Study on exploring the possible employment implications of connected and automated driving

Final Report

Client: European Commission, DG RTD
Rotterdam, 02 October 2020

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ECORYS

Abstract

This report presents the findings of the study on exploring the possible employment implications of connected and automated driving (CAD). The study was implemented on behalf of the Directorate-General for Research and Innovation (DG RTD) of the European Commission. It provides an *analysis of the short, medium- and long-term impacts of CAD on jobs, employment, skills and knowledge,* as well as an *investigation and elaboration of options in key policy areas* in order for the European Union to take timely action. The main report presents four different scenarios outlining future CAD deployment and fleet compositions up to 2050. The main part of the report provides an analysis of the employment and social impacts along these four scenarios, highlighting expected quantitative as well as qualitative impacts. Finally, 22 policy options were developed and are presented in the final part of this report. These policy options have been operationalised by adding a timeline and by describing the role of various actors with the goal of setting the groundwork for a social roadmap for CAD deployment. The supporting annexes provide additional information with more detailed findings, as well as information on the methodology used.

Résumé

Ce rapport présente les conclusions de l'étude. Cette dernière explore les implications possibles de la Conduite Connectée et Automatisée (CCA) sur l'emploi. Elle a été réalisée pour le compte de la Direction Générale pour la Recherche et l'Innovation (DG RTD) de la Commission Européenne. Elle fournit une analyse *des impacts à court, moyen et long terme de la CCA sur l'emploi, les compétences et la connaissance, et elle explore et présente des options dans des domaines politiques-clés* pour que l'Union Européenne puisse prendre des mesures à temps. La partie principale du rapport présente quatre scénarios alternatifs du déploiement de la CCA et de la composition des flottes automobiles jusqu'en 2050. Il fournit une analyse des impacts quantitatifs et qualitatifs sur l'emploi et sur d'autres indicateurs sociaux sous les quatre scénarios développés. La partie finale présente 22 options politiques accompagnées d'un calendrier d'implémentation et d'une description du rôle des différents acteurs dans le but d'établir un fondement solide pour la feuille de route sociale du déploiement de la CCA. Les annexes fournissent des résultats plus détaillés et des informations sur la méthodologie utilisée.

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Abbreviations

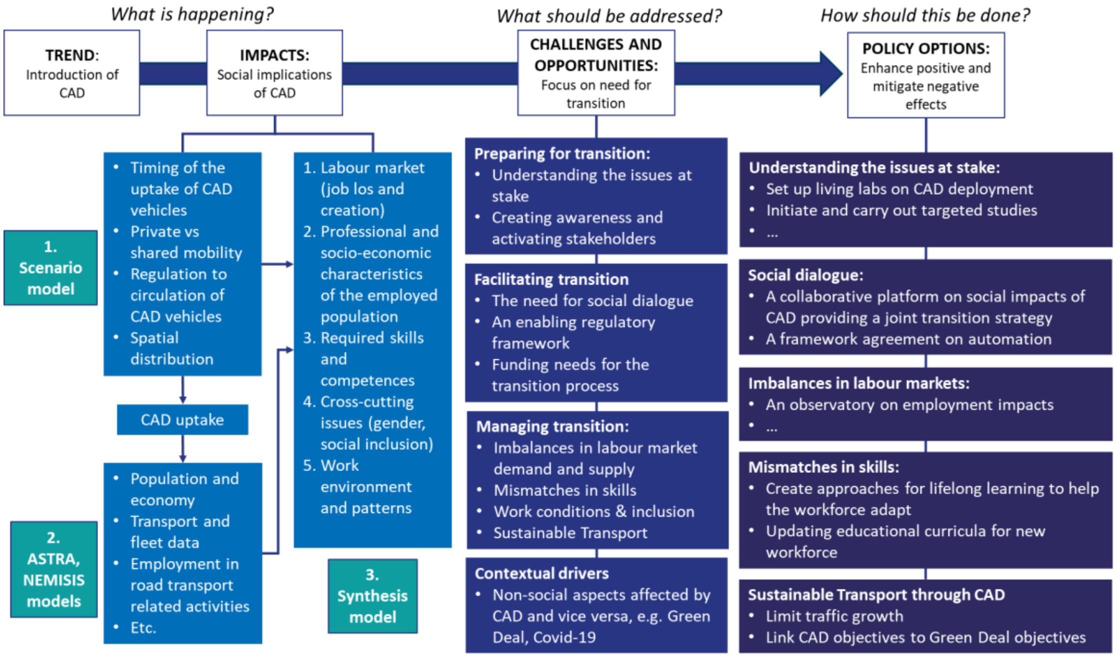
Abbreviation	Meaning
ACEA	European Automobile Manufacturers' Association
ADAS	Advanced Driver Assistance System
ASTRA	ASsessment of TRAnsport strategies (model)
ATI	Academia and training institutes
AV	Automated Vehicle
AVRI	Autonomous Vehicle Readiness Index
BEV	Battery Electric Vehicle
CAD	Connected and Automated Driving
CAM	Center of Automotive Management
CAR	Centre for Automotive Research
CAV	Connected and Autonomous Vehicles
CCAM	Cooperative, Connected, Automated and Autonomous Mobility platform
CEF	Connecting European Facility
CF	Cohesion Fund
CGE	Computable General Equilibrium
C-ITS	Cooperative Intelligent Transport Systems
CNG	Compressed Natural Gas
DG GROW	Directorate-General for the Internal Market, Industry, Entrepreneurship and SMEs
DG MOVE	Directorate-General for Mobility and Transport
DG RTD	Directorate-General for Research and Innovation
EFTA	European Free Trade Association
EGD	European Green Deal
EIB	European Investment Bank
ERDF	European Regional Development Fund
ERTICO	European Road Transport Telematics Implementation Coordination Organisation
ERTRAC	European Road Transport Research Advisory Council
ESF	European Social Fund
ESIF	European Structural and Investment Fund
ETF	European Transport Workers' Federation
FAO	Full Automated Operations
FCEV	Fuel Cell Electric Vehicle
FOT	Foreign trade module
FTE	Full-time-equivalent (employment)
GHG	Greenhouse Gas
GVA	Gross Value Added
GVW	Gross Vehicle Weight
HAZMAT	Hazardous Material
HDV	Heavy-duty vehicle
HQ	Headquarter
I2I	Infrastructure to Infrastructure communication
ICT	Information Communication Technology
IRU	International Road Transport Union
ITF	International Transport workers Federation
JRC	Joint Research Centre

Abbreviation	Meaning
KIT	Karlsruhe Institute for Technology
KPI	Key Performance Indicator
LDV	Light-duty vehicle (for freight transport, i.e. light truck with a GVW up to 3.5t)
LFS	Labour Force Survey
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
M-Five	Mobility, Futures, InnoVation, Economics
MAC module	Macroeconomic module
MaaS	Mobility as a Service
MDOT	Michigan Department of Transportation
NACE	Statistical Classification of Economic Activities in the European Community
NEMESIS	New Econometric Model for Environment and Strategies Implementation for Sustainable Development
NUTS	Nomenclature of Territorial Units for Statistics
OBU	(vehicle) Onboard Unit
ODD	Operational Design Domains
OEM	Original Equipment Manufacturer
OSH	Occupational Safety and Health
PHEV	Plug-in Hybrid Electric Vehicle
Pkm	Passenger Kilometres
R&I	Research and Innovation
RC	Research community
RE-MOB	Regional database mobility
RSU	Roadside Unit
SAE Level	Vehicle automation levels according to the Society of Automotive Engineers
SILC	Statistics on Income and Living
Sce	Scenario
SME	Small and medium-sized enterprise
SP	Social Partner
SRSP	Structural Reform Support Programme
START	Secretariat Technical Assistance to Region in Transition
STEM	Science, technology, engineering, and mathematics
STRIA	Strategic Transport Research and Innovation Agenda
TCO	Total Cost of Ownership
TFP	Total Factor Productivity
Tkm	Tonne-kilometre
TMC	Traffic Management Centre
ToR	Terms of Reference
TRT	Trasporti e Territorio
V2I	Vehicle to Infrastructure communication
V2N	Vehicle to mobile Network communication
V2V	Vehicle to Vehicle communication
V2X	Vehicle-to-everything communication
VAL	Véhicule automatique léger
Vkm	Vehicle kilometre
VTT	Technical Research Centre of Finland
UITP	International Association of Public Transport

Executive Summary

This Executive Summary presents the main findings of the study in terms of the development of scenarios, the assessment of employment and other social impacts as a result of introduction of Connected and Automated Driving (CAD) and the development of policy options to respond to the identified impacts and related challenges and opportunities. These items are presented in Figure ES.1, indicating the sequence between trend, impacts, challenges and opportunities and policy options.

Figure E.S.1 Structure of the study approach



Source: Ecorys.

Scenarios and effects

Four scenarios are developed in this project, which are not intended to be forecasts, but more the exploration of consistent and coherent alternative hypothetical future developments of CAD, which serve as a basis for discussing potential employment and other social impacts (both positive and negative) and outlining policies to prevent or mitigate negative and enhance positive effects.

The scenarios, encompassing two “boundary conditions”, analysing maximum and minimum uptakes and two intermediate cases, are:

- Scenario 1: Fast, private, unrestricted and partially distributed (Maximum uptake);
- Scenario 2: Fast, private, restricted and partially distributed (Intermediate uptake);
- Scenario 3: Moderate, shared, restricted and with limited distribution (Moderate uptake);
- Scenario 4: Slow, shared, restricted and with limited distribution (Low uptake).

The scenarios are designed taking into consideration a number of driving factors, including the timing of the uptake of CAD vehicles; the model of personal mobility; the conditions for the circulation of CAD vehicles in urban and rural areas; the different deployment over time in the different European countries, the degree of users' acceptance and the cost of vehicles and services.

The Scenario Model provides results for the following parameters:

- Car fleet composition, which consider the whole fleet of private cars, cars used for car sharing services and taxis;
- Bus fleet composition;
- Freight vehicles fleet composition, encompassing all the different classes of good vehicles i.e. articulated trucks, large trucks, medium trucks and light-duty vehicles[1];
- Passenger transport activity in terms of passenger-kilometres travelled by all modes and road vehicle-kilometres;
- Freight transport activity in terms of tonnes-kilometres of road modes.

The Scenario Model results show that the uptake of CAD determines the magnitude of the impacts, according to the underlying assumptions of the scenarios.

If technology development allows for connected and autonomous vehicles (CAVs) to be available at a relatively affordable cost, it is likely to increase the use in personal mobility, which leads to a significant increase in passenger transport activity, although the motorisation rate is not necessarily expected to grow (see Section 3.3.1). The increase in transport activity will be not only in terms of travelled passenger kilometres, but mainly in terms of vehicles travelling on the road, where empty trips might represent a noticeable share of such increased activity.

Under the conditions assumed in Scenario 1, (fast technology development, and no restriction for the circulation of CAD vehicles) car traffic in EU27 could increase by 28% in 2050 relative to the reference case at the same year, leading to unsustainable congestion and substantial external costs for society, especially in urban areas. Also in Scenario 2, where restriction to CAD vehicles circulation are applied, car traffic is still expected to increase by 11% in 2050 relative to the reference case. Even in scenarios assuming propensity towards shared mobility (Scenario 3), the number of car vkm is expected to grow, as the higher demand for shared cars outperforms the more efficient use of vehicles. This calls for a decisive role to be played by transport governance authorities to limit such growth by not only imposing restrictions or bans to autonomous private cars, but also by adopting other measures, e.g. tailored pricing policies for empty autonomous vehicles, including those of taxi and shared services.

Employment impacts

The introduction of CAD affects employment in transport services, vehicle and component manufacturing and construction. It displaces a very large number of driver jobs, particularly in freight transport, and results in significant restructuring of employment in the remaining transport services. IT employment will expand rapidly, as well as – depending on the scenario – stewards employed to facilitate automated passenger transport services and mobility operators in freight transport. In manufacturing, the demand for new, more valuable vehicles and components will boost job growth. We see a similar dynamic in construction with the need for new connectivity

[1] Here, light duty vehicles only comprise light trucks with a gross vehicle weight up to 3.5t (in the sense of light commercial vehicles).

infrastructures. This job growth will, however, not be enough to offset much larger job losses in transport services.

Employment impacts vary widely by the scale and scope of technology adoption, as reflected in Table E.S.1. For freight transport, developments follow the basic timeframe of CAD development in the scenarios, with the strongest transition and job losses in the fast uptake scenarios 1 and 2 and the least severe impact in slow uptake scenario 4, while scenario 3 is in between. The picture is more complicated for passenger transport services, since employment impact depends more on whether the focus of CAD adoption is private or shared. Job losses are stronger in scenarios 3 and 4, which have significant growth of ridesharing. The ridesharing disruption is particularly strong in scenario 3, together with the other, smaller automated services displacing around 900,000 bus and taxi jobs, while also creating 600,000 new jobs. In scenarios 1 and 2, CAD is mostly adopted in private car fleets, which leaves the passenger transport services sector relatively less affected.

Table E.S.1 Employment changes EU27, in thousand jobs

	Transport Services						Manufacturing [in CAD relevant sectors][2]		
	Passenger			Freight					
	2020[3]	2035	2050	2020[4]	2035	2050	2020	2035	2050
Scenario 1	2,122	+91	-46	4,508	+1,749	-2,302	9,190	-164	-168
Scenario 2	2,122	+91	-87	4,508	+1,431	-2,620	9,190	-164	-196
Scenario 3	2,122	+89	-265	4,508	+1,104	-1,247	9,190	-162	-239
Scenario 4	2,122	+89	-157	4,508	+899	+549	9,190	-163	-256
Employment in 2020 represents absolute employment in thousands of jobs.									
Employment in 2035 and 2050 shows the employment change compared to 2020 in thousand jobs.									

Source: M-Five.

These figures depict the change of employment in 2050 compared to 2020 and include some other trends, such as increasing general transport demand and increasing productivity in manufacturing. They therefore have to be seen in this context. In freight transport, increasing demand is much stronger and results in much stronger job growth until around 2035 than in passenger transport services.

The dynamics of the CAD transition are quite different in the passenger and freight sectors.

In passenger transport services, a variety of automated and non-automated modes coexist and compete with each other, such as both automated and non-automated buses and autonomous ridesharing. Freight transport services experience a much sharper decline in employment as vehicle fleets are rapidly transformed with new automated and cost-saving vehicles, resulting in job losses of up to 58% compared to 2020 levels in the case of scenario 2. If the CAD transition is still in early stages by 2050, it is possible to see overall job growth as the impact of transport demand expansion exceeds job losses due to CAD, as can be seen in scenario 4.

Apart from general declines in transport services employment in most scenarios, we also expect a significant restructuring of jobs and skill requirements. CAD will obviously mostly replace driver

[2] Employment in CAD-relevant manufacturing sectors includes employment in the sectors Vehicles, Electronics, Computers, and Communication.

[3] 2020 results have been calibrated to match empirical data, but some adjustments had to be made to account for differences in scope. We calibrated public transport to 80% of the country level data from Transport in Figures (2016), not aiming at the full values because they include urban rail while this study does not. Transport in Figures data does not include taxi employment, so we used data from an EU report to calibrate taxi employment: Grimaldi, CERTeT Università Luigi Bocconi, Wavestone (2016).

[4] 2020 results for freight transport have been calibrated to match Transport in Figures 2016 data, including both road freight transport and postal and courier data.

jobs. On the other hand, IT jobs are set to grow rapidly. In passenger transport, stewards will be on many automated vehicles to provide customer services and possibly security. In freight transport, we expect a transition period between traditional drivers and fully autonomous vehicles, when mobility operators supervise level 4 trucks and light-duty vehicles. There is possibly also an increasing role for staff in control centres, both in passenger and freight transport services.

Manufacturing employment is gradually declining over time due to improving productivity[5], declining importance of manufacturing industries and a shrinking labour force in several European countries. The introduction of CAD somewhat stabilises this trend. With the roll-out of automated vehicles, employment increases as vehicles become more valuable (with more high-value components)[6] and fleet renewal accelerates[7], driving up vehicle sales especially in scenario 1 and 2 with fast uptake of CAD.

Similar to the manufacturing sectors, the decrease in employment in the construction sector is also dampened by the introduction of CAD. Construction directly benefits from investments in CAD infrastructure. Being quite dependent on general economic activity, this sector is also boosted indirectly by GDP growth induced by the introduction of CAD and high vehicle sales.

In order to gain a complete overview of the employment impacts of CAD technologies, it is necessary to consider indirect, i.e. second-round effects. The transition to automated transport accelerates growth through a boost to fleet renewals, higher value vehicles and infrastructure and facility investments. This not only affects the manufacturing and services sectors described above, but also increases aggregate demand in the economy as a whole, which indirectly drives employment. Rising GDP and its positive indirect effects on employment can partially compensate for the lost employment in transport services. However, it is not enough to offset the large job losses completely.

Social impacts

The introduction of CAD is expected to have far reaching employment impacts in the road transport sector and beyond. These demand-related effects, in turn, are anticipated to have various social impacts. Namely, it is forecasted that CAD will affect skill requirements for various occupations in the transport sector; it also has the potential to alter the gender balance in the sector, the age distribution of employees (in particular drivers and their future counterpart – mobility operators), and their income levels. The implementation of CAD is also likely to have some impacts on the sector's cross-cutting issues, which include the shortage of drivers currently experienced in Europe and social inclusion in the road transport, both from an employment and a customer perspective. Finally, it could also come with the introduction of new business models and work environments, such as mobile offices.

The findings on the impacts on skill requirements show for the driving occupation in freight transport the introduction of mobility operators from SAE level 4 on, who will either operate on-board or remotely. There skills differ from a traditional driver with reduced needs for manoeuvring skills and increased need for supervision skills. In addition, mobility operators can combine their work with

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5 This means that the same level of output can be produced with fewer inputs and less employment, mostly driven by technological advances.

6 While operating automated vehicles is generally expected to be cheaper than operating traditional vehicles (as a condition of their introduction), automated vehicles will be more expensive, because they require a lot of extra technology.

7 New vehicle purchases are an outcome of the Scenario Model. See chapter 3.3 for the development of the fleet. Generally, demand for autonomous vehicles as a breakthrough technology at accessible price is substantial. On supply side, there is room to increase capacity and hence production in the automotive industry.

several non-driving related tasks (e.g. administrative tasks). For passenger transport services, we see that drivers will remain in the vehicle until SAE level 5, but take up more customer-oriented tasks. Starting from SAE level 5 (driverless) on, on-board stewards could be introduced in passenger transport for customer relation purposes and to ensure safety and security on the vehicle. In other professions, we expect a general shift towards more IT and customer-related skills.

In terms of the impacts on professional and socio-economic characteristics, CAD is expected to attract younger employees as new skill sets are required (e.g. mobility operators) and the nature and pace of the work changes. Regarding gender, the introduction of CAD has the potential to introduce more women into this male dominated profession, since the need for broader skillsets as well as the use of automated vehicles make the profession more accessible. Alternatively however, the implementation of CAD increases the need for more IT-related skills, whereas both STEM education and IT jobs suffer from a gender gap. On salaries, the demand for overall higher qualification levels and IT skills, which are very transferable, point towards a positive effect on income.

Regarding the impacts on cross-cutting issues, one important aspect is the current driver shortage. The findings from the impact assessment show that CAD will not substantially alter demand in the short- to medium-term and neither is it likely to increase supply as workers might be turned away by the prospective transition towards automation. In the long-run, CAD can alleviate the problem of the shortage of drivers as it will reduce substantially (depending on the scenario) the demand for drivers. Another important aspect is social inclusion. From the employment perspective, CAD has the potential to open up the profession to more disabled people, since people with reduced mobility may become mobility operators. Similarly, taking the consumer perspective, CAD could increase the inclusion of people with reduced mobility (elderly, disabled people) by increasing their mobility and travelling independence. Finally, once CAD becomes more affordable, sharing a vehicle rather than privately owning one becomes more economical thereby providing low-cost mobility solutions to low-income people. The trend towards sharing is expected to continue, however, cars are likely to also remain status symbols and those who can afford them will continue buying them, including . autonomous ones.

For the impacts coming from new business models, the study showed a possibility of increased competition on the taxi market with the introduction of robo-taxis. Robo-taxis without any onboard staff will also decrease accessibility for people that might need assistance with boarding a vehicle. Furthermore, automated shuttles without staff provide lower cost alternatives in line based public transport, consequently providing an opportunity to increase service coverage and frequency. Furthermore, CAD might affect the way we travel, with longer commutes becoming less inconvenient in an automated vehicle, where people can combine the commute with work or entertainment. This might lead to commuters accepting a longer distance between home and workplace. Similarly, as traveling will not be limited by fatigue, private cars become a more attractive choice for long trips over other modes.

