FUTURE IMPLICATIONS OF COOPERATIVE, CONNECTED AND AUTOMATED MOBILITY

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Abstract

Roads across the world will gradually become populated with vehicles that are able to drive autonomously and communicate with their surroundings, totally transforming the way in which we currently move from one place to another. Together with its electrification, road transport connectivity and automation will enable the disruption of a sector which has remained substantially unchanged (at least from a conceptual point of view) since the vehicle became mass produced during the first half of the twentieth century. Advances in the field of Artificial Intelligence (AI), on which vehicle automation relies, will further contribute to accelerate this disruption. In turn, vehicle connectivity and automation will boost a paradigm change in mobility use and the adoption on a large scale of Mobility-as-a-Service (MaaS) travel options. The term Cooperative, Connected and Automated Mobility (CCAM) synthesizes the concept of a future mobility in which all the actors are connected, are able to communicate and cooperate in a seamless and automated way.

Given the central role of mobility for our society and economy, the implications of a transformation in the transport sector will not be limited to transport and mobility but will regard many other aspects of our society like public health or land use. As the development of our mass production and consumption economic model has been initiated by the revolution in the vehicles production process (so that this economic model is also referred to as Fordism ([1]), the technologies available in forthcoming vehicles may well enable a new transition in our economic and social systems. Yet uncertainty in predicting the implications of these changes remains high, especially given the intrinsic complexity of our social and economic systems.

Objective of the paper is therefore to analyse the possible implications on society and economy of a disruption in the road transport sector as a result of CCAM. It builds upon different scenarios and tries to define the main impacts in different sectors using a mixed qualitative-quantitative approach.

Results show that in all different scenarios the policy implications of the transformation can be high (e.g. significant increase in vehicle travel) and that the evolution of the system has to be carefully monitored in order to promptly cope with possible negative effects.

([1]) More information available at: https://www.britannica.com/topic/Fordism

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Connected and Automated Vehicles, Mobility-as-a-Service, Social and political implications

1. Introduction

The development of automated driving technologies is gaining momentum and it has become no more a question of if but when Autonomous Vehicles (AV) will be a reality on our roads (Mosquet et al., 2015; DHL Trend Research, 2014). As their market deployment approaches, with some levels of autonomy already available in the market (up to SAE level 2 technologies, SAE International, 2016), their economic and societal implications should be investigated. It is expected that Cooperative, Connected and Automated Mobility (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 will bring changes in the labour market, making some occupations and skills less relevant, while at the same time requiring new and more advanced skills. Given that Europe accounts for 23% of global motor vehicle production (being second after China ([2])) and almost 72% of inland freight is transported by road in Europe (European Commission, 2017a), 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. However, a limited number of publications exists on the analysis of their socio-economic implications.

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 (both these figures are the result of our analysis) and stands as the largest private Research and Development (R&D) investor in the EU (European Commission, 2017d). 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 (e.g. Letter of Intent on testing and large scale demonstrations of Connected and Automated Driving (CAD), GEAR 2030 High Level Group). In the "Europe on the Move" communication from May 2017, 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, 2017d). 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, 2017c), where CCAM will be a key pillar.

In order to understand and anticipate some of the likely economic and employment changes brought about by CAVs, an analysis of recent data and 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, power 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

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

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.

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 term 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.

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), this study aims at specifically addressing the automation and connectivity trends in particular.

