting ○ repair of screens and windows ○ repair of motor vehicle seats — tyre and tube repair, fitting or replacement — anti-rust treatment — installation of parts and accessories not as part of the manufacturing process This class excludes: — retreading and rebuilding of tyres, see 22.11
Power	D35.1	Electric power generation, transmission and distribution	This group includes the generation of bulk electric power, transmission from generating facilities to distribution centres and distribution to end users.

Sector	Code	Description	Detailed description
Land development and Traffic police	O84.13	Regulation of and contribution to more efficient operation of businesses	This class includes: — public administration and regulation, including subsidy allocation, for different economic sectors: ○ agriculture ○ land use ○ energy and mining resources ○ infrastructure ○ transport ○ communication ○ hotels and tourism ○ wholesale and retail trade — administration of research and development policies and associated funds to improve economic performance — administration of general labour affairs — implementation of regional development policy measures, e.g. to reduce unemployment This class excludes: — research and experimental development activities, see division 72
	O84.24	Public order and safety activities	This class includes: — administration and operation of regular and auxiliary police forces supported by public authorities and of port, border, coastguards and other special police forces, including traffic regulation, alien registration, maintenance of arrest records — provision of supplies for domestic emergency use in case of peacetime disasters This class excludes: — operation of police laboratories, see 71.20 — administration and operation of military armed forces, see 84.22

Sector	Code	Description	Detailed description
Education	O85.32	Technical and vocational secondary education	This class includes provision of education typically emphasising subject-matter specialisation and instruction in both theoretical background and practical skills generally associated with present or prospective employment. The aim of a programme can vary from preparation for a general field of employment to a very specific job. This class includes: — technical and vocational education below the level of higher education as defined in 85.4 — tourist guide instruction — instruction for chefs, hoteliers and restaurateurs — cosmetology and barber schools — computer repair training — driving schools for occupational drivers e.g. of trucks, buses, coaches, schools for professional pilots This class excludes: — technical and vocational higher education, see 85.4 — performing art instruction for recreation, hobby and self-development purposes, see 85.52 — automobile driving schools not intended for occupational drivers, see 85.53 — job training forming part of social work activities without accommodation, see 88.10, 88.99
	O85.4	Higher education	This group includes the furnishing of post-secondary non-tertiary and academic courses and granting of degrees at baccalaureate, graduate or post-graduate level. The requirement for admission is a diploma at least at upper secondary education level. This group excludes: — adult education as defined in 85.5

Sector	Code	Description	Detailed description
Education *(continued)*	O85.5	Other education	This group includes general continuing education and continuing vocational education and training for any profession, hobby or self-development purposes. It excludes educational activities as outlined in groups 85.1-85.4, i.e. pre-primary education, primary education, secondary education or higher education. It includes camps and schools offering instruction in athletic activities to groups or individuals, foreign language instruction, instruction in the arts, drama or music or other instruction or specialised training, not comparable to the education in groups 85.1 - 85.4.
Construction of roads and motorways	F42.11	Construction of roads and motorways	This class includes: — construction of motorways, streets, roads, other vehicular and pedestrian ways — surface work on streets, roads, highways, bridges or tunnels: ○ asphalt paving of roads ○ road painting and other marking ○ installation of crash barriers, traffic signs and the like — construction of airfield runways This class excludes: — installation of street lighting and electrical signals, see 43.21 — architectural and engineering activities, see 71.1 — project management for construction, see 71.1
Medical	Q86.10	Hospital activities	This class includes: — short- or long-term hospital activities, i.e. medical, diagnostic and treatment activities, of general hospitals (e.g. community and regional hospitals, hospitals of non-profit organisations, university hospitals, military-base and prison hospitals) and specialised hospitals (e.g. mental health and substance abuse hospitals, hospitals for infectious diseases, maternity hospitals, specialised sanatoriums).

Sector	Code	Description	Detailed description
Medical *(continued)*	Q86.10 *(conti-nued)*	Hospital activities *(continued)*	The activities are chiefly directed to inpatients, are carried out under the direct supervision of medical doctors and include: ○ services of medical and paramedical staff ○ services of laboratory and technical facilities, including radiologic and anaesthesiologic services ○ emergency room services ○ provision of operating room services, pharmacy services, food and other hospital services ○ services of family planning centres providing medical treatment such as sterilisation and termination of pregnancy, with accommodation This class excludes: — laboratory testing and inspection of all types of materials and products, except medical, see 71.20 — veterinary activities, see 75.00 — health activities for military personnel in the field, see 84.2 — dental practice activities of a general or specialised nature, e.g. dentistry, endodontic and pediatric dentistry; oral pathology, orthodontic activities, see 86.2 — private consultants' services to inpatients, see 86.2 — medical laboratory testing, see 86.90 — ambulance transport activities, see 86.90
Legal activities	M69.1	Legal activities	This class includes: — legal representation of one party's interest against another party, whether or not before courts or other judicial bodies by, or under supervision of, persons who are members of the bar: ○ advice and representation in civil cases

Sector	Code	Description	Detailed description
Legal activities *(continued)*	M69.1 *(continued)*	Legal activities *(continued)*	○ advice and representation in criminal cases ○ advice and representation in connection with labour disputes ○ general counselling and advising, preparation of legal documents: ○ articles of incorporation, partnership agreements or similar documents in connection with company formation ○ patents and copyrights ○ preparation of deeds, wills, trusts etc. — other activities of notaries public, civil law notaries, bailiffs, arbitrators, examiners and referees This class excludes: — law court activities, see 84.23
Oil and gas	B06	Extraction of crude petroleum and natural gas	This division includes the production of crude petroleum, the mining and extraction of oil from oil shale and oil sands and the production of natural gas and recovery of hydrocarbon liquids. This division includes the activities of operating and/ or developing oil and gas field properties. Such activities may include drilling, completing and equipping wells; operating separators, emulsion breakers, desalting equipment and field gathering lines for crude petroleum; and all other activities in the preparation of oil and gas up to the point of shipment from the producing property. This division excludes: — oil and gas field services, performed on a fee or contract basis, see 09.10 — oil and gas well exploration, see 09.10 — test drilling and boring, see 09.10 — refining of petroleum products, see 19.20 — geophysical, geologic and seismic surveying, see 71.12