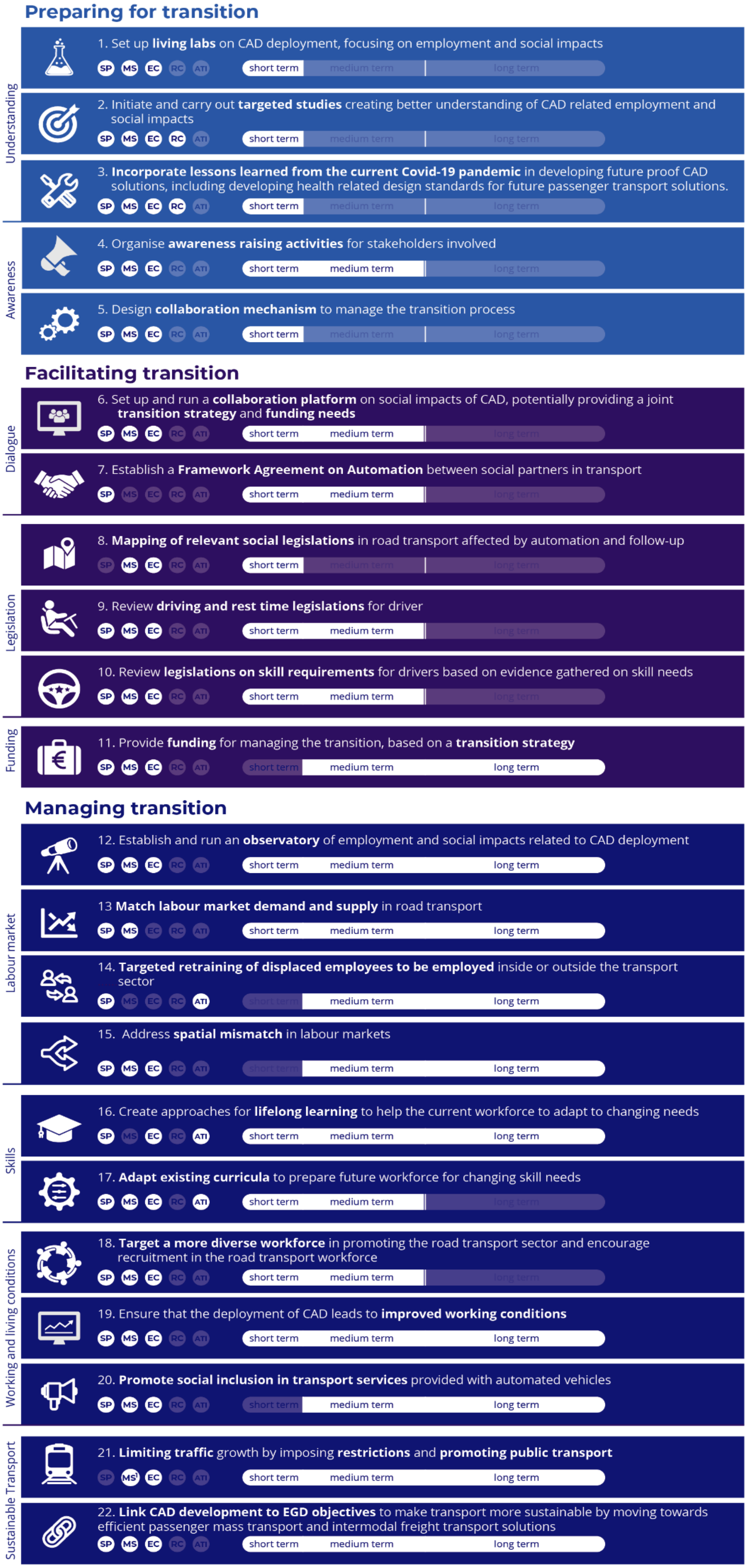
Finally, CAD will also impact work environments with fully automated vehicle potentially becoming a temporary or secondary office space for many professions that include a lot of travelling. Moreover, if driving is not seen as part of the work (because the driver can rest), then the length of a working day might not be restricted anymore by legislation that restricts the maximum number of driving hours in a day or minimum duration of breaks, thereby increasing the length of work shifts. Control centres, could become a completely new work environment, where mobility operators supervise and remotely operate vehicles. Finally, even in freight transport a human user might be required on fully automated vehicles to deter crime and perform security or administrative tasks related to logistics turning the cabin into a combination of office, security room and hotel room.

Policy options and the process towards a social roadmap of CAD

As indicated in Figure ES.1, challenges and opportunities are defined based on the identified employment and social impacts. These challenges and opportunities are defined in terms of preparing, facilitating and managing the transition towards CAD deployment, based on which policy options are defined. Figure E.S.2 on the next page presents the 22 defined policy options, clustered per transition domain, with underlying challenges and opportunities. For each policy option we present the stakeholders involved distinguishing between the following categories:

- Social partners, i.e. companies and workers (SP);
- Member States, i.e. the national governments and their regional and local authorities (MS);
- European Commission, i.e. decision-makers at the EU level (EC);
- Research community; i.e. scientific researchers on CAD and social aspects (RC);
- And academia and training institutes, i.e. educational institutions (ATI).

Figure E.S.2 Phasing of policy options, with stakeholder involvement



Source: Ecorys. Note: [1] Includes the involvement of municipalities (For PO-21).

Synthesis

The deployment of CAD in road transport is an ongoing process, which will take us from current SAE level 2, with drivers support features, to fully connected and automated vehicles, i.e. SAE level 5, in the coming decades. The progress (technical, legal, general acceptance, etc) that will enable CAVs to drive widespread on our roads is expected to take place at the earliest after 2035. Consequently, major impacts on the mobility systems and on employment seem to appear only after 2035. This can be concluded from our consultation with the stakeholders in the sector, and the scenario analysis framed by this consultation, as well as through our model-based analysis.

CAD deployment at aggregate EU level is stimulating growth and jobs in scenarios with fast deployment and high penetration of CAVs for private use. Results are mixed for scenarios with slower deployment of CAD and when fostering sharing modes. Looking closer at the details of structural change and employment, our analysis reveals that demand for employment in freight transport could strongly decline after 2035 as a result of fast deployment of CAD SAE level 4 and 5 trucks. In particular, the number of traditional driver jobs is expected to sharply decline, while new demand for mobility operators will emerge, resulting as net effect in less jobs. In passenger transport services, the level of jobs is expected to be maintained, but a conversion from driver jobs to supervision jobs can be expected. For both, freight and passenger services, the number of jobs operating the systems is increasing and the level of IT skills required is also growing. On the one hand, this structural change of jobs in transport services can make the sector more attractive, including an average increase in salaries. On the other hand, it will require re- and up-skilling of the workforce in the mobility sector.

Earlier than for the transport services, jobs start the structural change for manufacturing jobs in the automotive industry, though these changes are by far less drastic. Employment in electronics, computers and IT sectors is increasing from today on for developing the new CAD technology, both for vehicles and for the infrastructure. The increase becomes stronger after 2030 when the manufacturing of SAE level 4 and level 5 vehicles is covering larger shares of the new purchased vehicle fleet. There seem to be a tendency that manufacturing of CAD vehicle technology is regionally much more concentrated than traditional or current vehicle manufacturing in Europe.

The analysis reveals that the transport service sector over the next two decades is expected to face two rather distinct transition periods. In the first decade, a growing shortage of drivers will have to be addressed. Afterwards, with SAE levels 4 and 5 vehicles deployed, a reduction of traditional driver jobs, combined with requirements for re- and up-skilling towards other jobs, including mobility operators, will be the central topic. This against the background of an ageing driver population, with a workforce that is reducing in size due to retirement and a remaining workforce, which needs to be subject to lifelong learning in order to adapt to changing job requirements.

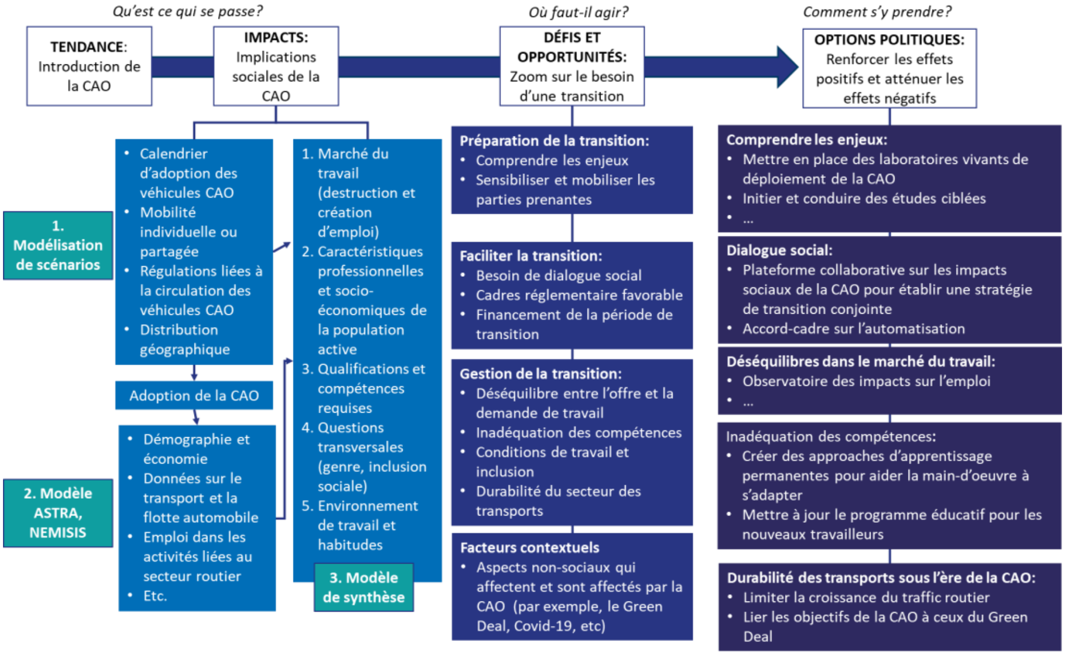
This complex situation needs to be addressed through a holistic transition pathway, to be developed and implemented by the key stakeholders in the process. Our study presents the basis for developing a social roadmap for CAD, including a set of policy options that should be taken in the short-, medium- and long-term. The policies will prepare the transition, for example by enabling knowledge generation in living labs, adapting the legislation where required, etc.; and facilitate and manage the transition towards SAE level 4 and 5, for example by re- and up-skilling of the workforce, monitoring the transition process, etc. In doing so, CAD development needs to be linked to European Green Deal objectives to make transport more sustainable and by moving towards efficient passenger mass transport and intermodal freight transport solutions. Moreover, lessons learnt from the current Covid-19 pandemic needs to be incorporated in developing future proof CAD solutions, including developing health related design standards for future passenger transport solutions.

A core element of a successful transition will be the co-operation and dialogue between industry, and transport workers, as well as authorities and the transport users, which needs to be supported by policy makers at the level of the EU and the Member States.

Résumé analytique

Ce résumé présente les conclusions principales de l'étude. Il décrit les scénarios développés et l'impact de l'introduction de la Conduite Automatisée et Connectée (CAO) sur l'emploi ainsi que sur d'autres indicateurs sociaux. Il présente ensuite les options de politiques publiques pour renforcer les opportunités et minimiser les défis liés à ces impacts. Ces éléments sont présentés dans la Figure ES.1, qui illustre le lien entre les scénarios développés (basés sur une analyse des tendances), les impacts, les défis et les opportunités ainsi que les options de politiques publiques.

Figure E.S.3 Structure de l'approche d'étude



Source: Ecorys

Scénarios et effets

Quatre scénarios sont développés au cours de ce projet, non pas avec la prétention de prévoir, mais plutôt de présenter une analyse rigoureuse des développements possibles de la CAO. Ces scénarios servent ensuite de base pour discuter de les impacts (positifs et négatifs) de la CAO sur l'emploi et sur d'autres indicateurs sociaux et pour définir des politiques visant à prévenir ou à atténuer les effets négatifs et renforcer les effets positifs.

Les scénarios développés comprennent deux "cas limites", qui analysent les situations d'adoption maximale et minimale des CAO, et deux cas intermédiaires:

- Scénario 1: Rapide, privé, illimité et partiellement distribué dans les États Membres de l'UE (Adoption maximale);
- Scénario 2: Rapide, privé, restreint et partiellement distribué (Adoption intermédiaire);
- Scénario 3: Modéré, partagé, restreint et avec une distribution limitée (Adoption modérée);
- Scénario 4: Lent, partagé, restreint et avec une distribution limitée (Adoption faible).

La conception de ces scénarios prend en compte un certain nombre de facteurs déterminants, notamment le moment d'adoption des véhicules CAO, le modèle de mobilité personnelle, les conditions de circulation des véhicules CAO dans les zones urbaines et rurales, les différentes périodes de déploiement dans les différents pays européens, le degré d'acceptation des utilisateurs et le coût des véhicules et des services associés.

L'analyse de scénarios fournit des résultats pour les indicateurs suivants:

- La composition de la flotte de voitures, qui considère l'ensemble des voitures privées, les voitures utilisées pour les services de covoiturage et les taxis;
- La composition de la flotte d'autobus;
- La composition de la flotte de véhicules utilitaires, qui comprend toutes les catégories de véhicules destinés au transport de marchandises, ç'est-à-dire les camions articulés, les gros camions, les camions moyens et les véhicules légers[8];
- Le niveau d'activité de transport de passagers, représenté par la mesure de passager-kilomètre parcourus par tous les modes de transports et la mesure de véhicule-kilomètre;
- Le niveau d'activité de transport des marchandises, représenté par la tonne-kilomètre de tous les modes de transport concernés.

Pour les différents indicateurs ci-dessus, l'analyse montre que le niveau d'adoption de la CAO détermine l'ampleur de ses impacts selon les paramètres du scénario en question.

Si le développement technologique permet de mettre à disposition des Véhicule Autonomes et Connectés (VAC) à un coût relativement abordable, il est probable que la mobilité individuelle augmente, ce qui peut entraîner une augmentation significative de l'activité de transport de passagers sans nécessairement requérir une augmentation de la motorisation (voir section 3.1.1). Les activités de transport augmenteront non seulement en termes de voyageurs-kilomètres parcourus, mais surtout en termes du nombre de véhicules circulant sur la route avec une part importante de trajets à vide.

Sous les conditions posées par le Scénario 1 (développement technologique rapide et circulation de VAC non restreinte), le trafic automobile dans la zone UE27 pourrait être 28% supérieur à celui du scénario de référence défini par l'étude d'ici 2050, ce qui entraînerait une congestion non-viable et des coûts externes substantiels pour la société, particulièrement dans les zones urbaines. Dans le cas du Scénario 2, dans lequel on assume une circulation restreinte des VAC, le trafic automobile pourrait augmenter de 11% comparé au scénario de référence d'ici 2050. Même dans le cas où on assume une propension plus large de mobilité partagée (Scénario 3), une hausse du nombre de véhicule par kilomètre est attendue puisque l'augmentation de la demande de véhicules partagés surpasse les gains liés à l'optimisation de l'usage de véhicules. Ces résultats soulignent l'importance du rôle des autorités de gouvernance des transports pour limiter cette croissance. Celles-ci seront cruciales non seulement pour imposer des restrictions ou des interdictions aux véhicules privés autonomes, mais aussi pour adopter d'autres mesures tel que la tarification sur-mesure des voyages à vide de véhicules autonomes, y compris dans le cas des taxis et des services partagés.

Impacts sur l'emploi

L'introduction de la CAO pourrait affecter l'emploi dans les domaines des services de transports, de la fabrication de véhicules et de composants et de la construction. Elle peut détruire un très grand nombre d'emplois de conducteurs, particulièrement dans le transport des marchandises, et elle peut entraîner une restructuration importante de l'emploi dans les autres services de transport. Par ailleurs, les emplois dans le secteur des technologies de l'information pourraient s'accroître rapidement, et, selon le scénario, l'emploi de stewards pourrait lui aussi augmenter pour faciliter

[8] Ici les véhicules utilitaires légers ne comprennent que les camions légers d'un poids total autorisé en charge inférieur à 3,5 tonnes (dans le sens de véhicules utilisés à des fins commerciales)

l'automatisation des services de transport de passagers et d'opérateurs de mobilité dans le transport de marchandises. Dans le secteur manufacturier, la hausse de la demande de nouveaux véhicules et de composantes à plus forte valeur ajoutée stimulera la croissance de l'emploi. Nous observons une dynamique similaire dans le secteur de la construction étant donné le besoin de nouvelles infrastructures de connectivité. Cependant, cette croissance de l'emploi ne sera pas suffisante pour compenser la perte d'emploi dans les services de transports.

Comme le montre la Table E.S.1, l'impact sur l'emploi varie considérablement selon l'ampleur et la portée de l'adoption des technologies. Pour le transport des marchandises, l'évolution de l'emploi suit le calendrier du développement de l'emploi de la CAO avec une transition et une perte d'emploi plus fortes dans les scénarios d'adoption rapide (scénarios 1 et 2) et l'impact le moins grave dans le scénario d'adoption lente (scénario 4). Le scénario 3 se situe entre les deux.
Le tableau est plus compliqué dans le cas des services de transport de passagers car l'impact sur l'emploi dépend davantage de si la CAO est adoptée à fins de mobilité individuelle ou partagée. La perte d'emploi est plus accentuée dans les scénarios 3 et 4, qui prévoient une croissance significative du covoiturage. Le covoiturage est particulièrement disruptif dans le scénario 3, il pourrait, avec les autres services de transports automatisés plus petits, détruire environ 900 000 emplois liés aux bus et aux taxis, tout en créant 600 000 nouveaux emplois. Dans les scénarios 1 et 2, la CAO sera principalement adoptée à des fins de mobilité individuelle, ce qui laisse le secteur des services de passagers relativement moins touché.

Tableau E.S.2 L'emploi change dans l'UE27, en milliers d'emplois

	Services de transport						Secteur manufacturier [concerne les secteurs affectés par la CAO][9]		
	Passagers			Marchandises					
	2020[10]	2035	2050	2020[11]	2035	2050	2020	2035	2050
Scénario 1	2,122	+91	-46	4,508	+1,749	-2,302	9,190	-164	-168
Scénario 2	2,122	+91	-87	4,508	+1,431	-2,620	9,190	-164	-196
Scénario 3	2,122	+89	-265	4,508	+1,104	-1,247	9,190	-162	-239
Scénario 4	2,122	+89	-157	4,508	+899	+549	9,190	-163	-256
Les chiffres d'emploi en 2020 mesure l'emploi absolu en milliers d'emplois.									
Les chiffres pour 2035 et 2050 indiquent le changement par rapport à 2020 en milliers d'emplois.									

Source: M-Five.

Ces chiffres décrivent l'évolution du nombre d'emploi entre 2020 et 2050 et incluent d'autres tendances, telles que l'augmentation de la demande générale de transport et l'accroissement de la productivité dans le secteur manufacturier. Ils doivent donc être considérés dans ce contexte. L'augmentation de la demande est beaucoup plus forte dans le transport de marchandises par rapport au transport de passagers, ce qui se traduit par une croissance de l'emploi plus accentuée jusqu'en 2035.

[9] Les emplois liés au développement de la CAO dans le secteur manufacturier incluent les sous-secteurs des véhicules, de l'électronique, des ordinateurs et de la communication.

[10] Les résultats de 2020 ont été calibrés pour correspondre aux données empiriques actuelles. Cependant, quelques ajustements ont été fait pour prendre en compte les différences de portée. Pour les transports publiques, nous avons choisi de ne prendre en compte que 80% des données nationales de l'étude *Transport in Figures* (2016). Nous n'avons pas considéré les valeurs entières car elles comprennent le rail urbain alors que cette étude ne le considère pas. Les données du rapport *Transport in Figures* data n'incluent pas les chiffres d'emploi des taxis. Nous choisissons donc d'utiliser les données d'un rapport de l'UE pour tenir compte les emplois du secteur des taxis : *Grimaldi, CERTeT Università Luigi Bocconi, Wavestone* (2016).

[11] Les données 2020 pour le secteur des marchandises ont été calibrés pour correspondre aux données de *Transport in Figures (2016)*, qui comprend à la fois le transport routier de marchandises et les données de services postaux et de messagerie.

Les dynamiques de la transition vers la CAO diffèrent considérablement entre le secteur du transport de passagers et celui des marchandises.