2. Methodological approach

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 and EU Reference Scenario 2016, 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

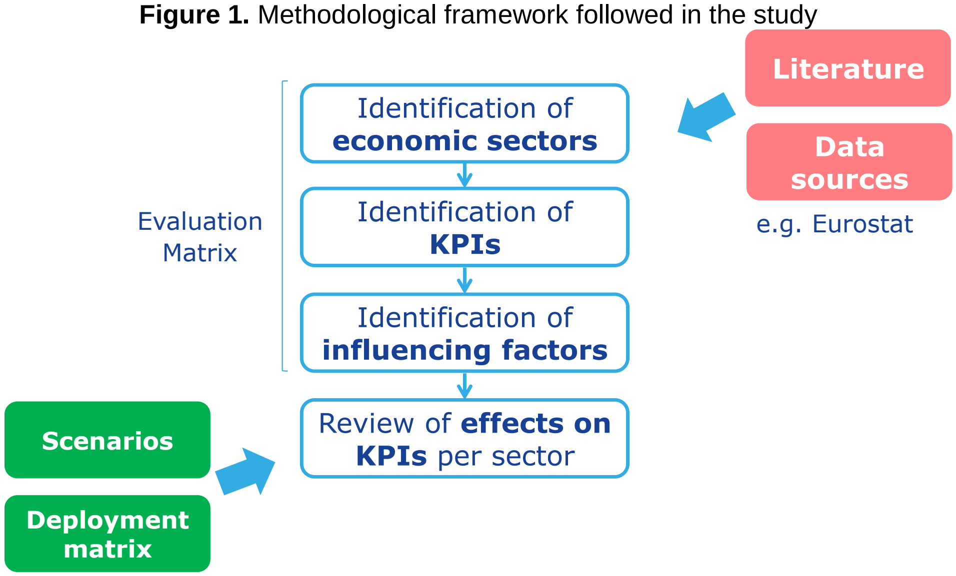
Source: Own elaborations.

These scenarios, together with a set of KPIs like persons employed, turnover, number of enterprises, personnel costs, Value Added (VA), serve as a basis for the estimation of economic impacts per sector. To this aim, influencing factors like impacts of CAVs on traffic, accidents or the environment are identified. Besides a qualitative analysis based on literature, an attempt to provide some quantitative assessment is performed using the data available from existing sources

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

(e.g. Eurostat Database ([4]) and EU Reference Scenario 2016 ([5])), and relating it to the scenarios. For what concerns the employment analysis, data from Eurofound has been used, that includes employment share figures from Eurostat Labour Force Survey (LFS) and task indicators from Eurofound's database ([6]). 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. The methodological framework used in the study is summarised in **Error! Reference source not found.**.

Figure 1. Methodological framework followed in the study



Source: Own elaborations.

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

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([4]) Data from EU-28 2015, from different Eurostat Databases, namely: Structural Business Statistics (SBS) and National Accounts (NA) (available at: http://ec.europa.eu/eurostat/data/database) and according to NACE Rev. 2 classification of economic activities (Eurostat, 2008).

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

([6]) Eurofound's European Jobs Monitor 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). Specifically, the analysis of occupations is using ISCO-08 International Standard Classification of Occupations (International Labour Organization, 2012).

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.