Sector	Code	Description	Detailed description
Oil and gas *(continued)*	G46.71	Wholesale of solid, liquid and gaseous fuels and related products	This class includes: — wholesale of fuels, greases, lubricants, oils such as: ○ charcoal, coal, coke, fuel wood, naphtha ○ crude petroleum, crude oil, diesel fuel, gasoline, fuel oil, heating oil, kerosene ○ liquefied petroleum gases, butane and propane gas ○ lubricating oils and greases, refined petroleum products
	G47.3	Retail sale of automotive fuel in specialised stores	This class includes: — retail sale of fuel for motor vehicles and motorcycles — retail sale of lubricating products and cooling products for motor vehicles This class excludes: — wholesale of fuels, see 46.71 — retail sale of liquefied petroleum gas for cooking or heating, see 47.78
Land development	H52.21	Service activities incidental to land transportation	This class includes: — activities related to land transport of passengers, animals or freight: ○ operation of terminal facilities such as railway stations, bus stations, stations for the handling of goods ○ operation of railroad infrastructure ○ operation of roads, bridges, tunnels, car parks or garages, bicycle parkings, winter storage of caravans — switching and shunting — towing and road side assistance — liquefaction of gas for transportation purposes This class excludes: — cargo handling, see 52.24

Sector	Code	Description	Detailed description
Land development *(continued)*	M71.11	Architectural activities	This class includes: — architectural consulting activities: ○ building design and drafting ○ town and city planning and landscape architecture This class excludes: — activities of computer consultants, see 62.02, 62.09 — interior decorating, see 74.10

Source: Own elaborations (based on Eurostat, 2008).

Annex 2. Road transport activity

Data on road transport activity is obtained from the PRIMES model used in EU Reference Scenario 2016, which employs a combined econometric and engineering approach to obtain transport activity by transport mode. The specific dataset used is coming from the updated baseline scenario from Hill et al. (forthcoming 2018), as shown in Table 45.

Table 45. Road transport activity data in the 2005-2050 period

EU28:0_F														
	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	'10-'20	'20-'30	'30-'40	'40-'50
ROAD TRANSPORT (Activity in Gvkm)											Annual % change			
Passenger Transport	**3106.9**	**3245.8**	**3347.2**	**3515.9**	**3652.9**	**3851.5**	**4013.7**	**4152.6**	**4264.7**	**4378.1**	0.8	0.9	0.8	0.5
Public road transport	**29.2**	**29.4**	**30.4**	**31.6**	**32.4**	**33.2**	**34.2**	**35.2**	**36.0**	**36.8**	0.7	0.5	0.6	0.4
Buses	7.8	8.1	8.7	9.4	10.0	10.6	11.0	11.4	11.6	11.9	1.5	1.1	0.7	0.5
Coaches	21.4	21.3	21.7	22.1	22.4	22.7	23.2	23.8	24.4	24.9	0.4	0.3	0.5	0.4
Private cars	**2694.5**	**2817.8**	**2900.1**	**3042.4**	**3159.1**	**3335.7**	**3475.0**	**3593.0**	**3687.4**	**3783.7**	0.8	0.9	0.7	0.5
Small cars	1063.8	1109.0	1144.4	1205.3	1256.7	1330.9	1388.8	1436.6	1475.1	1514.2	0.8	1.0	0.8	0.5
Medium cars	1140.8	1195.3	1233.6	1346.9	1411.1	1502.5	1571.0	1640.6	1697.7	1753.7	1.2	1.1	0.9	0.7
Big cars	489.9	513.5	522.1	490.3	491.3	502.3	515.2	515.8	514.6	515.7	-0.5	0.2	0.3	0.0
2wheelers	**111.7**	**112.1**	**118.4**	**124.8**	**130.8**	**136.9**	**144.3**	**151.8**	**159.2**	**166.5**	1.1	0.9	1.0	0.9
Motorcycles	68.7	67.4	71.2	75.0	78.7	82.4	87.1	91.6	96.1	100.6	1.1	1.0	1.1	0.9
Mopeds	43.0	44.7	47.2	49.8	52.1	54.4	57.3	60.2	63.0	65.9	1.1	0.9	1.0	0.9
Light duty vehicles - passenger	**271.5**	**286.6**	**298.2**	**317.1**	**330.6**	**345.7**	**360.2**	**372.6**	**382.1**	**391.1**	1.0	0.9	0.8	0.5
Freight Transport	**335.9**	**324.4**	**350.3**	**374.5**	**405.4**	**435.6**	**460.5**	**481.8**	**497.1**	**511.3**	0.0	0.0	0.0	0.0
Light duty vehicles - freight	**163.2**	**150.9**	**154.1**	**161.5**	**176.8**	**192.1**	**202.9**	**213.2**	**220.7**	**227.0**	0.7	1.7	1.0	0.6
Heavy Duty vehicles	**172.7**	**173.4**	**196.2**	**213.0**	**228.6**	**243.5**	**257.7**	**268.6**	**276.4**	**284.3**	2.1	1.3	1.0	0.6

Gvkm: billion vehicle kilometres.

Source: Updated baseline scenario from Hill et al. (forthcoming 2018).

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