Dans les services de transport de passagers, divers modes automatisés et non-automatisés coexistent et sont en concurrence, comme le cas des bus automatisés et non-automatisés ou le cas du covoiturage autonome. Par contre, les services de transports de marchandises connaissent un déclin de l'emploi plus marqués puisque les flottes de véhicules seront rapidement transformées par l'arrivée de nouveaux véhicules automatisés et plus économiques, ce qui entraînera des pertes d'emploi pouvant atteindre 58% comparé aux niveaux de 2020 dans le cas du scénario 2. Dans le cas où la transition vers la CAO est encore à un stade de développement précoce en 2050, il est possible d'observer une croissance nette de l'emploi puisque l'impact de la hausse de la demande de transports surpassera la perte d'emploi liée à la CAO, comme on peut le voir dans le scénario 4.

Outre le déclin général du nombre d'emplois liés aux services de transports dans la plupart des scénarios, nous prévoyons également une restructuration profonde des emplois et des compétences requises. La CAO remplacera surtout les emplois de conducteur. D'une part, les emplois liés au secteur des technologies de l'information devraient augmenter. Dans le transport de passagers, des stewards seront positionnés dans beaucoup de véhicules pour assurer le service à la clientèle et, éventuellement, leur sécurité. Dans le transport de marchandises, nous prévoyons une période de transition entre les conducteurs traditionnels et les véhicules entièrement autonomes, période pendant laquelle des opérateurs de mobilité superviseront les camions et les véhicules légers. Le personnel des centre de contrôle pourraient aussi jouer un rôle de plus en plus important dans le transport de passagers et de marchandises.

Les emplois du secteur manufacturier connaissent in déclin progressif causé par l'amélioration de la productivité[12], la diminution de l'importance des industries manufacturières et la diminution de la main d'œuvre dans plusieurs pays d'Europe. L'introduction de la CAO contribue à stabiliser cette tendance. Avec le déploiement des véhicules automatisés, l'emploi augmente à mesure que les véhicules gagnent en valeur (avec des composantes à plus grande valeur ajoutée)[13] et la restructuration de la flotte automobile s'accélère[14], ce qui, à terme, mènera à la hausse des ventes de véhicules, en particulier dans les scénarios 1 et 2 avec l'adoption rapide de la CAO.

Tout comme dans le secteur manufacturier, le déclin de l'emploi dans le secteur de la construction est également atténuée par l'introduction de la CAO. En effet, la construction bénéficie directement des investissements dans les infrastructures de la CAO. Ce secteur est très dépendant de l'activité économique en général et il sera indirectement stimulé par la croissance du PIB induite par l'introduction de la CAO et la hausse des ventes de véhicules.

Pour avoir un aperçu complet de l'impact des technologies liées à la CAO, il est essentiel de considérer les effets secondaires. La transition vers le transport automatisé accélère la croissance économique en stimulant le renouvellement de la flotte automobile, les véhicules à forte valeur ajoutée et les investissements liés aux infrastructures et aux installations. Ceci n'affecte pas seulement le secteur manufacturier et les secteur de services décrits ci-dessus. Il augmente

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12 Ceci signifie qu'il sera possible de produire le même niveau de production avec moins d'intrants et moins d'emplois, principalement en raison des progrès technologiques.

13 En général, on s'attend à ce que l'opération de véhicules automatisés soit moins chère que celle des véhicules traditionnels (il s'agit en effet de la condition de leur introduction), cependant les véhicules automatisés seront plus chers car ils nécessiteront beaucoup de technologies supplémentaires pour opérer.

14 L'achat de nouveaux véhicules est l'un des résultats considérés par notre modélisation de scénarios. Voir chapitre 3.3 sur le développement de la flotte automobile. En général, on prévoit une demande importante de véhicules autonomes, si ils sont présentés comme technologie disruptive à prix abordable. Du côté de l'offre, il est possible d'augmenter la capacité de production dans l'industrie automobile.

également la demande globale dans l'ensemble de l'économie, ce qui stimule indirectement l'emploi. La croissance du PIB et ses effets positifs indirects sur l'emploi peuvent partiellement compenser la perte d'emploi dans le secteur des services de transport. Cependant, cela ne suffira pas pour compenser entièrement la perte substantielle d'emplois.

Social impacts

L'introduction de la CAO est prévue avoir un impact substantiel dans le secteur du transport routier et au-delà. Ces effets reliés à la demande devraient, à leur tour, avoir diverses répercussions sociales. La CAO est prévue affecter les besoins en compétences de diverses professions dans le secteur des transport. Elle peut également affecter la représentation des sexes dans le secteur, la distribution par classe d'âge (en particulier les conducteurs et leur futurs homologues—les opérateurs de mobilité), et les niveaux de revenus. La mise en œuvre de la CAO est aussi susceptible d'affecter les questions transversales du secteur des transports routier, notamment le manque de conducteurs observé en Europe et l'inclusion sociale, tant du point de vue de l'emploi que du client. Enfin, l'implémentation de la CAO pourrait aussi s'accompagner de l'introduction de nouveaux modèles d'affaire et d'environnements de travail, tels que les bureaux mobiles.

Dans le secteur du transport de marchandises, l'impact sur les besoins en compétences dans les métiers de conducteur concerne principalement l'introduction d'opérateurs de mobilité à partir du niveau SAE 4[15]. Ces derniers opéreront soit à bord, soit à distance. Les compétences requises diffèrent de celles d'un conducteur traditionnel dans la mesure où les opérateurs de mobilité auront besoin de moins de compétences de manœuvre et plus de compétences de supervision. En outre, les opérateurs de mobilité peuvent combiner leur travail avec plusieurs tâches non liées à la conduite (comme les tâches administratives par exemple). Dans le secteur du transport de passagers, on constate que les conducteurs resteront postés dans le véhicule jusqu'au niveau SAE 5, mais qu'ils assumeront plus de tâches orientées vers le client. À partir du niveau SAE 5 (sans conducteur), des stewards pourraient être introduits à bord pour assurer les relations client et pour assurer la sécurité et la sûreté du véhicule. Dans d'autres professions, on s'attend à une évolution générale vers davantage de compétences informatiques et de compétences liées aux relations client.

En termes d'impact sur les caractéristiques professionnelles et socio-économiques, la CAO devrait attirer des employés plus jeunes car de nouvelles compétences requises (par exemple les opérateurs de mobilité), la nature du travail et son rythme changent. En ce qui concerne le genre, l'introduction de la CAD a le potentiel d'introduire plus de femmes dans des professions dominées par des hommes, puisqu'un éventail de compétences plus large sera demandé et que l'usage de véhicules automatisés rendra les professions du transport routier plus accessible. Par ailleurs, la mise en œuvre de la CAO augmente le besoin en compétences informatiques alors que l'enseignement des STEM et les emplois informatiques souffrent d'un écart important entre les sexes. Concernant les salaires, la demande de niveaux de qualifications plus élevés et de compétences informatiques dans les emplois liés à la CAO pointent à un effet positif sur les revenus. De plus, ce sont des qualifications qui tendent à être polyvalentes.

En ce qui concerne l'impact sur questions transversales, il est important de prendre en compte la pénurie actuelle de conducteurs. Les conclusions de l'analyse montrent que sur le court et le moyen terme, la CAO n'aura pas d'effets sur la demande de conducteurs, et elle n'est pas susceptible d'accroître l'offre car les travailleurs pourraient se voir refuser le passage à

[15] Le niveau SAE est une nomenclature officielle qui classe les véhicules selon leur capacité à assister les conducteurs. La SAE International (Society of Automotive Engineers) a ainsi identifié 5 niveaux de conduite autonome.

l'automatisation. Sur le long terme, par-contre, la CAO peut réduire le problème lié à la pénurie de conducteurs puisqu'elle réduira considérablement (selon le scénario) la demande de conducteurs. Un autre aspect à prendre en compte est la question d'inclusion sociale. Du point de vue de l'emploi, la CAO peut permettre à davantage de personnes handicapées d'accéder à la profession puisque les personnes à mobilité réduite peuvent devenir des opérateurs de mobilité. Du point de vue du consommateur, la CAO pourrait permettre d'inclure plus de personnes à mobilité réduite (personnes âgées, handicapés) en augmentant leur mobilité et leur autonomie de déplacement. Enfin, une fois que la CAO sera plus abordable, partager un véhicule deviendra plus économique qu'en posséder un, ce qui permettra d'offrir des solutions de mobilité à moindre coûts pour les personnes à faible revenu. La tendance à l'usage de véhicule partagé devrait se poursuivre, cependant, les voitures sont prévues rester des symboles de statut social et ceux qui peuvent se le permettre continueront à les acheter pour usage privé, y compris dans l'ère des voitures autonomes.

Concernant l'impact découlant du développement de nouveaux modèles commerciaux, notre étude montre la possibilité d'un accroissement de la concurrence sur le marché des taxis avec l'introduction des robot-taxis. Les robot-taxis sans personnel à bord diminueront l'accessibilité pour les personnes qui pourraient avoir besoin d'assistance pour monter à bord d'un véhicule. En outre, les navettes automatisées sans personnel offrent des alternatives moins coûteuses aux services de transports communs traditionnels, ce qui pourrait permettre d'augmenter la couverture et la fréquence des services. Additionnellement, la CAO pourrait affecter notre manière de nous déplacer. Les trajets plus longs devraient être moins contraignants dans un véhicule automatisé puisqu'il sera possible de combiner le déplacement avec le travail ou les loisirs. Ceci pourrait amener une plus grande acceptation des long trajets entre la maison et le travail. Dans la même logique, les voitures privées deviennent un choix attractif pour les longs trajets, relatif aux autres modes de transport, puisque la fatigue ne sera plus une contrainte.

Enfin, la CAO affectera aussi notre environnement de travail puisque les véhicules entièrement automatisés pourraient devenir un espace de travail temporaire ou secondaire pour de nombreuses professions qui impliquent beaucoup de déplacements. En outre, si la conduite n'est plus considérée comme une part entière du travail (puisque le conducteur peut se reposer), la durée d'une journée de travail pourrait ne plus être limitée par des législations qui incluent un nombre maximal d'heures de conduite par jour ou une durée minimale de pauses, ce qui aura pour conséquence d'augmenter la durée des postes de travail. Les centres de contrôle pourraient devenir un nouvel environnement de travail, de part lequel les opérateurs de mobilité superviseront et commanderont les véhicules. En ce qui concerne le transport de marchandises, la présence humaine pourrait être requise à bord de véhicules entièrement automatisés pour prévenir la criminalité et pour effectuer des tâches de sécurité ou administratives liées à la logistique, transformant le véhicule en une combinaison entre bureau, salle de sécurité et chambre d'hôtel.

Les options de politiques et le processus vers une feuille de route sociale de la CAO

Comme indiqué dans la Figure ES. 1, les défis et opportunités sont définis sur la base des impacts sur l'emploi et sur les autres indicateurs sociaux. Les défis et opportunités sont formulés en termes de préparation, de facilitation et de gestion de la transition vers le déploiement de la CAO et ils constituent le fondement des politiques définies. La Figure ES.2 présente les 22 options de politiques, regroupées par domaine de transition, avec les défis et opportunités sous-jacents. Pour chaque option, nous présentons les acteurs concernés en distinguant les catégories suivantes :

- Les partenaires sociaux, c'est-à-dire les entreprises et le travailleurs (PS)
- Les États membres, ç'est-à-dire les gouvernements nationaux et leurs autorités régionales et locales (EM)
- La Commission Européenne, ç'est-à-dire les autorités au niveau de l'UE (CE)
- La Communauté de recherche, ç'est-à-dire les chercheurs scientifiques qui adresse la CAO et ses aspects sociaux (CR)
- Le milieu académique et les instituts de formation, ç'est-à-dire les établissements d'enseignement (AIF)

Figure E.S.4 Les options politiques par phase et la participation des parties prenantes

Défis et opportunités	Options politiques pour préparer la transition
Comprendre les enjeux	1. Mettre en place des **laboratoires vivants** pour le déploiement de la CAC, consacrés à l'analyse des impacts sur l'emploi et sur les autres indicateurs sociaux.
	2. Initier et mettre en oeuvre des **études ciblées** sur la compréhension des impacts de la CAC sur l'emploi et sur les autres indicateurs sociaux.
	3. **Intégrer les leçons apprises de la pandémie de Covid-19** pour développer des solutions CAC évolutives, y compris le développement de normes de santé pour le transport de passsagers.
Sensibiliser et mobiliser les parties prenantes	4. Organiser des **activités de sensibilisation** pour les parties prenantes.
	5. Développer des **mécanismes de collaboration** pour le suivi du processus de transition.
	Options politiques pour faciliter la transition
Le besoin de dialogue social	6. Lancer une plateforme de collaboration sur les impacts sociaux de la CAC, potentiellement dans l'optique d'apporter **une stratégie conjointe et d'assurer le financement.**
	7. Établir un **accord-cadre sur l'Automatisation**, qui engagera les partenaires sociaux actif dans les transports.
Cadre réglementaire favorable	8. **Cartographie et suivi des législations sociales** affectées par l'automatisation dans le secteur des transports routiers
	9. Révision des **lois relatives à la conduite et au repos** du conducteur.
	10. Révision des lois concernant les **qualification requises** pour les conducteurs. La révision doit être basée sur les évidences collectées concernant les qualifications requises.
Financement du processus de transition	11. Mettre à disposition des fonds pour gérer la transition sur la base d'une **stratégie de transition.**
	Options politiques pour assurer le suivi de la transition
Déséquilibres entre l'offre et la demande de travail	12. Mettre en place et lancer un **observatoire des impacts sur l'emplois et des impacts sociaux** du déploiement de la CAC.
	13 **Équilibrer l'offre et la demande de travai**l dans les transports routiers.
	14. **Formation ciblées des travailleurs déplacés** pour intégrer les emplois à l'intérieur ou à l'extérieur du secteur des transports
	15. **Addresser le déséquilibre géographique entre l'offre et la demande de travail** causé par la transformation des tendances régionales dans le secteur manufacturier et les services de transports.
Inadéquation des compétences liées à l'automatisation	16. Créer des **approches d'apprentissage permanentes** pour aider la main d'oeuvre actuelle à s'adapter aux changements de qualifications requises
	17. Adapter le **programme éducatif** actuel pour préparer les nouveaux travailleurs aux changements de besoin en compétences.
Conditions de travail, attractivité du secteur et inclusion sociale	18. **Cibler une main d'oeuvre plus diversifiée** à travers la promotion du secteur des transports routiers et encourager le recrutement dans les transports routiers
	19. S'assurer que le déploiement de la CAC apporte des **amélioration des conditions de travail**.
	20. **Promouvoir l'inclusion sociale dans services de transports** liés aux véhicules autonomes.
Transports durables dans l'ère de la CAC	21. **Minimiser l'augmentation du trafic routier** en imposant des restrictions et en promouvant les solutions de mobilité partagée.
	22. **Lier les développement de la CAC aux objectifs du Green Deal européen** pour rendre les trans-ports plus durables en adoptant des solutions efficaces de transports de passagers en masse et de transport intermodal de marchandises .

Source: Ecorys. Remarque: 1 Comprend la participation des municipalités (pour PO-21).

Synthèse

Le déploiement de la CAO dans les transports routiers est un processus continu qui nous fera passer du niveau SAE 2 actuel, avec les fonctions de support aux conducteurs, au niveau SAE 5, qui implique l'usage de véhicules entièrement connectés et automatisés dans les prochaines décennies. Les progrès (techniques, juridiques, l'acceptation générale, etc.) qui permettront la circulation des VAC sur nos routes sont prévus être implémentés au plus tôt après 2035. Par conséquent, les impacts majeurs sur les systèmes de mobilité et sur l'emploi ne semblent prendre effet qu'après cette date. Ce résultat ressort de notre consultation avec les acteurs du secteur et de l'analyse de scénario qui a pris place pendant cette consultation, ainsi que de notre analyse basée sur des modèles.

Le déploiement au niveau de l'UE stimule la croissance et l'emploi dans des scénarios considérant un déploiement rapide et une pénétration rapide des VAC à usage privé. Les résultats sont mitigés dans les scénarios considérant un déploiement relativement lent et focalisés sur l'usage collectif. En observant de plus près les changements structurels et ceux de l'emploi, il ressort de notre analyse que la demande d'emploi dans le transport des marchandises pourrait baisser considérablement après 2035 en raison du déploiement rapide des camion à CAO SAE 4 et SAE 5. En particulier, le nombre de conducteurs traditionnels est prévu de diminuer de manière importante, tandis qu'une nouvelle demande d'opérateurs de mobilité apparaîtra, ce qui aura pour effet une réduction nette du nombre d'emplois. Dans le transport de passagers, le niveau d'emploi devrait rester stable, mais une conversion des emplois de conducteurs en emploi de supervision est attendue. Tant dans les services de transport de marchandises que de passagers, le nombre d'emplois liés à l'exploitation des systèmes augmente et le niveau de compétences informatiques requis s'accroît. D'une part, ce changement structurel des emplois peut rendre le secteur plus attractif et implique une augmentation des salaires moyens. D'autres part, ce changement exigera une requalification et une amélioration des compétences de la main-d'œuvre dans le secteur de la mobilité.

Les emplois du secteur manufacturier liés à l'industrie automobile commenceront à changer plus tôt que ceux des services de transport, bien que ces changements sont prévus être beaucoup moins drastiques. L'emploi dans les secteurs de l'électronique, de l'informatique et des technologies de l'information a déjà commencé à augmenter pour développer les technologies autour de la CAO, tant pour les véhicules que pour l'infrastructure. Cette augmentation est prévue s'accélérer après 2030, période à partir de laquelle la production de véhicules SAE 4 et 5 couvrira une plus grande part de la flotte automobile achetée. Il semble y avoir une tendance vers une concentration plus régionale de la production de véhicules connectés et automatisés comparé au modèle de production traditionnel ou celui qui prévaut actuellement en Europe.

L'analyse révèle que les service de transport rencontrera deux périodes de transition distinctes au cours des deux prochaines décennies. Au cours de la première, il faudra faire face à la pénurie croissante de conducteurs. Au cours de la deuxième décennie, avec le déploiement des niveaux SAE 4 et 5, il faudra se concentrer sur la réduction des emplois de conducteur traditionnels et la nécessité d'organiser une requalification et une amélioration des compétences de la main-d'œuvre pour la préparer à transiter vers d'autres emplois, tel que celui d'opérateur de mobilité. Il faudra considérer ces sujets dans un contexte d'une population de conducteurs vieillissante, avec une main-d'œuvre qui se réduit en raison de départ à la retraite, et d'une main-d'œuvre restante qui nécessitera un long processus d'apprentissage pour s'adapter aux exigences changeantes des emplois.

Étant donné la complexité de la situation, il faudra s'assurer que le parcours de transition soit holistique. Il doit être élaboré et mis en œuvre par les principaux acteurs du processus. Notre étude présente une base pour développer une feuille de route sociale pour la CAO, et elle comprend un ensemble d'options politiques à implémenter dans le court, moyen et long-terme. Ces politiques, d'une part, prépareront cette transition en permettant par exemple la génération de connaissances dans des laboratoires vivants, ou en adaptant le cadre légal si nécessaire, etc. D'autre part, elles permettront de faciliter et d'assurer le suivi de la transition vers les niveaux SAE 4 et 5, par exemple en assurant une requalification et une amélioration des compétences de la main-d'œuvre, ou en assurant le suivi du processus de transition, etc. Dans ce processus, le développement de la CAO doit être lié aux objectifs du « Green Deal » européen pour rendre le secteur des transports plus durable. Il doit s'orienter vers des solutions efficaces de transport de passagers en masse et de transport intermodal de marchandises. En outre, les leçons apprises de la pandémie de Covid-19 doivent être intégrées dans des solutions CAO évolutives, y compris le développement de normes de santé pour le transport de passager.

Un élément-clé pour le succès de la transition sera la coopération et le dialogue entre l'industrie, les employés du secteur des transports, les autorités et les usagers. Cette coopération devra être soutenue par les décideurs politiques au niveau de l'UE et des États membres.

PART 1:
Introduction and methodology

1 Introduction to this report

1.1 Background of this report

This Final Report summarises the findings of a 16 month study on exploring the possible employment implications of connected and automated driving (CAD). The study was contracted by the Directorate-General for Research and Innovation (DG RTD) of the European Commission with the purpose of providing evidence to a much discussed but not much researched topic. Specifically, the report provides an:

1. Analysis of the short, medium and long term impacts of CAD on jobs, employment, skills and knowledge, as well as possible changes in work patterns and the work environment, business and operation models;
2. Investigation and elaboration of options in key policy areas, i.e. jobs, employment, skills, growth, transport and R&I, in order for the European Union to take timely action for the safeguarding and enhancement of the positive effects and the avoidance or mitigation of the negative effects of CAD on jobs and employment.