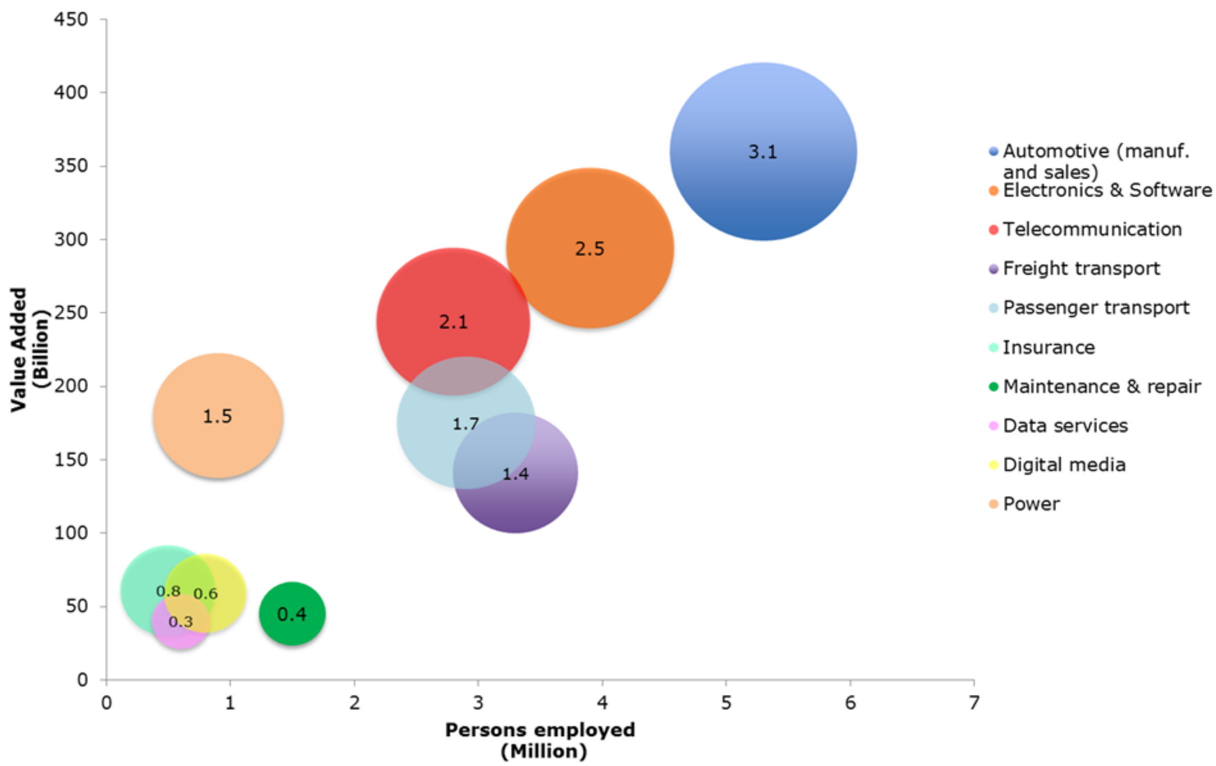
The reader is invited to consider the estimations presented in this study as well qualified indications of future trends and potential orders of magnitude, and not as absolute numbers.

3. Results, discussion and implications

a. Main economic findings

Figure 2 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. These sectors are analysed below.

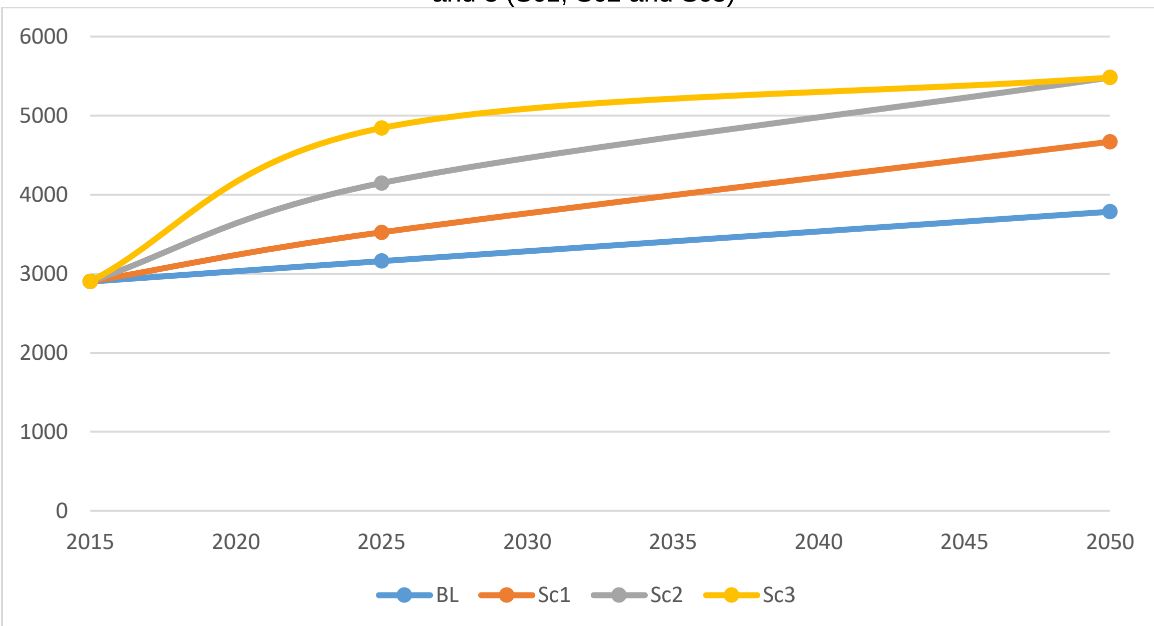
Figure 2. Current state of the main sectors affected by CCAM, showing 2015 figures on Value Added (VA), persons employed and share of Gross Value Added (GVA) in the total EU-28