In implementing this project, we brought together a project consortium consisting of:

- Experts in project management, social impacts and policy development from Ecorys Nederland B.V. (Ecorys).
- Experts in designing future transport scenarios from Trasporti e Territorio SRL (TRT);
- Experts in developing economic and employment models from M-Five GmbH (M-Five) and Société EURopéenne d'ECOnomie SARL (SEURECO);
- Stakeholder experts providing data from the road transport and manufacturing companies namely the International Road Transport Union (IRU), the International Association of Public Transport (UITP), and ERTICO ITS-Europe (ERTICO);
- Technical expertise on the development of CAD from the Technical Research Centre of Finland Ltd (VTT) and the Centre for Automotive Management (CAM).

1.2 Content of this report

The report presents the main findings of the study including the CAD deployment scenarios, the assessment of employment and other social impacts, the development of policy options, as well as supporting results of literature review and stakeholder consultation. The report is divided into three parts:

- PART 1 – Introduction and Methodology;
- PART 2 – Scenarios and impacts of CAD;
- PART 3 – Policy Options towards a social roadmap for CAD.

Each parts consist of several chapters. Table 1.1 presents the contents of this report as a guide to readers.

Table 1.1 A guide to readers

PART 1 – Introduction and Methodology
Chapter 1 – Introduction A short introduction outlining the background and content of the report.
Chapter 2 – Methodology

A short chapter outlining the methodology applied for this study. It contains information on definitions, scope, overall approach, as well as the methodology of the scenario model, the economic and employment models, the synthesis model, and the policy options. Supporting annexes are Annex B, C, and E.
PART 2 – Scenarios and impacts of CAD
Chapter 3 – Scenarios for future CAD deployment This chapter presents the uptake of CAD along four deployment scenarios including information on fleet composition as well as passenger and freight transport activity. Annex B provides additional results.
Chapter 4 – Employment impacts of CAD In this chapter the findings of the economic and employment models are presented in the form of employment numbers for the four scenarios up to 2050 for road transport services and manufacturing. These results are presented by job category (e.g. drivers), at EU, national and regional level.
Chapter 5 – Other social impacts of CAD This chapter presents findings on social impacts of CAD, such as changing skill requirements in road transport, changes in the professional and socio-economic characteristics of the sector, cross-cutting issues, and finally social impacts based on new business models and work environments.
PART 3 – Policy Options towards a social roadmap for CAD
Chapter 6 – Policy options for CAD deployment This chapter takes the identified impacts in the previous chapters and summarises them under challenges and opportunities in order to propose policy options to address these. These policy options are separated by preparing, facilitating, and managing the transition.
Chapter 7 – Towards a social roadmap for CAD deployment Chapter 7 operationalises the identified policy options by adding a timeline and by describing the role of various actors (public authorities, social partners, academia, etc.). It sets the ambition to work towards a social roadmap for CAD.
Chapter 8 – Synthesis A short synthesis bringing together the main findings of the report.
Bibliography The literature used throughout the main report.

In addition, supporting information was collected in annexes. These are collected in a separate document, which contains the annexes listed in Table 1.2.

Table 1.2: Content of the Annex Report

ANNEXES
Annex A – Data Collection Framework An overview over the data used in the Scenario, ASTRA, NEMESIS, and Synthesis model.
Annex B – The Scenario Model and Scenarios A detailed description of the model and its separate modules and results for the four scenarios.
Annex C – The Economic and the Synthesis models A detailed description of the ASTRA and NEMESIS model as well the Synthesis model. This Annex includes also detailed modelling results, and a comparison between ASTRA and NEMESIS results.
Annex D – Literature review and sources A literature review conducted at the beginning of the study. The review covers topics such as the state of play, a timeline for CAD, possible impacts, and an overview over policies and CAD related projects. It also includes a longlist of over 100 academic and grey literature.
Annex E – Stakeholder consultations The results of the stakeholder consultations fed into the scenario development, impacts as well as policy options. The Annex includes an overview over the types of consultations and a summary of results from the first and second round of interviews, and the survey.
Annex F – Aggregated survey results

The full results from the survey.
Annex G – Workshop minutes Reporting summarising the findings from the three workshops and the final conference.
Annex H – Impact on business models A more detailed description of the analysis on the impact of new business models and work environments. A short description is in Chapter 5.
Annex I – Policy measure matrix A matrix connecting policies with the identified challenges and opportunities.

2 Methodology of the study

2.1 Definitions and scope

This section presents commonly used terms and their definitions in this report as well as the scope of the study.

2.1.1 Definitions

The following definitions are applied in the study:

- Automated systems typically run within a well-defined set of parameters and are restricted in what tasks they can perform;
- In contrast, an autonomous system learns and adapts to dynamic environments, and evolves with the environment;
- Connected vehicles can exchange information wirelessly with other vehicles and infrastructure, but also with the vehicle manufacturer or third-party service providers;
- Automated vehicles, on the other hand, are vehicles with features that go beyond driver support features (so beyond SAE levels 0 to 2) and where drivers do not have to drive when these features are engaged (SAE levels 4, 5 and in certain circumstances also level 3);
- However, in this study, automated passenger transport services (robo-bus, robo-taxi and ride-sharing) are defined as SAE level 5, while automated freight transport services also include SAE level 4;[16]
- SAE level 4 freight vehicles will require a mobility operator who is not driving but supervising the vehicle and intervening in rare circumstances. Mobility operators could take on other tasks during a ride, and could work either in the vehicle or a remote control centre;
- In passenger transport, SAE level 5 vehicles (e.g. robo-bus) will require early-on a steward on-board, who has a customer relations as well as safety and security function in order to help customers unfamiliar with automated vehicles to get accustomed to them.

Furthermore, we created four scenarios for the deployment of CAD along which we analysed the employment and social impacts. These scenarios are defined as follows:

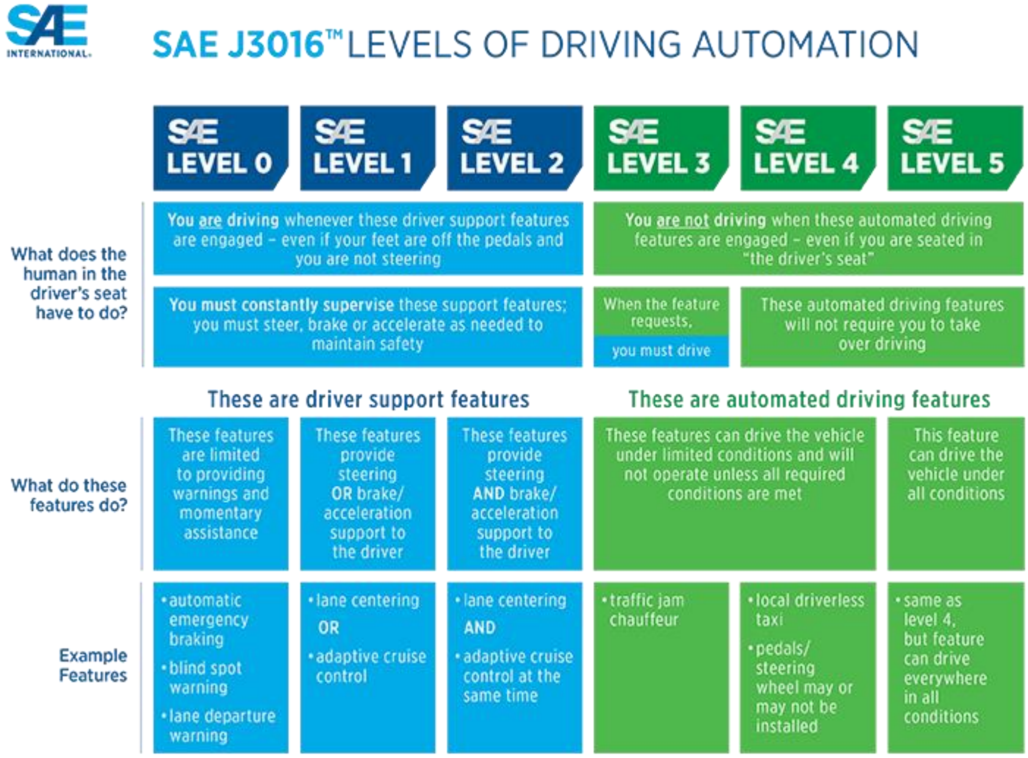
- Scenario 1 (Fast, private, unrestricted and partially distributed) is the scenario with the maximum penetration of Level 5 vehicles due to a combination of fast technology development and null restriction to the circulation of CAD vehicles in urban and rural areas;
- Scenario 2 (Fast, private, restricted and partially distributed) is the scenario with an intermediate penetration of Level 5 vehicles and is aimed to test the role that the restriction to the circulation of CAD vehicles could play in a scenario where fast technology development will take place;
- Scenario 3 (Moderate, shared, restricted and with limited distribution) is the scenario with a moderate penetration of Level 5 vehicles and is designed to take into account a situation where future technological development will happen at a slower pace than in the previous two scenarios;
- Scenario 4 (Slow, shared, restricted and with limited distribution) is designed as a boundary condition to consider a low penetration of CAD vehicles due to slow technological improvement coupled with low acceptance from final users.

Figure 2.1 showcases the six automation levels, as established by SAE International, which are separated by driver support features (SAE levels 0 to 2) and automated driving features (SAE

[16] The changes in freight transport are more gradual than in passenger transport. We expect significant employment saving potential starting from platooning on SAE level 3. Level 4 freight vehicles may be able to function mostly autonomously on fixed routes that are relatively low in complexity.

levels 3 to 5). Technological progress is likely to come through a gradual expansion of Operational Design Domains (ODD) of automated vehicles.

Figure 2.1 SAE Levels of Driving Automation for On-Road Vehicles



Source: SAE, J3016 "Levels of Driving Automation" standard.

2.1.2 *Scope of the study*

Geographical scope

The geographical scope of the study is the EU after the departure of the UK, or EU-27. All of the main aggregate results presented in the main text are for all EU-27 countries. We include other non-EU countries in the maps (UK, NO, CH) in Chapter 4 and some more detailed results for non-EU countries in Annex C.

Time-line of the analysis

The study has a time horizon up to 2050, at which time (depending on the scenario), CAD technology will have been deployed to a large extent on EU roads. A timeframe is applied, distinguishing between the short-term (2021-2025), medium-term (2026-2035) and long-term (2036-2050) period, both for assessing impacts and defining policy options.

Services covered

The study considers both road passenger transport services as well as freight transport services.

Road passenger transport services include the conventional services taxi, car-sharing, and conventional bus. Automated passenger transport services are robo-bus, robo-taxi and ride-sharing, defined as SAE level 5. Road freight transport includes conventional light-duty vehicles and heavy-duty vehicles as well as their automatic equivalents with SAE level 4 and 5.

Jobs covered

The study covers drivers as well as six non-driver job categories, namely administration, management, IT staff, customer service, stewards & operation staff and maintenance. Specifically, it also looks at the newly emerging job profiles, namely mobility operators and stewards (for definitions see Section 2.1). In addition, the study covers employment in certain manufacturing sectors without differentiating further between occupations.

Sectoral coverage

Employment in CAD-relevant manufacturing sectors includes employment in the vehicle, electronics, computer, and communication sectors. In addition, the study assesses the employment impact in the construction sector as it is involved in the construction of CAD infrastructure and of new production facilities for CAD components.

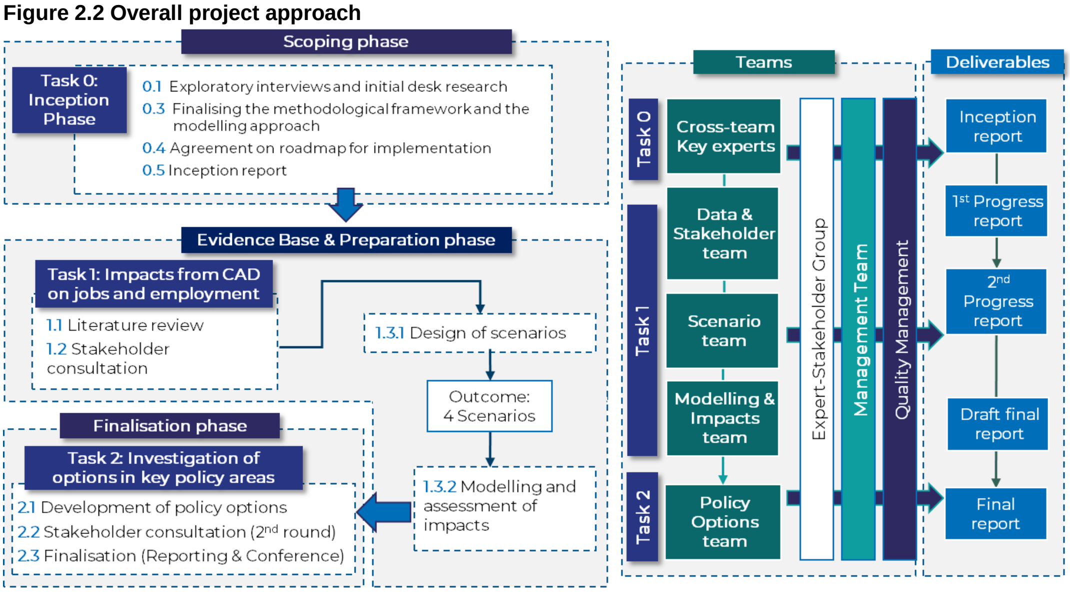
2.2 General approach

The two objectives of the study are:

- The analysis and assessment of the short, medium and long term impacts of CAD on jobs, employment, skills and knowledge, taking into account possible changes in work patterns and the work environment, business and operation models;
- The investigation and elaboration of options in key policy areas, i.e. jobs, employment, skills, growth, transport and R&I, in order for the European Union to take timely action for the safeguarding and enhancement of the positive effects and the avoidance or mitigation of the negative effects of CAD on jobs and employment. These options take into account possible implications and correlations with other policy areas such as energy, environment, safety and health.

These two objectives are translated into two main tasks, which are the assessment of employment and social impacts of CAD and the investigation of policy options. The two main tasks, together with a breakdown of specific subtasks, teams, and deliverables are presented in Figure 2.2.

Figure 2.2 Overall project approach



Source: Ecorys.

In the sections hereafter, we present shortly the methodology for the modelling of impacts, the definition of policy options, the data collection of data, the literature review and the stakeholder consultations. In these sections, reference is made to more detailed information on methodology, which is presented in the annexes.

2.3 Scenario and modelling approach

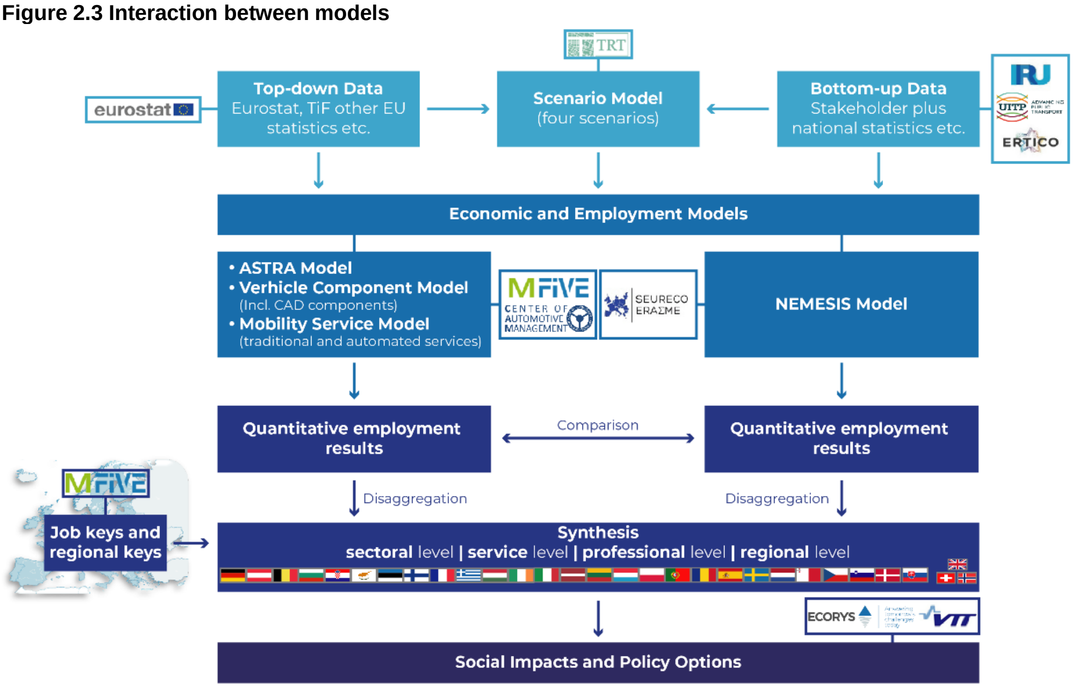
2.3.1 Introduction

In the context of this study, CAD scenarios are the inputs for the modelling tools ASTRA and NEMESIS that are applied for the estimation of the impact of CAD on employment. Therefore, the scenarios consist of numeric values for a set of variables used as exogenous elements within ASTRA and NEMESIS.

In order to provide a consistent set of quantitative inputs, a Scenario Model has been developed. The outputs of this model represent some of the exogenous inputs required by ASTRA and NEMESIS to calculate the impact on employment. All outputs of the Scenario Model are endogenously estimated, building on assumptions about some key variables that are supposed to be drivers of the required outputs. For instance, one major element of CAD scenarios is the uptake of autonomous vehicles. This is an output of the Scenario Model where the estimation of the uptake is calculated on the basis of various elements, such as technological development, acceptance, etc. More specifically, quantitative assumptions on these elements are endogenously used by the Scenario Model to produce its output in terms of CAD vehicle uptake. This output is then used as input for ASTRA and NEMESIS models.

The economic models provide input in the synthesis model, delivering the impacts as defined in the ToR. The interaction between the various models is presented in Figure 2.3.

Figure 2.3 Interaction between models



Source: M-Five.

2.3.2 Scenarios and Scenario Model

Design of the scenarios

It is worth clarifying that CAD scenarios are not forecasts but the exploration of consistent and coherent alternative hypothetical future developments which serve as a basis for discussing potential impacts on the employment sector (both positive and negative) and outlining policies to prevent or mitigate negative impacts.

Explorative in nature, scenarios have the advantage over forecasts in that they are more flexible, creative and can broaden the perspectives of long-term planning by highlighting unexpected dynamics**.** To this aim, four CAD scenarios have been designed to explore hypothetical situations: two extreme boundary conditions simulating a maximum and a minimum uptake for CAD vehicles and two intermediate cases. Scenarios are intentionally highly differentiated to explore different potential dynamics and magnitudes of impacts in the occupational sector.

CAD scenarios have been designed on the basis of evidences collected from stakeholders' consultation and from literature.

It is worth to mention that diverging perspectives emerge in relation to the timing of CAD deployment: outcome from literature dated back few years ago suggests a closer in time uptake of full automated vehicles, whereas CAD researchers interviewed during the stakeholders' consultation suggest a more conservative timeline, with Level 5 vehicles hardly available on the market before the next 15 - 20 years. As similar opinions emerged as well from the survey performed in the context of this study, CAD scenarios have been designed to explore different timing for the uptake of full automated vehicles comprised in the time horizon 2035 to 2045.

This timeframe is based both on the stakeholders' views and on the capabilities of the models which can be not executed beyond 2050.

Besides the timeline for Level 5 uptake, a number of distinguishing factors characterise the scenarios including cost of ownership, model for personal mobility, usage of shared services, number and level of restrictions in the circulation of CAD and spatial distribution.

Preliminary CAD scenarios have been presented to stakeholders during a dedicated workshop hold in Brussels on the 30 January 2020. A significant part of the discussion during the workshop was focused on clarifying the different scenarios' assumptions and the approach used by the Scenario Model to simulate such assumptions. The discussion focused as well on policy aspects lying outside the scope of the modelling suite including among others: insurance issues and liability rules, infrastructure readiness and legal framework, responsibilities in case of technical breakdowns and traffic accidents etc.

Clarifications provided by the project team on the explorative nature and contents of the CAD scenarios proved to be exhaustive and no needs for major changes in the scenarios' design emerged.