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

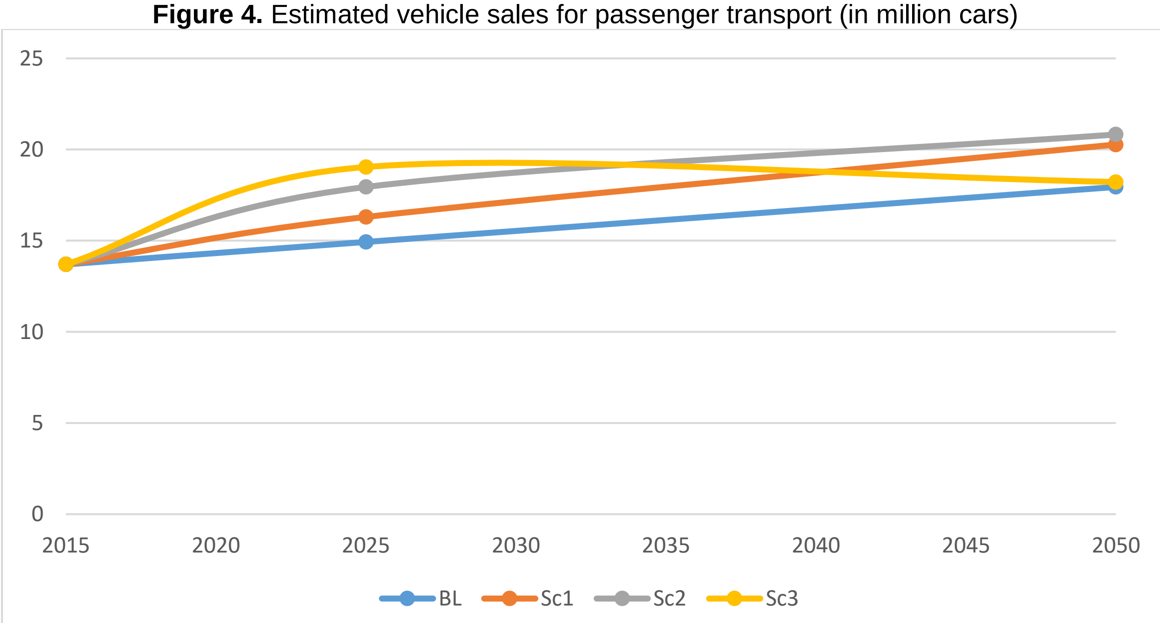
Concerning the **automotive** sector, CAVs may reinforce vehicle sales as travel activity increases. The higher the level of automation, the stronger the effect on Vehicle Kilometres Travelled (VKT), mostly as a result of a reduction in driving costs (including changes in the value of travel time) and new users like young people, elderly or disabled (as cited in e.g. Wadud et al., 2016). Even though new mobility service models (MaaS) may 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 may considerably impact vehicle sales. Our scenario estimations provide ranges of passenger vehicle sales increases over baseline from 18% to 39% during the period 2015-2025 and from 33% to 51% in the period 2015-2050. Figure 3 and Figure 4 show VKT and vehicle sales projections respectively. In Figure 4, it is possible to observe long-term lower vehicle sales in Scenario 3, despite higher VKT, as a result of a dominant MaaS-based travel regime. Using current average passenger car prices (Hill et al., forthcoming 2018), total revenues from passenger car sales could exceed €550 billion by 2050 in a world resembling scenario 2. 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 in 2050 using average vehicle prices for Light, Medium and Heavy Duty Vehicles (from Hill et al., forthcoming 2018 and Lastauto Omnibus-Katalog, 2017).

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



Source: Own elaborations.

Figure 4. 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 hardware and software components needed for automated driving. Whereas software will gain a more dominant role (in terms of monetary value proportion) with regard to today (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 and estimated prices for AVs from the litterature (e.g. Wadud, 2017), total revenues from the sector could almost reach €180 billion by 2025 for both passenger and freight AVs.

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 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 (Bertoncello et al, 2016)) and users are already demonstrating willingness to pay for services built around this data (Dungs et al., 2016).

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, 2016), justifying 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). A more detailed analysis on employment is given in the next section.

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 reductions could represent up to €53 billion in 2050. Revenues from new insurance categories (e.g. cyber security, product liability for software and hardware) have not been considered in these calculations.

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, 2017d). The Original Equipment Manufacturer (OEM) privileged access to car sensor data would make them 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 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 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	↑
Passenger transport	↓
Insurance	↓
Maintenance and repair	↓
Power	↑

Source: Own elaborations.

b. Main findings on employment

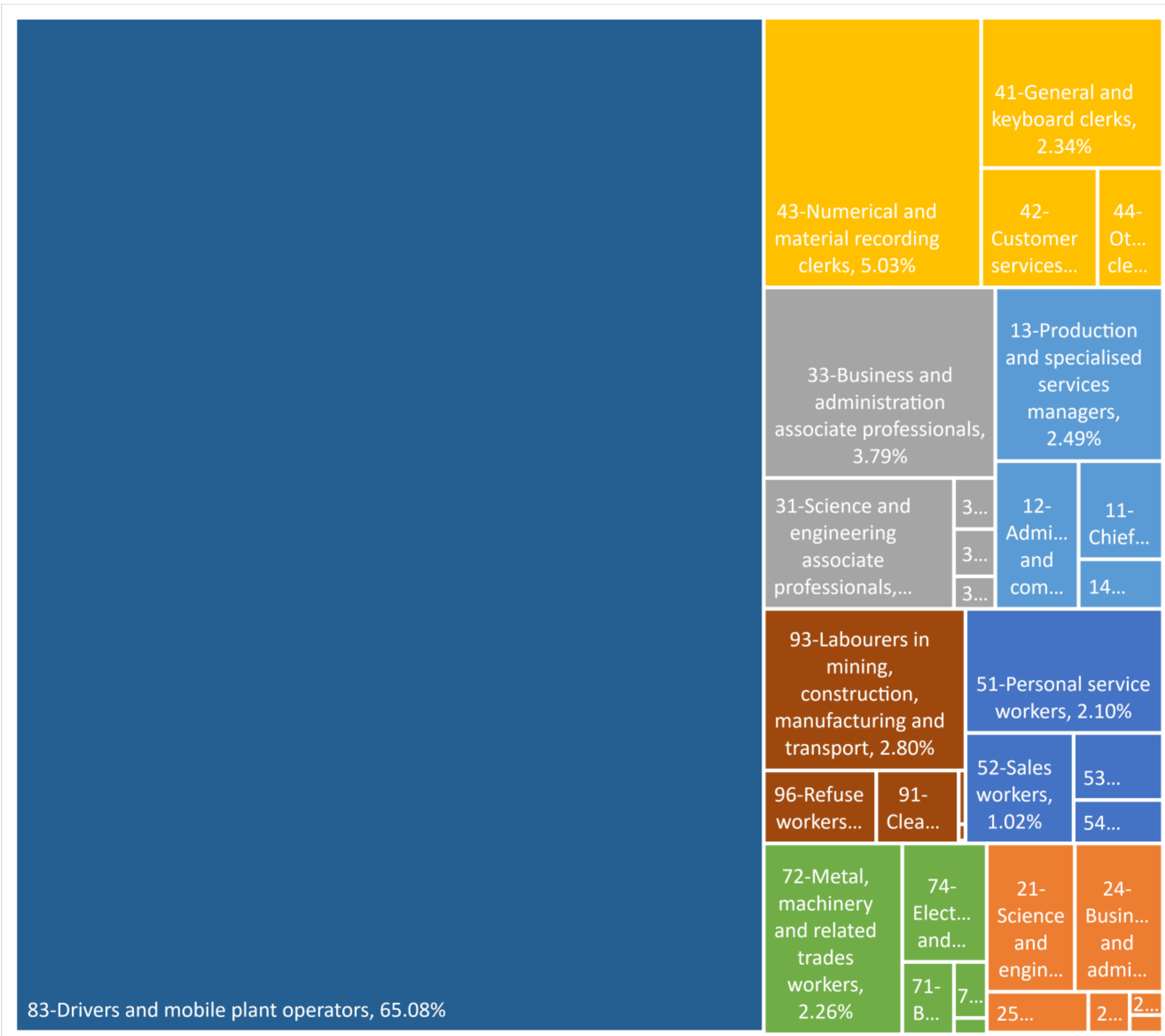
Concerns on job destruction by machines can be dated back to the first industrial revolution. The short run effects of implementing effective technologies negatively impacted workers (The White House, 2016) but in the long run, technology advancements eventually led to higher job creation (ITF, 2017). In general, estimating the **number of jobs at risk of automation** has been proven 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 are at risk.