Scenario Model

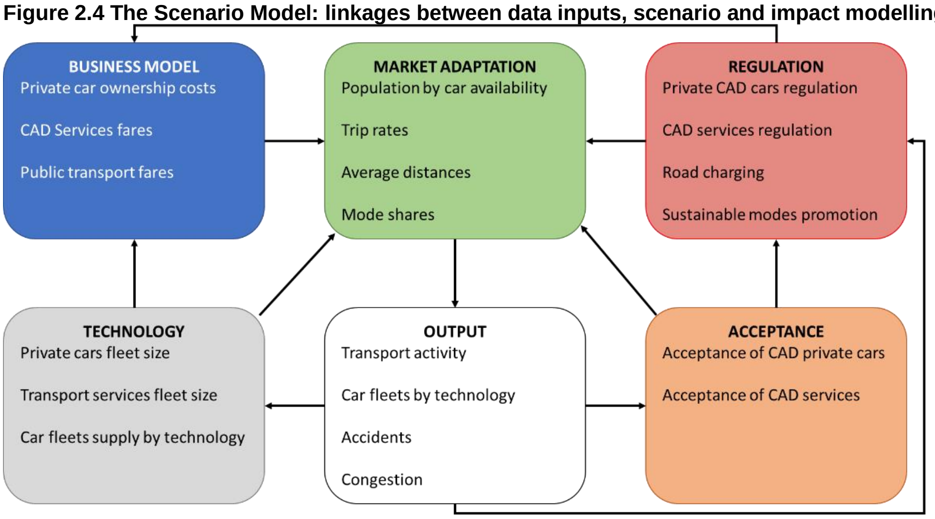
The four scenarios for the development of CAD are defined with the support of a dedicated System Dynamics Scenario Model specifically designed to analyse alternative uptakes of CAD in an integrated manner as a result of different dynamics of both the supply and the demand sides.

System Dynamics is a modelling technique particularly suited to frame, understand and discuss the dynamic behaviour of complex systems and problems. The basis of the method is the recognition that the structure of any system, the many circular, interlocking, sometimes time-delayed relationships among its components, is often just as important in determining its behaviour as the individual components themselves. A System Dynamics model consists of a set of hypotheses on the relationship between causes and resulting effects. Hypotheses may be based on theory or only informed by theory, but empirical inputs from statistics, surveys or other observations may also be used.

Relationships are represented by equations that are written and solved by mathematical simulation. In other words, a System Dynamic model does not have a specific set of unknown parameters or variables whose value is estimated as a solution of the model. Instead, most of the model variables change dynamically over time as an effect of the interaction of positive or negative feedback loops. This can be considered as the most important characteristics of any complex systems.

The Scenario Model is made of six main modules connected to each other as shown in Figure 2.4. A brief description of the main role of each module is given below. More details can be found in Annex B.

Figure 2.4 The Scenario Model: linkages between data inputs, scenario and impact modelling



Source: TRT.

The outputs of the model are a quantitative description of the four alternative scenarios to be used as input by the economic and employment models, ASTRA and NEMESIS, in order to estimate the economic and jobs related impact.

2.3.3 *Economic and Employment Models*

Overview of the ASTRA Model

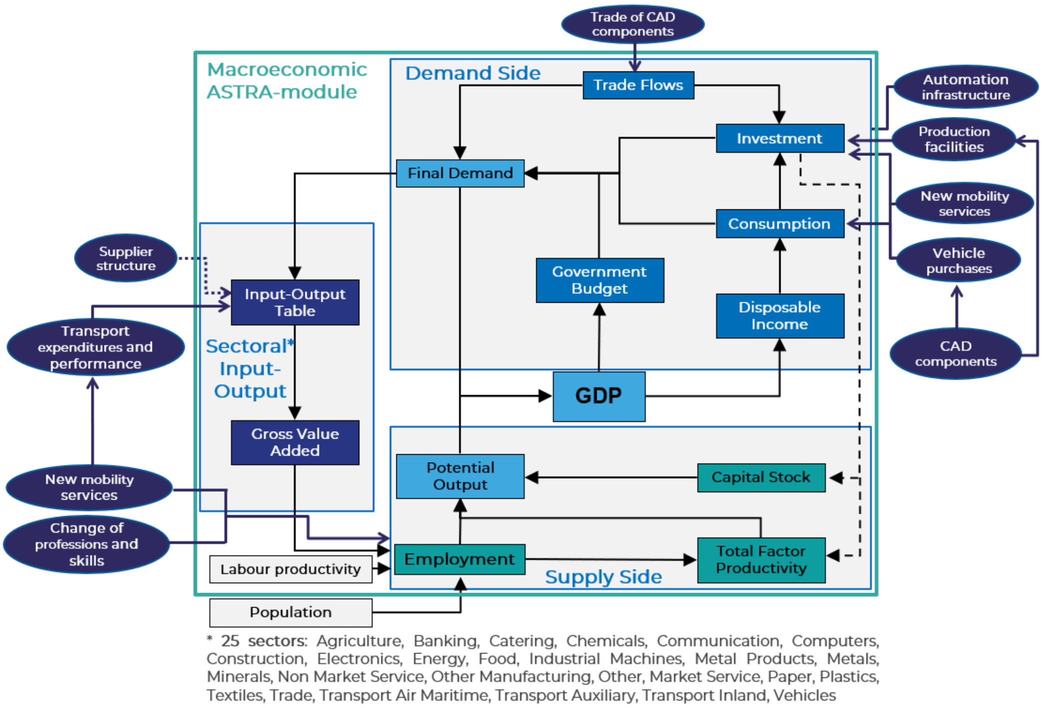
ASTRA, which means ASsessment of TRAnsport strategies, is an integrated assessment model applied for strategic policy assessment in the transport and energy field since more than 15 years. It covers EU27+3 (Norway, Switzerland and UK) countries. It builds on recursive simulations following the system dynamics concept and enables to run scenarios until 2050. In this project, only the foreign trade (FOT module) and economic sub-modules (MAC module) of ASTRA are linked with the Scenario Model to produce macroeconomic results. The MAC module consists of five elements: supply side, demand side, an input-output model based on 25 economic sectors, employment model and government model.

For further details on the modelling of ASTRA, see Annex C as well as Fermi et al. (2014).

CAD Impulses on the Economy

Figure 2.5 shows a conceptual overview of the macroeconomic linkages and selected CAD impulses (blue ellipses) using the ASTRA model. Detailed descriptions of the relationship of the variables and their modelling can be found in Annex C.

Figure 2.5 The macro-economic module of ASTRA and selected CAD effects



Source: M-Five.

The economic impulses from CAD are divided into different elements: The economy is affected by impulses from:

- New mobility services (see mobility service model, as described in Annex C);
- On-board vehicle equipment, i.e. CAD-components in vehicles that are produced for the domestic market as well as exported (see component model, as described in Annex C);
- Investment in infrastructure for CAD (see Annex C);
- Investments in semiconductor production facilities and software development (see Annex C).

The impulses arise from various mechanisms, that are modelled either endogenously in ASTRA due to dependencies on modelled developments (e.g. component model and mobility service model), that are based on the Scenario Model (e.g. private transport expenditures affecting consumption) or that are derived exogenously based on studies and data (e.g. CAD-infrastructure). Detailed descriptions of the respective modelling of above-mentioned impulses can be found in the Annex.

The vehicle component model is used to estimate the value of components installed in vehicles and forms the link between vehicle fleet scenarios and impact to economic sectors. It is adapted to the development of CAD technologies and their expected effects on the economy, especially sectoral jobs in manufacturing that depend on the components built in future cars, buses and trucks.

Transport services employment is calculated based on expenditures results of the Scenario Model and employment parameters. Transport expenditures (vehicle km multiplied with total cost of ownership or revenues from fares per vehicle km plus subsidies in some cases) is equivalent to revenues of transport services. This is multiplied with transport parameters for employment per million euros of revenues. These parameters depend on the structure of expenditures of transport services, skill levels of employees and therefore income levels as well as variation by country income level.

Automated modes are defined as automation level 5 in road passenger transport (automated taxis, ride-sharing etc.) because they are expected to be feasible only at this level and not at level 4. In road freight transport, in contrast, automated modes are defined as both level 4 and 5, accounting for the different dynamics in the sector. The transition to automated modes is more gradual in some ways in freight transport. For example, we expect significant effects starting at level 3 automation with platooning.

Overview of the NEMESIS Model

NEMESIS is a detailed macro sectoral simulation model for the EU economy. It includes all EU Member States, which can be simulated altogether or individually. The rest of the world is not explicitly modelled, but the model allows a simplified modelling of the external trade of EU with ten other world regions. There are 30 production sectors of which one sector for agriculture, 6 utilities, 13 manufacturing industries, construction, 3 transport services industries, 6 groups of market services and non-market services. The NEMESIS model also considers a detailed consumption mechanism allowing to disaggregate macro consumption into 27 categories.

2.3.4 *The Synthesis Model*

The quantitative impacts of the four CAD scenarios on the labour market are presented by focusing on three layers analysed by this project:

- Layer 1 provides sectoral results at the aggregate level of EU27 as well as at Member States level. The economic models consider 25 NACE[17] sectors in terms of ASTRA and 30 NACE sectors in terms of NEMESIS. The results are presented for five CAD-related sectors: vehicles, electronics, computers, construction and construction;
- Also, for layer 2 results are presented differentiating the job impacts due to changes in mobility services for freight and passenger transport. The road freight transport is sub-divided into the light-duty vehicles (up to 3.5 tonnes total weight) and heavy-duty vehicles (more than 3.5 tonnes total weight). The passenger transport is sub-divided into buses (classic and automated), taxi operations (classic and automated) as well as car and ridesharing. These results differentiate between impacts on drivers and non-driver job categories. In the first step, the non-driver category is aggregated;
- Layer 3 provides spatial results on the level of NUTS[18] II zones within EU27, as well as Norway and Switzerland. These results differentiate between domestic regions (NUTS II zones) and job categories. In distinction to layer 2 the job category “non-driver” is divided into six sub-categories: Administration, Management, IT, customer service, stewards & operation staff and maintenance. Finally, the national and service-based numbers are disaggregated for every job category and NUTS II zone.

The layer structure of the synthesis model is presented in Figure 2.6. More information on the synthesis model is presented in Annex C.

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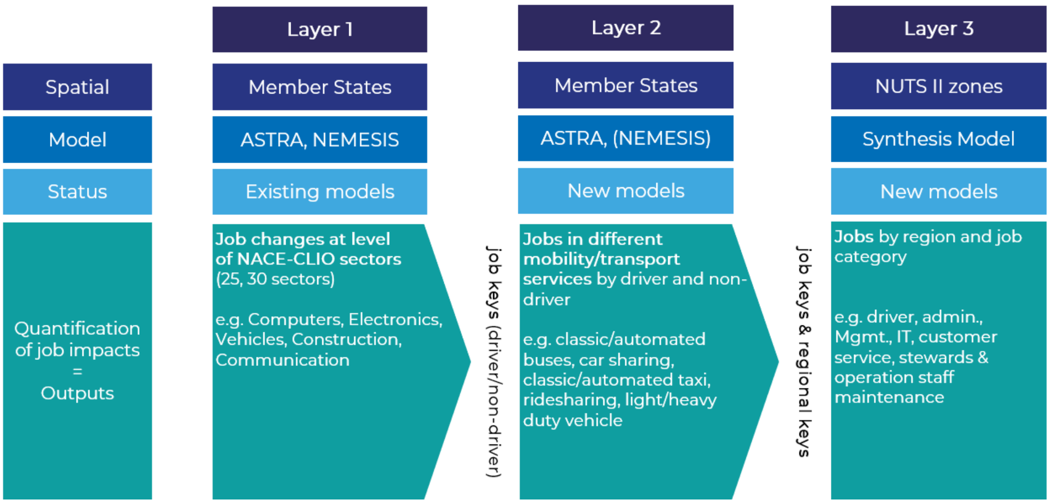
[17] NACE = Statistical Classification of Economic Activities in the European Community. The classification applied is an extended version used to elaborate Input-Output Tables for EU MS, which covers additional manufacturing sectors compared with NACE level 1 rev. 2 from 2008.

[18] NUTS = Nomenclature of Territorial Units for Statistics. The geocode standard refers to the subdivisions of countries for statistical purposes. The standard is developed and regulated by the European Union and covers the EU MS in detail.

Figure 2.6 The synthesis model and its three layers



Source: M-Five.

2.4 Policy options

The policy options are defined to respond to the identified impacts as to be able to enhance the positive effects and mitigate the negative effects of the introduction of CAD on jobs and employment. In order to establish the connection between impacts and policy options, an intermediate step has been introduced in which challenges and opportunities resulting from the employment and social impacts have been identified. The key challenge is to address the transition and policy options have been defined to prepare, facilitate and manage this transition. The policy options have been placed in time and tasks and responsibilities have been allocated to stakeholder involved, contributing to the development of a social roadmap for CAD.

Policy measures have been identified through literature review, interviews, and internal workshops between project partners on the identified impacts. They are placed in a policy measures matrix connecting them to challenges and opportunities, which is presented in Annex I. A dedicated policy options workshop has been organised to further develop insights in policy options as a response to the identified impacts. The minutes from the workshop are presented in Annex G.

2.5 Data inputs

The Scenario Model as well as the economic models use a range of data inputs from various sources. The data collected and produced in the modelling exercise will be submitted to the European Commission together with the Final Report.

For the Scenario Model, several parameters have been estimated by using data already available from other modelling tools, as well as data collected during the analysis carried out for different European transport modelling exercises. Other variables proved difficult to be collected, as they are specifically related to cost and performance of CAD vehicles by type of automation (SAE) level. Data from literature on these variables is not available yet and therefore assumptions have been performed on the basis of the input collected during the stakeholders’ consultation (i.e. interviews and workshops). Data inputs for the Scenario Model are listed in Table A.1 in Annex A.

The Scenario Model output includes all relevant data on transport performances and vehicle fleet development that is necessary for the economic models. Scenario Model outputs are also used for the Component Model and the Service Mobility Model. Missing data was researched in detail with the help of various sources and validated by the consortium members as well as by external experts (in some cases, e.g. infrastructure costs).

Additional desk research was conducted to add information and fill data gaps. For example, we compiled a company database of vehicle and supplier industry, a list of CAD services and technologies, innovation index, research on global "unicorns" (includes CAD-related start-ups within and outside the EU), and the identification of cluster regions. A full list with the input variables, their sources and the model part where inputs are used, is provided in Table A.2 in Annex A for the ASTRA model, the Component Model and the Mobility Service Model. Table A.4 provides the same for the Synthesis Model.

Some variables needed post-processing to make them usable in the models in the form of aggregation, disaggregation, extrapolation, classification or other kinds of transformations. For various reasons, however, some situations arise in which no suitable data was available. This was the case if, for example:

- A data source was found, but was out of date;
- the data series were incomplete in terms of time or space;
- the data were only accessible at a higher level of aggregation and disaggregation data were missing; or
- the aspect searched for was so new that no data are yet available or they were not representative of the basic population.

Nevertheless, we used various approaches to fill data gaps and thus generate values that correspond as closely as possible to the real values. The Annex A summarizes several of the basic principles, including informed assumptions, comparable variables, extrapolations, and typologies.

Employment parameters have partly been derived from German input-output tables. They have been adjusted for other countries to take account of varying income levels. Finally, they have been calibrated in order for modelling results to match empirical employment data for taxis (Grimaldi, CERTeT Università Luigi Bocconi, Wavestone, 2016), buses, light-duty and heavy-duty vehicles (Transport in Figures, 2016). As automated services are not yet commercially available, there is no empirical data on employment generated by them. We have used non-driver employment parameters to create substitutes for this data gap. Non-driver employment intensity can be seen as an indicator of the general level of complexity of managing a particular type of transport service. We have therefore closely linked employment projections for automated services to non-driver employment of similar conventional services.

2.6 Literature review

During the initial desk research, a first scan of the existing literature in the field was done with the following main purpose:

- Identify the current state of CAD recent developments in this highly transformative field to characterise the context for the study;
- Synthesize a first version of the landscape of CAD in Europe and major third countries to identify quantitative and qualitative data of relevance for the scenario's development and modelling tasks. This analysis has been carried out in particular to understand timelines for the deployment of CAD based on technology in development and market introduction estimates, the current industrial status, Autonomous Vehicle Readiness Index (AVRI) as well as recent and ongoing R&I projects and pilot initiatives;

- Get an overview of possible impacts of automated driving for a first insight into societal challenges based on previous studies;
- Look into possible policy options proposed in exiting literature.

This initial search yielded a plethora of material (research papers, reports, industry studies and surveys); out of those inventoried, at that early stage of the CAD study for further analysis, twenty-five publications (published in the period 2016-2019) were selected as most relevant to the scope of the study in Table D.7 (Annex D). Subsequently, and within the scope of the Task, the list of literature reviewed, has been augmented to include 85 more references as part of the ongoing literature review.

In addition, research project websites relevant to CAD were explored and a number of relevant research projects were identified and analysed which, along with the identified relevant Working Groups (WG) & Initiatives, events and CAD testing locations, allowed us to sketch the baseline CAD landscape, which was presented in the inception report and is updated continuously (e.g. with the additional literature in Annex D).

The literature review produced also a number of quantitative results and information has been fed in the scenario and modelling tasks in accordance to the data needs of these tasks as identified by the data collection framework, as presented in Annex A. A number of iterations were required to address the issue of incomplete data inputs and alternative data were defined and collected were possible. A detailed summary of the literature analysis is presented in Annex D.

2.7 Stakeholder consultations

As part of this study, we have conducted consultations with a wide range of stakeholders. We have conducted two rounds of interviews, a survey and three workshops, which build on previously held exploratory interviews. A summary of results of the stakeholder consultations as well as additional methodological aspects are presented in Annex E. Minutes from the workshops are presented in Annex G. Finally, the results from the survey that was carried out to gather specific information to complement the findings form literature and the interviews can be found in Annex F.

The consultation activities aimed at gathering insights on the state-of-play of CAD, support the development and validation of the four scenarios, discussing employment and social impacts caused by the implementation of CAD and finally potential policy responses. Table 2.1 presents the stakeholder consultations activities. A final conference to present the overall study took place online 15 September 2020. The conference was attended by up to 100 participants and during it we presented the employment and social impacts as well as the policy options. In addition, external speakers presented on the perception of citizens towards CAD, the set-up of living labs, future skill needs identified in the SKILLFUL project, and the research & innovation agenda of the CCAM platform. A panel of experts representing transport service providers, transport workers, research, cities, and vehicle manufacturers then debated the social challenges and opportunities of CAD, policy options to address these and set the overall stage for a collaborative approach on working towards a social roadmap for CAD. The full meeting report is presented in Annex G.[19]

[19] The conference was recorded and can be watched here: https://www.youtube.com/watch?v=I2dQ_b592K0.

Table 2.1 Stakeholder consultation

Stakeholder consultation tool	Objective	Details
Exploratory interviews	Exploratory discussion on the state-of-play of CAD introduction, identify relevant research and potential sources of information	12 interviews conducted
First round of interviews	Collecting inputs for designing the four scenarios	26 interviews conducted
Second round of interviews	Validating the four scenarios developed and obtaining inputs on policy measures	25 interviews conducted
First workshop	Discussions on impacts of CAD on types of transport services and business models	25 attendees
Second workshop	Discussion and validation of the four scenarios of CAD deployment	26 attendees
Third workshop	Present the identified employment and social impacts and discuss policy measures based on them	44 attendees
Final conference	Present the final results of the study and engage in a discussion on working towards a social roadmap for CAD	120 attendees
Survey	Collecting inputs for designing the four scenarios	84 respondents

Source: Ecorys.

PART 2:

Scenarios and impacts of Connected and Automated Driving

3 Scenarios for future CAD deployment

3.1 Summarised findings of scenarios for future CAD deployment and effects

The scenarios

Four scenarios have been designed to explore different conditions for the uptake of autonomous driving. These encompass two "boundary conditions" analysing maximum and minimum uptakes and two intermediate cases:

- Scenario 1: Fast, private, unrestricted and partially distributed (Maximum uptake);
- Scenario 2: Fast, private, restricted and partially distributed (Intermediate uptake);
- Scenario 3: Moderate, shared, restricted and with limited distribution (Moderate uptake);
- Scenario 4: Slow, shared, restricted and with limited distribution (Low uptake).

The scenarios are designed taking into consideration a number of driving factors, including the timing of the uptake of CAD vehicles; the model of personal mobility; the conditions for the circulation of CAD vehicles in urban and rural areas; the different deployment over time in the different European countries, the degree of users' acceptance and the cost of vehicles and services.

Scenario Model results

The Scenario Model provides results for the following parameters (see Section 3.2):

- Car fleet composition, which consider the whole fleet of private cars, cars used for car sharing services and taxis;
- Bus fleet composition;
- Freight vehicles fleet composition, encompassing all the different classes of good vehicles i.e. articulated trucks, large trucks, medium trucks and LDVs;
- Passenger transport activity in terms of passenger-kilometres travelled by all modes and road vehicle-kilometres;
- Freight transport activity in terms of tonnes-kilometres of road modes.

The Scenario Model results show that the uptake of CAD might determine impacts of different type and magnitude, according to the assumptions chosen for these driving (and interacting) factors.

If technology development allows for CAVs to be available at a relatively affordable cost, it is likely to have a positive attitude for their use in personal mobility, which determines a significant increase in passenger transport activity, although the motorisation rate is not necessarily expected to grow (see Section 3.3.1).