Currently AVs cannot perform all the tasks required in most driving-related jobs and there is much uncertainty if they ever will (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 to people that previously had a dislike for driving (Miller, 2015). Secondly, because lower demand for drivers will make the transport sector less accessible. The competition effect will not be restricted to the transport sector but spill over to all the other lower-skilled occupations where displaced drivers will apply (The White House, 2016).

According to our estimations, employment endangered of technological substitution (drivers and mobile plant operators, ISCO 83) working in land transport (NACE 49) amounts to approximately 1.5% of total EU-15 employment in 2012. Jobholders 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 ([7]). In Figure 5, 65% of people employed in the land transport sector (NACE 49) are occupied as drivers and mobile plant operators (ISCO 83). 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 account for 2% of occupation within the sector. For reference, ISCO-08 classification of occupations is specified in

Table **3** below.

Figure 5. Distribution of land transport (NACE 49) in occupations (ISCO-08) within EU-15 (2012)



Source: Own elaborations.

([7]) The selected occupations are taken from the International Labour Organization ISCO-08 International Standard Classification of Occupations.

Table 3. Occupation classification (ISCO-08)

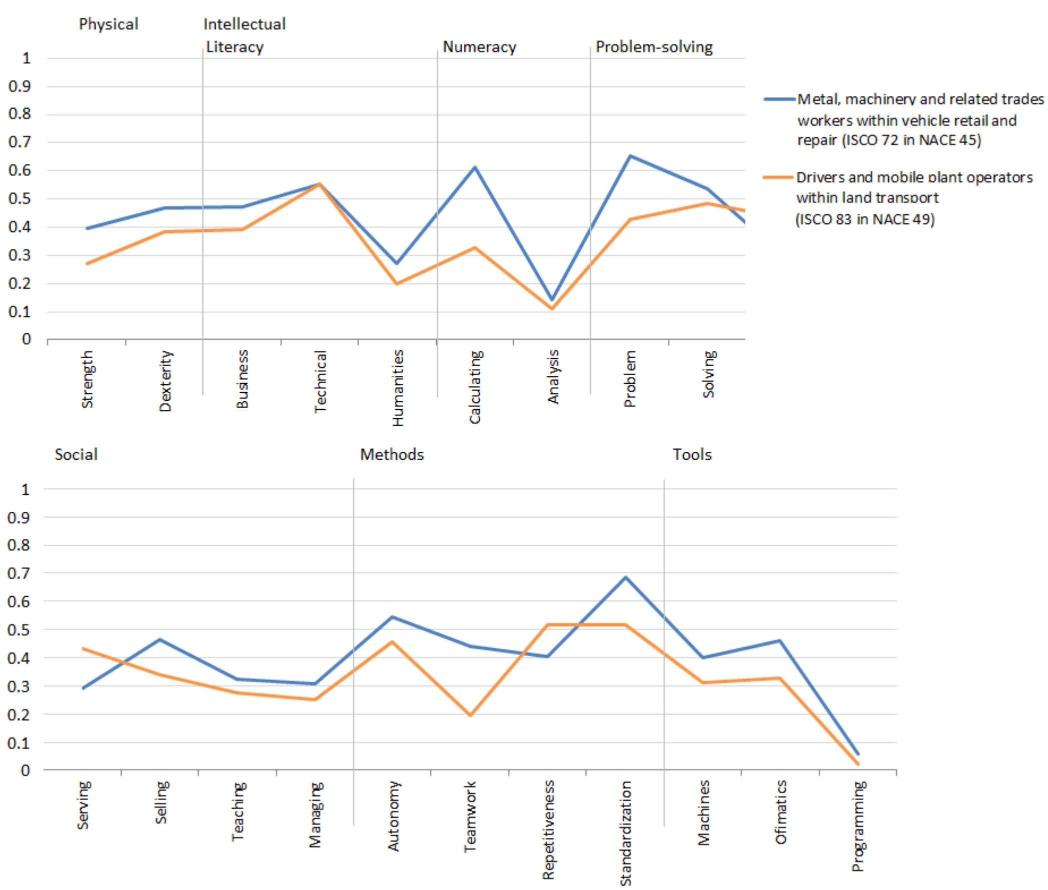
Occupation classification (ISCO-08)	
	Legislators, senior officials and managers
11	Chief executives, senior officials and legislators
12	Administrative and commercial managers
13	Production and specialised services managers
14	Hospitality, retail and other services managers
	Professionals
21	Science 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
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).

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 down to 0.5 million by 2040 according to different scenarios (ITF, 2017). A slow CAV uptake or an informative awareness campaign can help 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 (see Figure 6).The Centre Européen pour le Développement de la Formation Professionnelle (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 CAV monitoring.

Figure 6. Skill levels in ISCO 72 and ISCO 83 occupations (in a 0/1 scale representing the intensity to which each type of task is carried out)



Source: Own elaborations.

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 within the additional time previously spent in transport activities. This has been proven to be the case in other non-transport-related sectors (e.g. ITF, 2017; The White House, 2016). The European Commission (2016c) highlights that by 2025, about 50% of job offers in the EU will target highly qualified people. 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). The effect on labour market participation and on skills match between employers-employees is likely to be positive.

Another challenge is predicting what kind of **new occupations** will be created in the future. Even though recent labour market experiences suggest that they will be 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**, Spulber and Wallace (2016) state that the automation of the driving task will increasingly require supervision and selective intervention skills in opposition to manual control and manoeuvring skills. According to them, understanding the functioning of automated driving systems will be essential for a safe operation of AVs. In this regard, highly heterogeneous vehicle systems could represent a challenge. As automation is gradually deployed, progressive and continuous training could become more relevant than the current one-off initial training.