The increase in transport activity will be not only in terms of travelled passenger kilometres, but mainly in terms of vehicles travelling on the road, where empty trips might represent a noticeable share of such increased activity.

Under the conditions assumed in Scenario 1, (i.e. fast technology development, and no restriction for the circulation of CAD vehicles) car traffic in EU27 could increase by 28% in 2050 compared to the Reference Scenario at the same year, leading to unsustainable congestion and substantial external costs for society, especially in urban areas. Car traffic is still expected to increase by 11% at 2050 compared to the 2050 Reference Scenario, also in Scenario 2, where restriction to CAD vehicles circulation are applied. Even in scenarios assuming propensity towards shared mobility and a related regulation (Scenario 3), the number of car vkm in 2050 is expected to grow (5%

relative to the 2050 Reference), as the higher demand for shared cars outperforms the more efficient use of vehicles. This calls for a decisive role to be played by transport governance authorities to limit such growth by not only imposing restrictions or bans to autonomous private cars, but also by adopting other measures, e.g. tailored pricing policies for empty autonomous vehicles, including those of taxi and shared services.

Thus, the results of the scenarios suggest that the rise of CAD vehicles is a potential threat to liveability of cities under a range of different assumptions. Future transport governance should not only focus on setting rules on the usage of autonomous cars in urban and rural areas, but also on fostering the development of sustainable mobility patterns by favouring public transport options.

Indeed, due to the reduction of labour costs, autonomous driving has the huge potential to incentivise a flourishing of new high-frequency shared services, operating 24h and serving also low demand and remote areas. Scenario 3 and Scenario 4 clearly show that, if fully exploited, this potential will lead to avoiding indiscriminate traffic growth and to granting the sustainability of future road transport. A key role therefore is to be played by transport authorities in balancing the availability of new private and collective transport opportunities to citizens and in rethinking the role of public transport and its supply.

3.2 Background and presentation of the scenarios

3.2.1 Background

Scenario analysis is the process of evaluating possible future events through the consideration of alternative plausible, though, not equally likely, states of the world. It is a process used both in private and public sector to develop strategic plans that could accommodate uncertainty of the future (Milakis et al, 2015).

Scenarios developed in this project are not intended to be forecasts but the exploration of consistent and coherent alternative hypothetical future developments of CAD which serve as a basis for discussing potential impacts on the employment sector (both positive and negative) and outlining policies to prevent or mitigate negative impacts.

Explorative in nature, scenarios have the advantage over forecasts in that they are more flexible, creative and can broaden the perspectives of long-term planning by highlighting unexpected dynamics.

To this aim, scenarios are intentionally highly differentiated to explore different potential dynamics and magnitudes of impacts in the occupational sector.

3.2.2 Presentation of the scenarios

CAD scenarios are designed along the following key aspects:

- The timing of the uptake of CAD vehicles with particular reference to those automation levels expected to determine the biggest impact on mobility patterns;
- Whether the uptake in the market of personal mobility takes place according to a model of "private mobility" or according to a model of "shared mobility";
- Different conditions for the circulation of CAD vehicles in urban and rural areas (i.e. traffic restriction). It is assumed that the usage of CAD vehicles is always allowed on motorways and primary roads;

- The spatial distribution of CAD deployment with differentiated deployment in “forerunners” countries and “follower” countries.

These factors are the key elements characterising the scenarios, but other factors contribute to their content (e.g. acceptance from users, cost of vehicles and services, etc.). It is worth mentioning that these factors might be affected by other external factors. Examples include incentives on technology research (which could anticipate the timing of CAD uptake both in forerunners and follower countries) and the adoption of policies in response to the renovated environmental ambition of EU outlined in the European Green Deal (which could influence personal mobility towards a model of shared use).

There are four scenarios for the uptake of CAD: 2 “boundary conditions” analysing maximum and minimum uptakes and 2 intermediate cases:
- Scenario 1: Fast, private, unrestricted and partially distributed (Maximum uptake);
- Scenario 2: Fast, private, restricted and partially distributed (Intermediate uptake);
- Scenario 3: Moderate, shared, restricted and with limited distribution (Moderate uptake);
- Scenario 4: Slow, shared, restricted and with limited distribution (Low uptake).

The time period of the scenarios is between 2020 and 2050. All scenarios are built upon a Baseline Scenario, which reflects the socio-economic, transport, environmental and technological assumptions of European Commission’s EU Reference Scenario (European Commission, 2016). The EU Reference Scenario is one of the European Commission's key analysis tools in the areas of energy, transport and climate action. It is updated regularly, as it projects the impact of current EU policies on energy and transport trends as well as changes in the expected amount of greenhouse gas emissions. It provides projections for indicators, such as the share of renewable energy sources or levels of energy efficiency, in five-year steps up until 2050 for the EU as a whole and for each EU country. The Reference Scenario is not designed as a forecast of what is likely to happen in the future. It rather provides a benchmark against which new policy proposals can be assessed.

The following definitions are used:
- Cost: cost of ownership of CAD vehicle or cost of purchasing mobility services operated by CAD vehicles;
- Acceptance: users’ acceptance towards CAD technology influencing (i) the ownership of CAD vehicles and (ii) the usage of CAD mobility services[20];
- Restriction: i.e. restrictions to circulation of CAD vehicles in urban and rural areas[21];
- Empty trips: trips done by CAD vehicles without any passenger on board;
- Ride-sharing service: service operated by a shared automated taxi (Level 5), picking up various passengers (with various destinations);
- Robo-taxi service: similar to a traditional taxi service, transporting single passengers or groups of passengers with a common destination, operated by automated taxi (Level 5);
- Robo-bus: driverless bus with no limitations in size or scope, including both urban public transport and inter-city coaches.

3.2.3 Scenario 1: Fast, private, unrestricted and partially distributed - Maximum uptake (++++)

Scenario 1 is the scenario with the maximum penetration of Level 5 vehicles due to a combination of fast technology development and null restriction to the circulation of CAD vehicles in urban and

[20] In the Scenario Model acceptance is an exogenous input base value (whose trend is a matter of assumption/ calibration/ sensitivity analysis) modified as effect of accidents and congestion.

[21] Limitation to the circulation of vehicles is supposed to have an impact on the demand for vehicles. Higher restrictions imply lower demand.

rural areas. It assumes that technology will rapidly evolve and the transition from current Level 2 to Level 5 automation will take place in 15 years.

The gradual introduction in the market of progressively higher level of automated vehicles has allowed to prove the technology readiness in real conditions: technology is low cost, fully reliable and safe and this - coupled with the development of user friendly HMIs (human machine interfaces) - leads to a rapid increase of acceptance from users. Over time the demand for CAD vehicles is growing faster and faster.

The introduction in the market of progressively high level automated vehicles (all types) is assumed as follows: Level 3 in 2022, Level 4 in 2030, Level 5 in 2035. Ready on the market in 2035, Level 5 vehicles are assumed having a fast uptake until 2050 due to the combined effect of relatively low cost of operation and ownership and high propensity from the users. Under these assumptions (low cost and high acceptance) personal mobility takes place mainly in the form of private mobility with limited usage of shared services.

Local and national authorities do not pose any limitation to the circulation of fully automated vehicles which can operate without any restriction both in urban and rural areas.

Given the affordability of private cars and the absence of restrictive traffic regulation, robo-taxi and ride sharing services are used by a relatively low share of population although their cost is lower than the cost of conventional taxis. Same assumptions for Level 5 cars both in terms of time of uptake (2035) and regulation (no restriction to circulation in urban and rural areas) apply to them. With the aim to incentivise their usage, the regulation allows for robo-taxi and ride sharing services to circulate empty 24 hours per day.

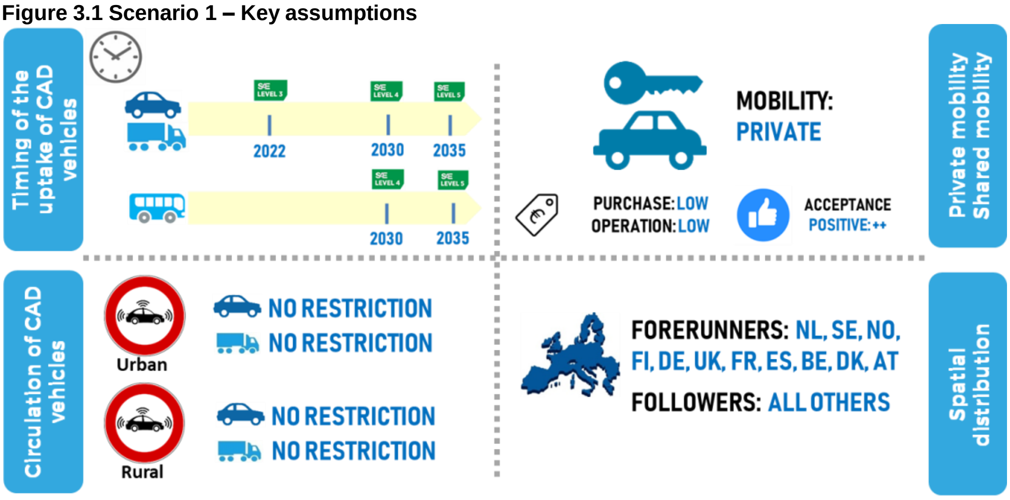
As for the other vehicles, the uptake of Level 5 buses (robo-bus) is expected to commence in 2035. It is assumed for Level 4 buses to be already available in 2030 and to be operated driverless only in restricted conditions (city centres closed to traffic, restricted areas such as hospitals, universities, company premises etc.). No Level 3 development is foreseen for buses that will basically jump from Level 2 to Level 4. This assumption is based on the consideration that - given the relatively limited size of the market - vehicles manufacturers will consider it to be too expensive to launch new models with an intermediate level of technology before Level 4.

The combination of low-cost technology of vehicles (both purchase and maintenance cost are lower than the current costs) and the elimination of labour cost will allow for robo-bus services to have a lower cost in comparison with current service.

Scenario 1 assumes that CAD deployment will follow a different pace in Europe with a bundle of countries (NL, SE, NO, FI, DE, AT, BE, DK, UK, FR, ES)[22] behaving as forerunner countries and all other countries following with a 5-year delay, due to gaps in terms of investments and infrastructure and technological readiness.

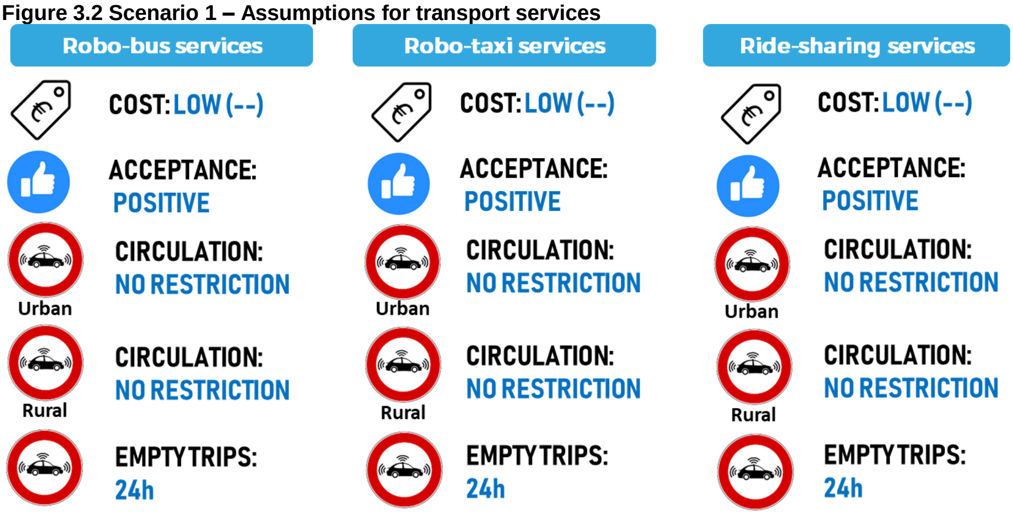
[22] According to the scientific literature and the documentation analysed, the choice for the forerunner countries considers: some of the most CAD-ready countries in Europe (i.e. NL, SE, NO, FI, DE, AT), two countries which are geographically very close to them (i.e. BE, DK) and other European countries whose legislation and policies are judged as better prepared for CAD (i.e. UK, FR, and ES).

Figure 3.1 Scenario 1 – Key assumptions



Source: TRT.

Figure 3.2 Scenario 1 – Assumptions for transport services



Source: TRT.

3.2.4 *Scenario 2: Fast, private, restricted and partially distributed - Intermediate uptake (+++)*

Scenario 2 is the scenario with an intermediate penetration of Level 5 vehicles and is aimed to test the role that the restriction to the circulation of CAD vehicles could play in a scenario where fast technology development will take place as assumptions on traffic restrictions are the only difference to Scenario 1. Similarly to Scenario 1, it assumes that technology will rapidly evolve and the transition from current Level 2 to Level 5 automation will take place in 15 years.

Also in this case, CAD technology is low cost, reliable and safe and this - coupled with the development of user friendly HMIs - leads to a rapid increase of acceptance from users. Over time the demand for CAD vehicles is growing faster.

Also in this case, it is assumed that fully automated vehicles (Level 5) are available on the market in 2035. Level 5 cars have a fast uptake due to the combined effect of relatively low cost of ownership and high propensity from the users. In this case personal mobility takes place mainly in the form of private mobility with limited usage of public and shared services.

To prevent an unregulated increase in transport activity leading to unsustainable congestion, contrary to Scenario 1 this scenario assumes that local and national authorities impose stronger limitations to the circulation of fully automated vehicles. For 10 years following the launch in the market of Level 5 vehicles, circulation in urban areas is restricted with the purpose of monitoring the evolution of mobility demand and preventing any unfavourable impact on travelled distances, trip frequencies and choice allocation on congestion, urban sprawl, modal shift etc.

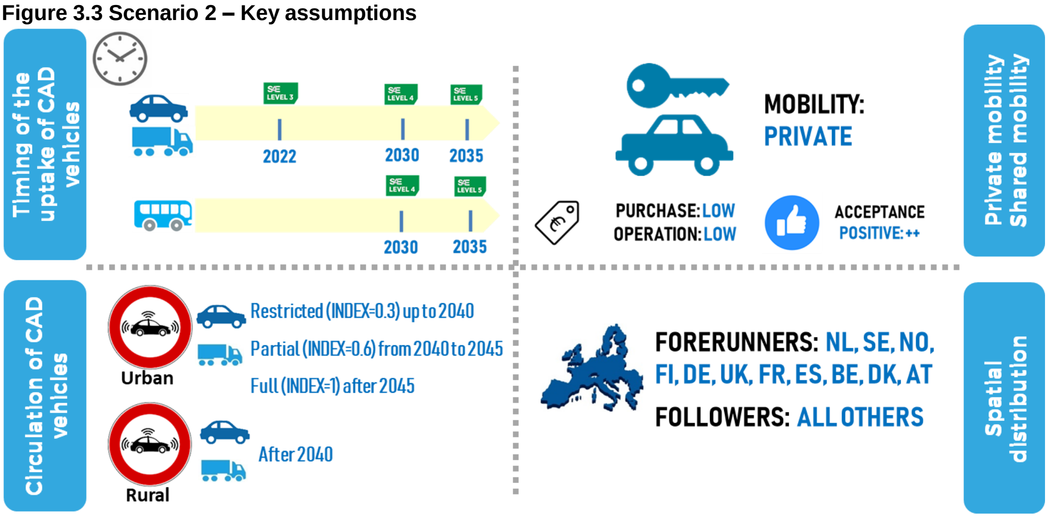
Since authorities need to understand the evolution of mobility trends following the deployment of fully automated vehicles, for the first 5 years after Level 5 entering the market the circulation in urban areas is quite restricted (until 2040). From 2040 to 2045 limits to circulation are less strict and only after 2045 Level 5 vehicles can circulate in urban areas without any restrictions. Assuming that infrastructure readiness in rural areas is slower than in urban areas, Level 5 vehicles in rural areas are allowed only after 2040.

Similarly to Scenario 1, robo-taxi and ride sharing services are used by a relatively low share of population although their cost is lower than the cost of conventional taxis. Same assumptions for Level 5 cars both in terms of time of uptake (2035) and regulation apply to them. With the aim to incentivise their usage, the traffic regulation allows for robo-taxi and ride sharing services to circulate empty 24 hours per day.

Similarly to Scenario 1, the uptake of Level 5 buses (robo-bus) is expected to be in 2035. It is assumed for Level 4 buses to be already available in 2030 and to be operated driverless only in restricted conditions (city centres closed to traffic, restricted areas like hospitals, universities, companies premises etc.). Also in this case, Level 3 development is not foreseen for buses that will basically jump from Level 2 to Level 4. The combination of low-cost technology of vehicles (both purchase and maintenance cost are lower than the current costs) the elimination of labour cost will allow for robo-bus services to have a lower cost in comparison with current service.

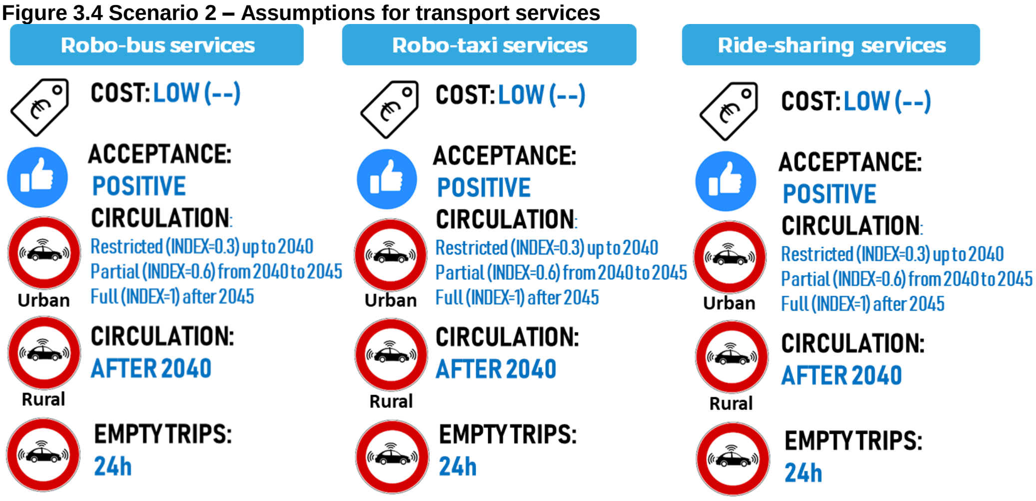
This scenario assumes that CAD deployment in Europe will follow the same pace of Scenario 1.

Figure 3.3 Scenario 2 – Key assumptions



Source: TRT.

Figure 3.4 Scenario 2 – Assumptions for transport services



Source: TRT.

3.2.5 *Scenario 3: Moderate, shared, restricted and with limited distribution - Moderate uptake (++)*

Scenario 3 is the scenario with a moderate penetration of Level 5 vehicles and is designed to take into account a situation where future technological development will happen at a slower pace than in the previous two scenarios. It assumes that the transition from current Level 2 to Level 5 automation will take place in 20 years.

The introduction in the market of high level automated vehicles is slowed down by the complexity of technological solutions which determine a relatively high cost of CAD vehicles in comparison with traditional ones. The overall propensity of final users to use CAD vehicles is rather neutral due to the high purchase costs of vehicles which limit their usage to a relatively high-income share of population. On the contrary, shared mobility is growing faster due to new emerging mobility services.

The scenario assumes that fully automated vehicles (Level 5) will be available on the market in 2040 preceded by a progressive uptake of Level 4 (2035) and Level 3 (2028).

From 2040 to 2050, Level 5 cars and trucks have a moderate uptake due to the combined effect of high purchase cost and neutral propensity from the users towards owning and using CAD vehicles.

The scenario envisages as well that, national and local authorities pose restrictions to the circulation of fully automated vehicles. The circulation of fully automated vehicles in urban areas is restricted and only after 2045 they can operate in rural areas. Parking fares are high in urban areas and low in rural areas.