4. 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. However, sectors like insurance and maintenance and repair are 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 in these sectors. The effects will go far beyond the automotive sector, into sectors like logistics, insurance, and more, eventually reaching sectors like health, construction, and land development, among others.

Important labour changes lie ahead for professional drivers who will face a gradual replacement of driving tasks by new and more technical roles. Some drivers' 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 global 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, with regards to job profiles, sectors, and regions. To reap benefits, it becomes crucial to anticipate the needs that come along with new business opportunities and workforce evolution.

Policymakers and industry players in Europe shall seize the opportunity of capturing these benefits within the EU by adopting different measures. The findings presented in this study 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 at this stage will be integrated in a modelling framework able to handle the dynamics and the causal loops intrinsic to the European economy.

References

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.

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.

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.

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.

CEDEFOP, *Drivers and mobile plant operators: skills opportunities and challenges, Analytical Highlights, Skills Panorama,* 2016.

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.

DHL Trend Research, *Self-driving vehicles in logistics: A DHL perspective on implications and use cases for the logistics industry*, 2014.

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.

European Commission, *EU Reference Scenario 2016: Energy, transport and GHG emissions - Trends to 2050*, Office for official publications of the European communities, Luxembourg, 2016a.

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.

European Commission, A NEW SKILLS AGENDA FOR EUROPE, Working together to strengthen human capital, employability and competitiveness COM(2016) 381 final, 2016c.

European Commission, *EU Transport in figures*, Statistical Pocketbook, 2017a.

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, 2017b.

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 2017c.

European Commission, *Autonomous cars: A big opportunity for European industry*, Digital Transformation Monitor, 2017d.

Eurostat, *NACE Rev. 2-Statistical Classification of Economic Activities in the European Community,* 2008.

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.

Gundermann, S., Dressler, N., Winterhoff, M., Aulbur, W., and Bernhart, W., *On the road toward the autonomous truck: Opportunities for OEMs and suppliers*, 2015.

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).

International Labour Organization, *ISCO-08, International standard classification of occupations 2008: structure, group definitions and correspondence tables*, International Labour Office, 2012.

ITF, *Managing the Transition to Driverless Road Freight Transport,* International Transport Forum Policy Papers, No 32, OECD Publishing, 2017.

Janssen, R., Zwijnenberg, H., Blankers, I., and de Kruijff, J., *Truck Platooning. Driving the future of transportation,* TNO, 2015.

Lanctot R., *Accelerating the Future: The Economic Impact of the Emerging Passenger Economy*, Strategy Analytics, 2017.

Lastauto Omnibus-Katalog, ISBN-10: 361330824X, ISBN-13: 978-3613308244, 2017.

Litman, T., *Autonomous vehicle implementation predictions*, Victoria Transport Policy Institute, 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.

Miller, J., 'Autonomous Vehicles: Implications for Employment Demand', *The Bridge*, Vol. 45, No 3, 2015, pp. 5-11.

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.

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.

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.

Palmer, K., *Driverless cars will shave '£265' off insurance premiums in five years,* The Telegraph, 23 May 2015.

POLIS, Road Vehicle Automation and Cities and Regions, Polis-European Cities and Regions Networking for Innovative Transport Solutions, 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.

Römer, M., Gaentzle, S., and Wess, C., *How Automakers Can Survive the Self-Driving Era,* ATKearney, 2016.

SAE International, *J3016 Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles,* Surface vehicle recommended practice, 2016.

SARTRE, D4.3, *Report on fuel consumption*, APPLUS+IDIADA, 2014.

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.

Spulber, A., and Wallace, R., *Impact of Automated Vehicle Technologies on Driver Skills,* Transportation Systems Analysis Group, 2016.

The White House, *Artificial Intelligence, Automation, and the Economy*, 2016.

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.

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.

World Economic Forum, *Digital Transformation of Industries: Logistics Industry,* White Paper in collaboration with Accenture, 2016.