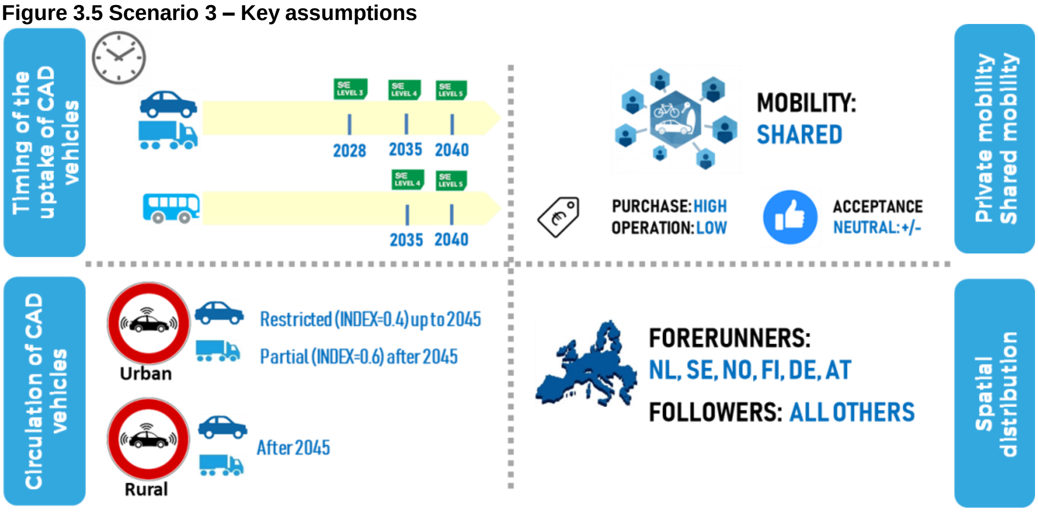
The increased demand for more sustainable mobility options and the reduction of labour cost due to driverless vehicles incentivises a flourishing of relatively low-cost new shared services operating 24h and serving also low demand and remote areas.

The improved quality and flexibility of shared services coupled with the high purchase cost of CAD vehicles incentivises a massive shift towards shared mobility: robo-taxi and ride sharing services are used by a high share of population also due to the wide promotion of shared vehicle use and the favourable rules on circulation which allow for their full usage in urban areas. For avoiding congestion growth, robo-taxi and ride sharing vehicles are allowed to circulate empty only during night.

The uptake of Level 5 buses (robo-bus) is expected to be at 2040, in line with the deployment for other vehicles. It is assumed for Level 4 buses to be already available in 2035 and to be operated driverless only in restricted conditions (city centres closed to traffic, restricted areas like hospitals, universities, companies premises etc.). No Level 3 development is foreseen for buses that will basically jump from Level 2 to Level 4, as it happens for scenarios 1 and 2. The elimination of labour cost will allow for robo-bus services to have a lower cost in comparison with current service. Robo-bus can operate without any restriction in urban areas and are allowed to circulate in rural areas only after 2045.

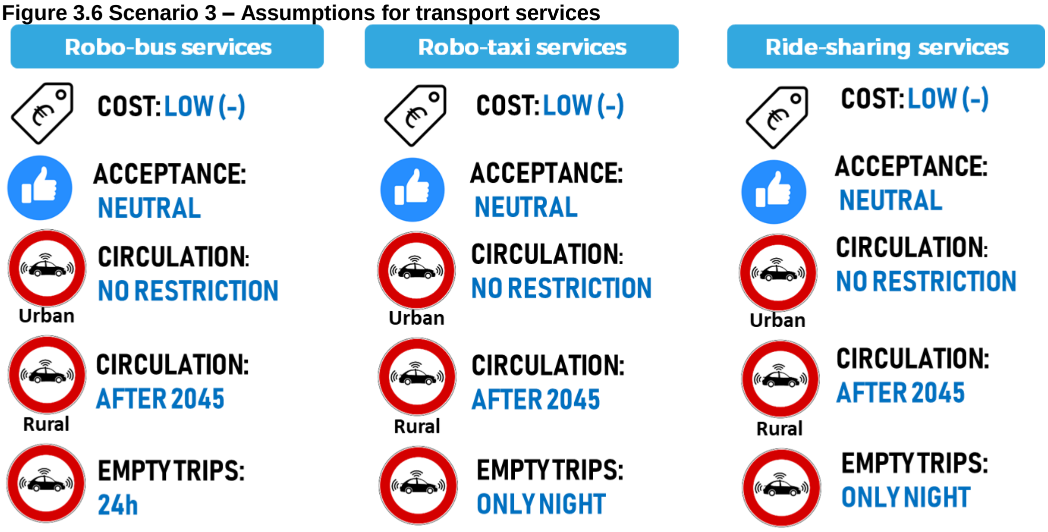
Scenario 3 assumes that CAD deployment will follow a different pace in Europe with only some of the most CAD ready countries (i.e. NL, SE, NO, FI, DE, AT) behaving as forerunners countries and all other countries following with a 5-years delay due to gaps in terms of investments and infrastructure and technological readiness.

Figure 3.5 Scenario 3 – Key assumptions



Source: TRT.

Figure 3.6 Scenario 3 – Assumptions for transport services



Source: TRT.

3.2.6 Scenario 4: Slow, shared, restricted and with limited distribution - Low uptake (+)

Scenario 4 is designed as a boundary condition to consider a low penetration of CAD vehicles due to slow technological improvement coupled with low acceptance from final users. It assumes that the transition to full automation (Level 5) will take place in 25 years for all types of vehicles.

Also in this case, the complexity of deployed technological solutions determines a relatively high cost of CAD vehicles in comparison with traditional ones. The overall propensity of final users towards CAD vehicle is rather low due to a combined effect of a generalised scepticism towards automated driving - maturated as a result of the observed delays in technological progress over the last 20 years - and the high purchase cost. Similarly to Scenario 3, it assumes that personal mobility develops accordingly to a model of shared mobility.

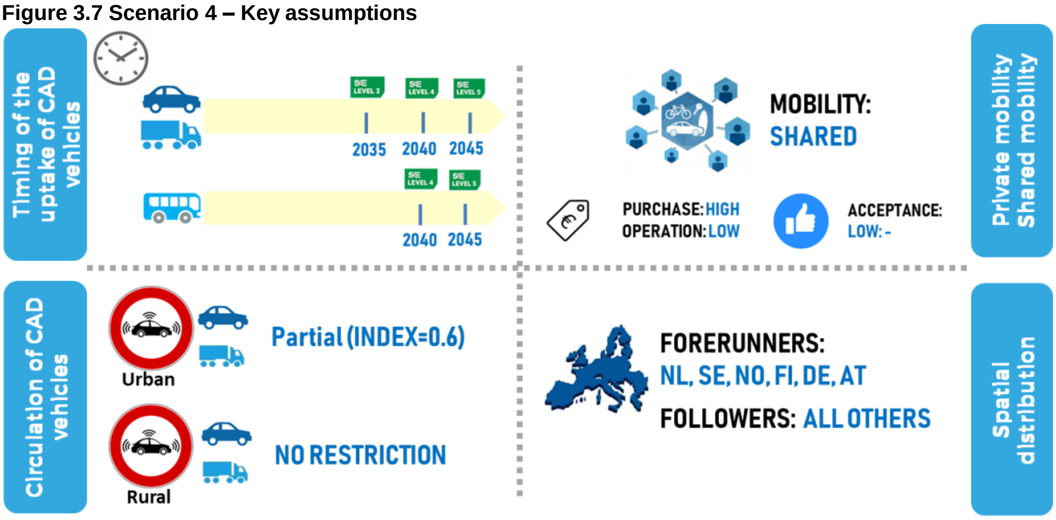
The scenario assumes that fully automated vehicles (Level 5) will be available on the market in 2045 preceded by a progressive uptake of Level 4 (2040) and Level 3 (2035) vehicles. Available on the market only in 2045, Level 5 vehicles have a low uptake until 2050 due to the combined effect of high purchase cost and low propensity from the users.

The scenario envisages that the low propensity towards CAD is also shared by regulators: national and local authorities pose restriction to the circulation of fully automated vehicles in urban areas.

Similarly to Scenario 3, also in Scenario 4 the reduction of labour cost due to driverless vehicles incentivises a flourishing of relatively low-cost new shared services operating 24h and serving also low demand and remote areas. The improved quality and flexibility of shared services coupled with the high purchase cost of CAD vehicles incentivises a massive shift towards shared mobility: robo-taxi and ride sharing services are used by a high share of population also due to the favourable traffic policies which allow for their full circulation in urban areas. For avoiding congestion growth, robo-taxi and ride sharing vehicles are allowed to circulate empty only during the night.

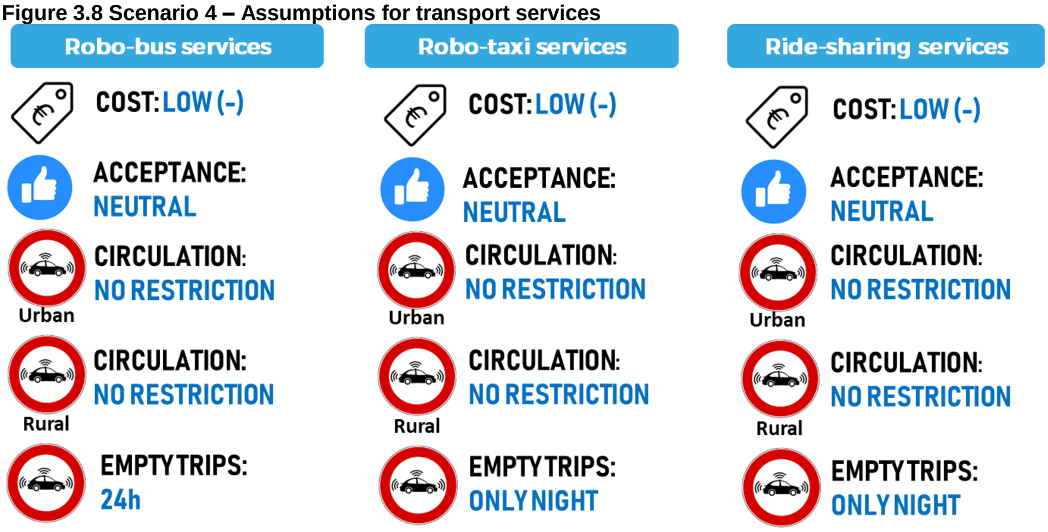
Scenario 4 assumes that CAD deployment in Europe will follow the same pace of Scenario 3 with only some of the most CAD ready countries behaving as forerunners countries (NL, SE, NO, FI, DE, AT) and all other countries following with a 5-years delay.

Figure 3.7 Scenario 4 – Key assumptions



Source: TRT.

Figure 3.8 Scenario 4 – Assumptions for transport services



Source: TRT.

3.3 Results of the Scenario Model

In the following we present a selection of key results on vehicles' fleet composition and transport activity for the Reference and the four CAD Scenarios. More detailed results on fleet composition are available in Annex B.

More specifically the following sections present results on:
- Car fleet composition, which consider the whole fleet of private cars, cars used for car sharing services and taxis;
- Bus fleet composition;
- Freight vehicles fleet composition, encompassing all the different classes of good vehicles i.e. articulated trucks, large trucks, medium trucks and LDVs;
- Passenger transport activity in terms of passenger-kilometres travelled by all modes and road vehicle-kilometres;
- Freight transport activity in terms of tonnes-kilometres of road modes.

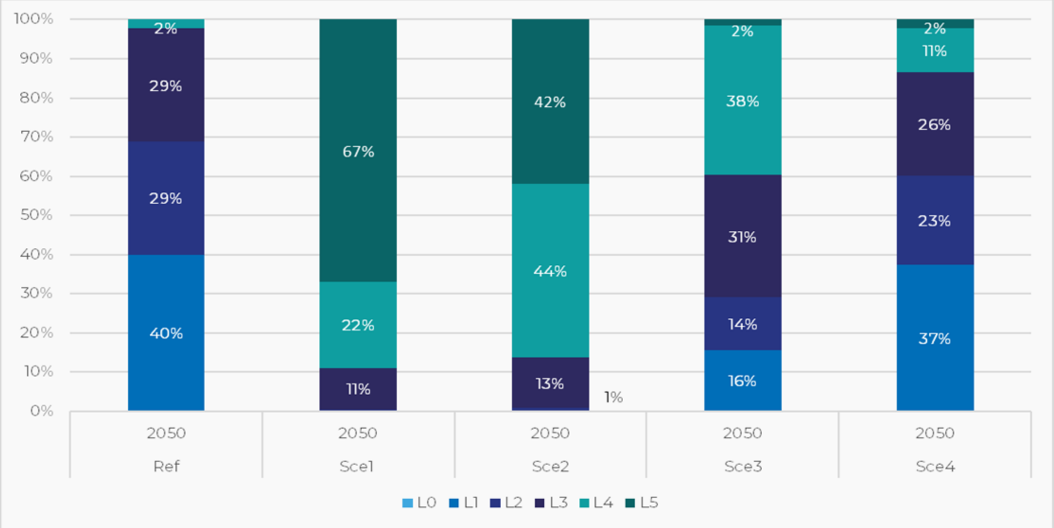
It is important to remark again that CAD scenarios are not intended to forecast the most likely uptake of autonomous vehicles but rather to explore alternative hypothetical situations as a basis for discussing potential impacts on the employment sector. Scenarios (and their results) are therefore intentionally highly differentiated to explore different potential dynamics and magnitudes of impacts.

3.3.1 Car fleet

Figure 3.9 shows the estimated composition of the car fleet by automation level[23] by 2050 for the Reference and the four CAD scenarios in EU27. The figure shows higher shares of CAD vehicles in the four scenarios in comparison with the Reference case. The stock share of full automated vehicles ranges from 67% in Scenario 1, where L5 vehicles are ready on the market since 2035 in forerunner countries and 2040 in follower countries, to 2% in Scenario 4 where L5 vehicles enter the market only in 2045 for forerunner countries and in 2050 for follower countries.

[23] Private cars, cars used for car sharing services and taxis.

Figure 3.9 Composition of car fleet by automation level in 2050 – EU 27



Source: TRT.

Figure 3.10 shows the size of the car fleet by 2050 for the Reference and the four CAD scenarios.

In the Scenario Model the size of the car fleet is resulting from a combination of different contrasting effects:

1. First, Level 5 cars can be shared in a family and therefore families originally owning more than one car are supposed to reduce their motorization rate in the future. This effect reduces the fleet[24];
2. Second, people who currently do not drive and do not own a car might be willing to purchase an autonomous car. This effect increases the fleet;
3. Finally, given the increased flexibility of shared mobility services, a share of population might be willing to give away the car and to rely exclusively on ride sharing services. This effect also reduces the fleet.

All scenarios take into account the first effect i.e. the possibility of self-driving cars to chauffeur more members of the same family. On top of this, in Scenario 1 and Scenario 2 the relatively low cost of automated cars and the positive propensity of users are supposed to determine an increase in the demand for vehicles from not driving persons (second effect) while renouncing to cars in favour of shared mobility services (third effect) is supposed to be very modest. In these scenarios the second effect counterbalance the first one and the reduction of the overall fleet is limited in comparison to the reference case.

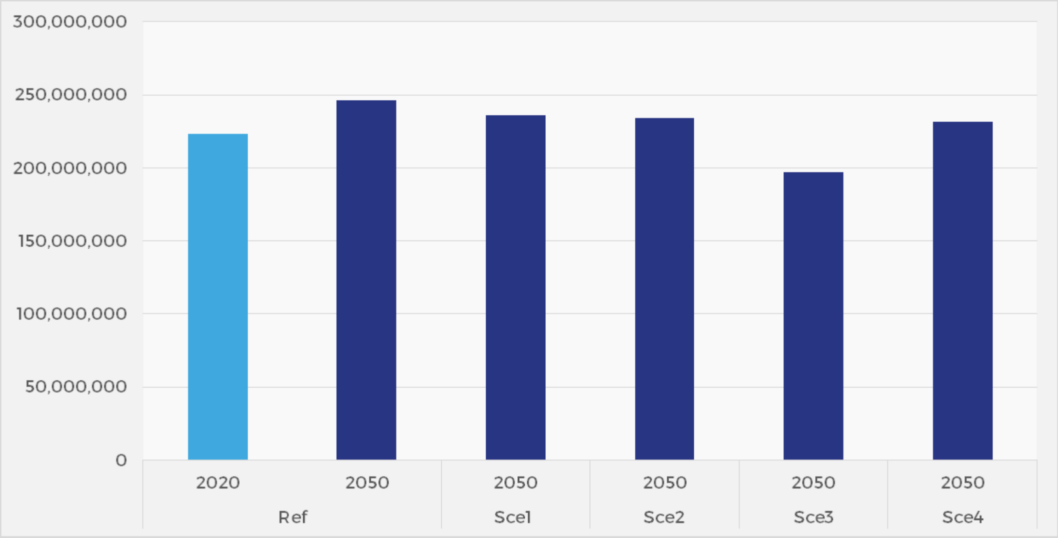
In Scenario 3, where it is assumed that circulation of private CAD vehicles is more restricted and that the propensity of individuals towards shared services is higher, the first and especially the second effect are less significant while the third effect is more relevant. Overall, the fleet grows less than in the previous scenarios and results to be lower than the fleet at 2020.

Finally, in Scenario 4 the three different effects operate similarly to Scenario 3, but given the five-year delay in the uptake of CAD the fleet decreases less than in Scenario 3.

[24] The intensity of effects is unknown of course. It might be that the propensity to drop one car is weaker than assumed here while the propensity of purchasing a car by those that otherwise would not drive is higher and so total fleet could increase. Under the assumption adopted in the model, there is room for organising within a household to share a car when this can relocate autonomously.

In the group of follower countries, the changes to the size of the fleet follow the same pattern but all effects are levelled out by the delayed uptake of CAD.

Figure 3.10 Size of car fleet in 2020 and 2050 - EU 27



Source: TRT.

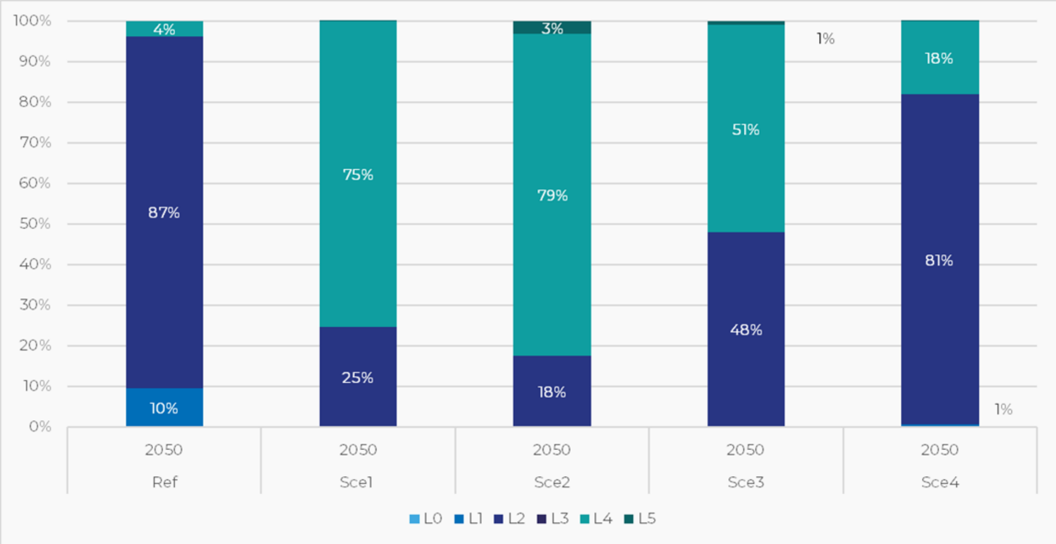
3.3.2 Bus fleet

Figure 3.11 shows the simulated composition of the bus fleet by automation level at 2050 for the Reference and the four CAD scenarios in EU27.

Consistently with the assumptions, no share of Level 3 buses is observed in the fleet as the technology development is supposed to skip this level and to jump directly to Level 4. This assumption is derived from the stakeholders' consultation who reported that the automotive sector is considering to skip the L3 buses production and to orient the future production directly to L4 vehicles.

In Scenario 1 and Scenario 2 the bus fleet at 2050 is dominated by Level 4 vehicles which are assumed to enter the market in 2030 for forerunner countries and 2035 for follower countries. The assumed strong attractiveness of private autonomous car, that are already available in the market in 2035 for forerunner countries and 2040 for follower countries, makes the demand for buses low and so the number of fully automated buses (Level 5) in the fleet is still negligible at the year 2050. The assumed limitations to the circulation of cars in Scenario 2, slightly increase the demand for buses and, consequently, the share of Level 5 vehicles at 2050 (see Figure 3.11).

Figure 3.11 Composition of bus fleet by automation level in 2050 - EU 27



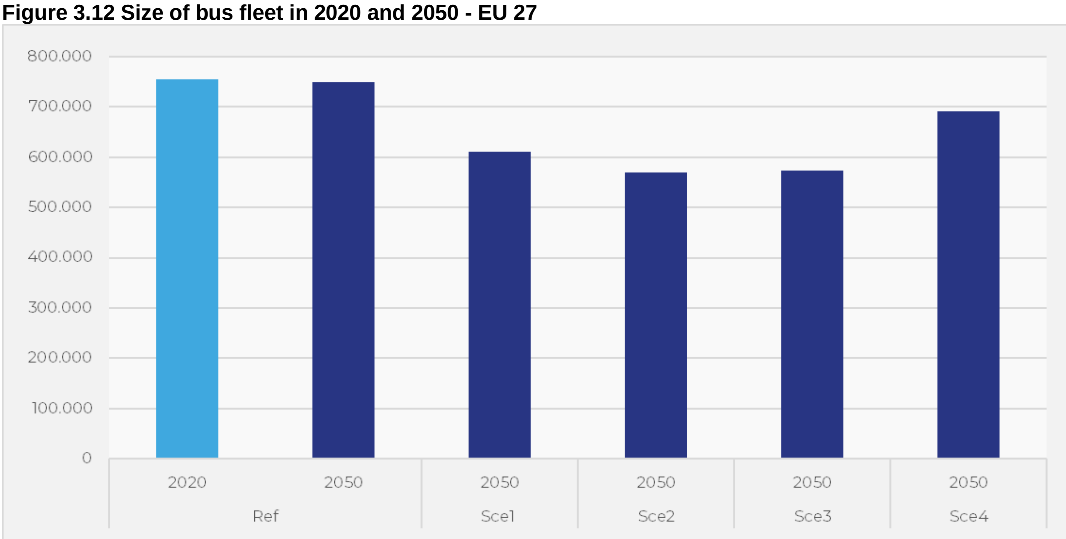
Source: TRT.

In Scenario 3, in 2050 Level 4 buses (available since 2035 for forerunner countries and 2040 for follower countries) represent 51% of the total bus fleet. The assumed uptake of Level 5 vehicles in 2040 for forerunner countries and 2045 for follower countries and the demand of collective transport which is higher than in the previous two scenarios (as personal mobility is supposed to take place mainly in the form of shared mobility) make it possible to expect a 1% share of Level 5 vehicles on the total fleet despite the regulation of driverless bus services would still limit them to specific circumstances.

Finally, given the assumed late deployment of Level 5 buses (2045 for forerunner countries and 2050 for follower countries), by 2050 the composition of the bus fleet in Scenario 4 is characterised by 81% of Level 2 vehicles and by 18% of Level 4 vehicles which are supposed to be available on the market since 2040 for forerunner countries and 2045 for follower countries (see Figure 3.11).

When focusing on the size of the bus fleet in 2050 reported in Figure 3.12, it can be noted that in all scenarios the fleet reduces in comparison with the Reference case in 2050 as a consequence of the shift towards private (autonomous) car or ridesharing.

Figure 3.12 Size of bus fleet in 2020 and 2050 - EU 27



Source: TRT.

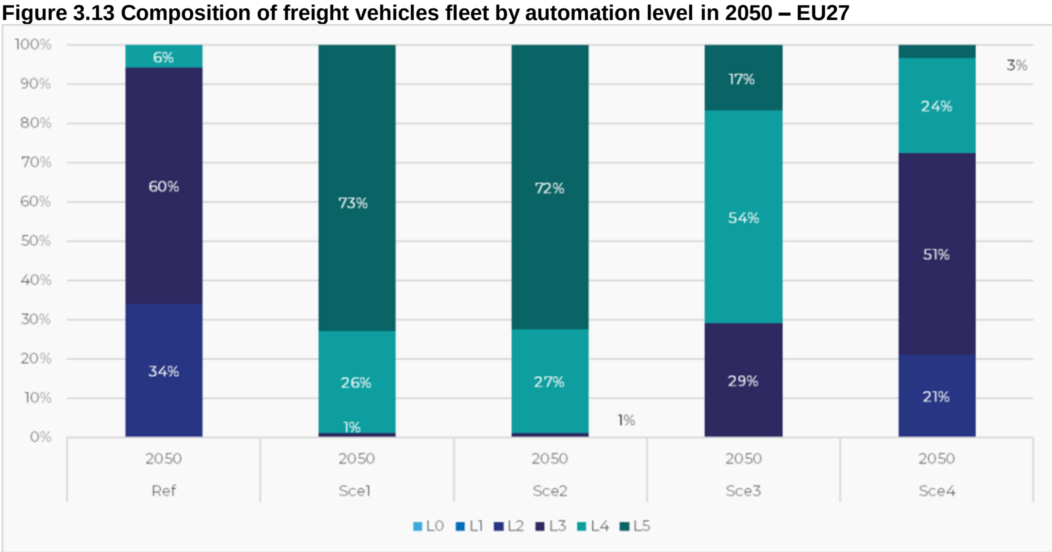
In Scenario 1 and Scenario 2, the bus fleet strongly reduces in comparison with the Reference case given the extremely low demand of public transport services as personal mobility is assumed to be mainly in the form of private mobility.

In Scenario 3 and Scenario 4, the competition of autonomous private cars is much weaker. Bus services are however challenged by the ride-sharing services so that also in these scenarios a reduction of the size of the bus fleet can be observed.

3.3.3 *Freight vehicles fleet*

The simulated composition of the freight vehicles fleet[25] by automation level in 2050 for the Reference and the four CAD scenarios in EU27 is shown in Figure 3.13.

Figure 3.13 Composition of freight vehicles fleet by automation level in 2050 – EU27



Source: TRT.

The envisaged uptake of Level 5 vehicles by 2035 for forerunner countries and 2040 for follower countries in Scenario 1 and Scenario 2, leads to a predominant share of fully automated trucks at 2050. Later uptakes of L5 vehicles envisaged in Scenario 3 (2040 for forerunner countries and 2045 for follower countries) and Scenario 4 (2045 for forerunner countries and 2050 for follower countries) lead to sensibly lower stock shares (17% in Scenario 3 and 3% in Scenario 4).

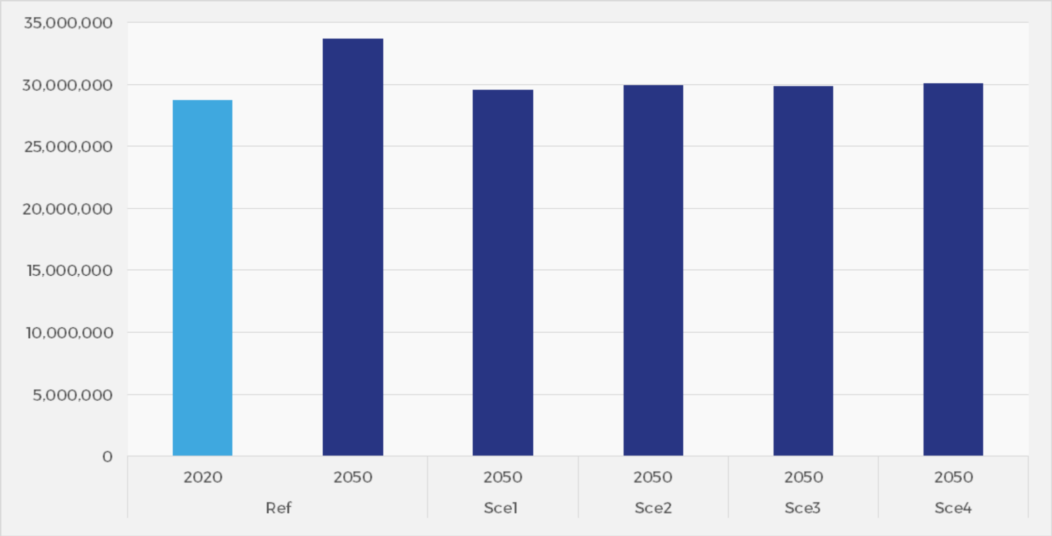
As shown in Figure 3.14 the overall impact on the size of the freight vehicles fleet is a reduction of 11% in comparison with the Reference fleet in 2050.

This can be explained as the combined effect of increased vehicles' efficiency due to the elimination of drivers' resting time rules (potentially leading to a reduction of the overall fleet) and of the reduction of transport costs[26] (potentially leading to an increased demand for road transport and thus to an increase of the fleet).

25 Articulated trucks, large trucks, medium trucks and LDVs.

26 The reduction of transport costs is higher for trucks than for cars because of the reduction of labour costs due to truck drivers.

Figure 3.14 Size of freight vehicles fleet in 2020 and 2050 – EU27



Source: TRT.

3.3.4 Passenger transport activity

Figure 3.15 shows the simulated road passenger transport activity by car (including, taxi, robo-taxi, carshare and rideshare) at 2020 and 2050 in terms of travelled vehicles-kilometres in the Reference and in the four CAD scenarios for EU27.

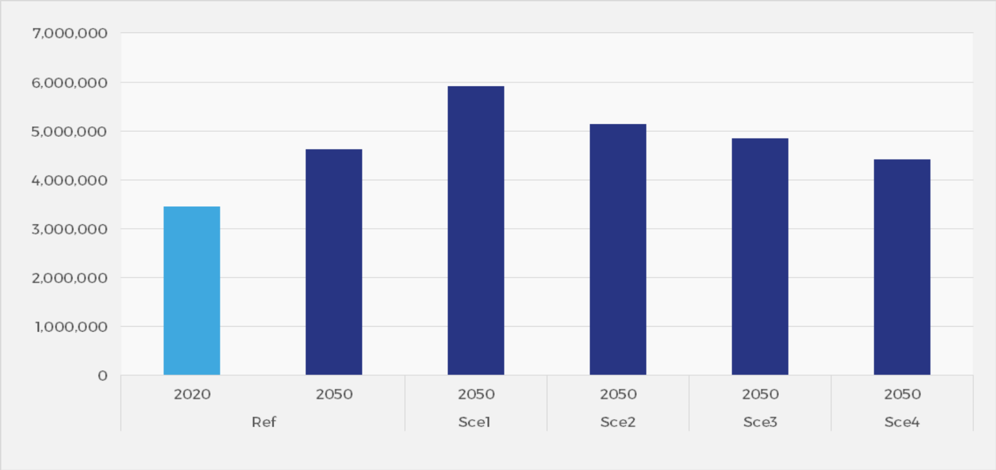
Simulations show that travelled vehicles-kilometres are 28% higher in Scenario 1 than in the Reference at the year 2050. This increase is due to the combined effect of three consequences of the early uptake of CAD vehicles. The first consequence is that more people would use car, shifting from other modes (including pedestrian, see below). The second consequence is that reduced stress of driving an automated car would induce some households to move in rural areas, thus increasing their average trip length. Third, in this scenario private cars do not have any restriction to circulation so they would move empty without any limitation to collect their owners wherever they are. This would add km travelled and would reduce the average occupancy factor of cars.

Limitations to the circulation assumed in Scenario 2 reduce the increase of travelled kilometres by car to 11% in comparison with the Reference at the year 2050.

Higher propensity towards shared mobility assumed in Scenario 3 (see also below), combined with restrictions to the circulation, limits the increase of travelled vehicle kilometres to 5% in comparison with the Reference at the year 2050. This is the combined effect of some less mobility and larger occupancy factor for ride-sharing services than for private cars.

The same type of effect is at work in Scenario 4, however due to the assumed later CAD deployment, travelled vehicle kilometres are 4% lower than in the Reference in 2050.

Figure 3.15 Passenger transport activity by car* in 2050 [Mio*vkm] – EU27



Note: *car, taxi, robo-taxi, carshare and rideshare. Source: TRT.

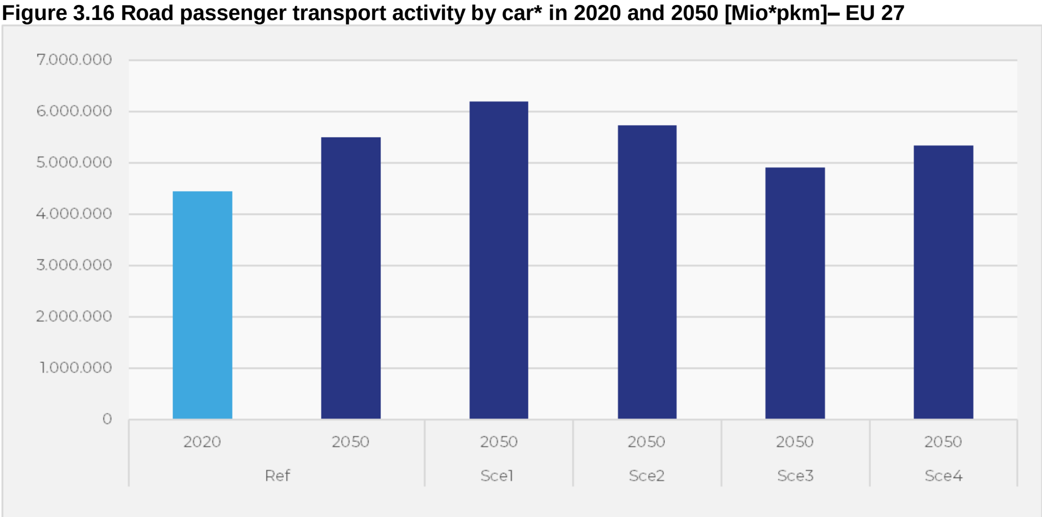
In focusing on road passenger transport activity by car (including, taxi, robo-taxi, carshare and rideshare) in 2050 in terms of passenger kilometres (see Figure 3.16), it can be noted that in Scenario 1 the increase is of 13% in comparison with the Reference in the year 2050. By comparing the increase in passenger kilometres (+13%) with the increase in vehicle kilometres (+28%), it emerges that road traffic grows much more than passengers' mobility. The main reason for this impact is the lack of any restriction to the circulation of private CAD vehicles, which can travel empty. The average occupancy factor of cars is therefore reduced.

In Scenario 2 the increase of passenger kilometres is of 4% (to be confronted with +11% increase in vkm) in comparison with the Reference in the year 2050. In this case, the assumed restriction to the circulation of autonomous cars poses some limitation to traffic growth.

In Scenario 3, passenger kilometres are 11% lower than in the Reference in the year 2050. This effect is mainly due to the massive shift towards shared mobility and to the consequent change of mobility patterns. People abandoning their personal car in favour of shared mobility services are indeed supposed to partially change their mobility habits by reducing their trip rates and trip lengths.

Later, CAD deployment assumed in Scenario 4 limits the reduction of passenger kilometres by car in comparison with the Reference in the year 2050 to 3%.

Figure 3.16 Road passenger transport activity by car* in 2020 and 2050 [Mio*pkm]– EU 27



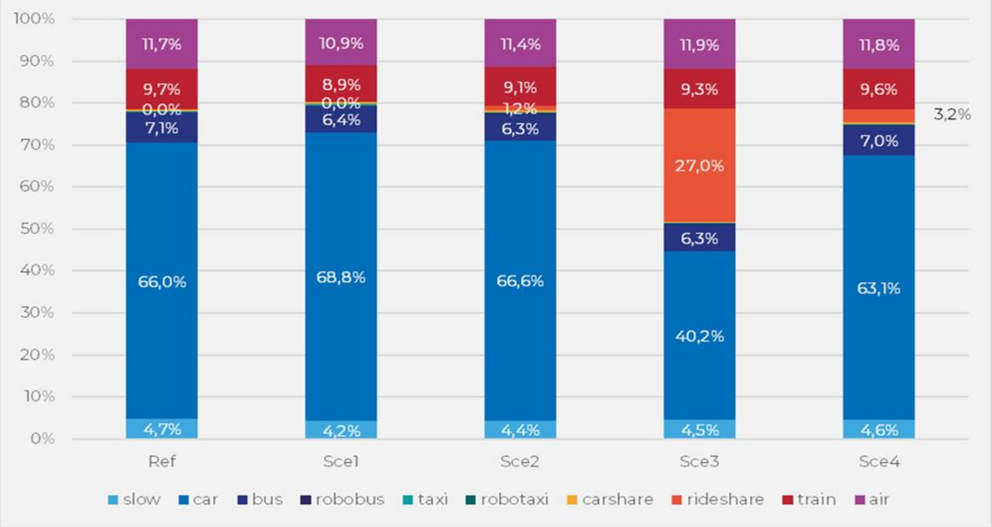
Note: *car, taxi, robo-taxi, carshare and rideshare. Source: TRT.

When looking at the mode share (Figure 3.17), simulations show a slight increased share of passenger-kilometres travelled by private cars in Scenario 1 and a slight decrease in the usage of collective transport (by bus and rail) in comparison to the Reference case.

In Scenario 2 the assumed restrictions to the circulation of private cars determine an increase of the share of ride sharing services.

Ridesharing services gain higher shares in Scenario 3, while the assumed late deployment of Level 5 vehicles envisaged in Scenario 4 (2045 in forerunner countries and 2050 in followers) limits the growth of shared services.

Figure 3.17 Passenger transport activity by mode in 2050 – EU27



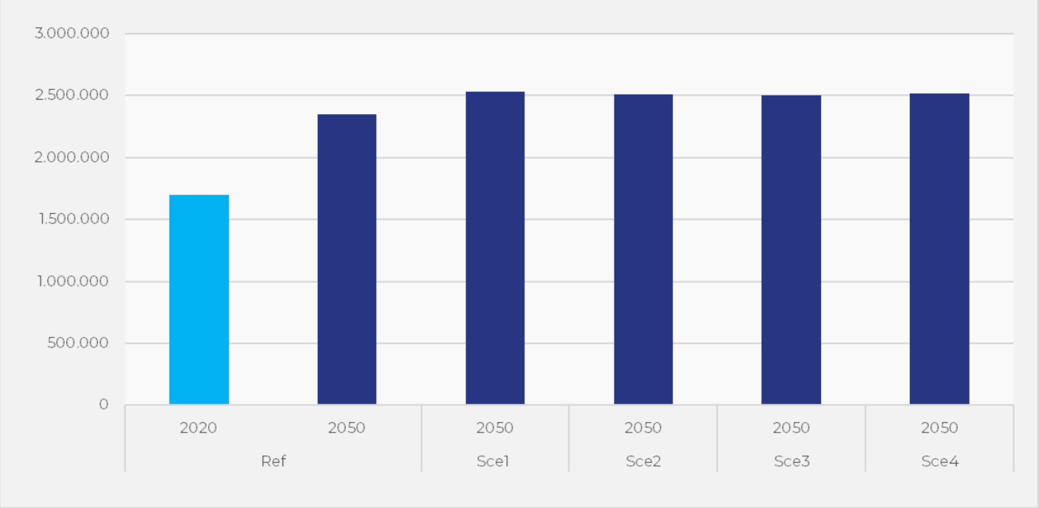
Source: TRT.

3.3.5 *Freight transport activity*

Road freight transport activity at 2020 and 2050 in terms of tonnes-kilometres in the Reference and in the four CAD scenarios for EU27 is shown in Figure 3.18.

It can be noted that road freight traffic increases in all scenarios of about 7-8% in comparison with Reference 2050, due to the reduction of transportation costs following from the reduction of drivers' labour costs.

Figure 3.18 Road freight transport activity in 2020 and 2050 [Mio*tkm]– EU27



Source: TRT.

3.3.6 Summary of results

Table 3.1 provides a synthesis of the Scenario Model's key results.

Table 3.1 Summary of key Scenario Model's results

Fleet composition at 2050 by automation level –EU 27	Level	Ref	Sce 1	Sce2	Sce 3	Sce 4
Car fleet [Mio*vehicles]	L0	0.00	0.00	0.00	0.00	0.00
	L1	98.09	0.00	0.00	28.95	86.00
	L2	70.79	1.18	2.29	25.04	52.15
	L3	71.48	24.61	29.44	58.11	60.96
	L4	5.60	51.91	102.84	71.63	26.36
	L5	0.00	158.08	99.69	13.60	5.97
	TOTAL	**245.95**	**235.79**	**234.26**	**197.34**	**231.44**
Bus fleet [Mio*vehicles]	L0	0.00	0.00	0.00	0.00	0.00
	L1	0.07	0.00	0.00	0.00	0.01
	L2	0.65	0.15	0.10	0.28	0.56
	L3	0.00	0.00	0.00	0.00	0.00
	L4	0.03	0.46	0.45	0.29	0.13
	L5	0.00	0.00	0.02	0.01	0.00
	TOTAL	**0.75**	**0.61**	**0.57**	**0.57**	**0.69**
Freight vehicles fleet [Mio*vehicles]	L0	0.00	0.00	0.00	0.00	0.00
	L1	0.00	0.00	0.00	0.00	0.00
	L2	11.49	0.00	0.00	0.02	6.33
	L3	20.32	0.30	0.30	8.67	15.50
	L4	1.91	7.73	7.96	16.18	7.33
	L5	0.00	21.50	21.66	4.97	0.95
	TOTAL	**33.72**	**29.54**	**29.92**	**29.84**	**30.11**
Transport activity at 2050 – EU 27		**Ref**	**Sce 1**	**Sce2**	**Sce 3**	**Sce 4**
Passenger transport activity by car [billion pkm]		5,501	6,191	5,732	4,898	5,341
Passenger transport activity by car [billion vkm]		4,621	5,909	5,136	4,855	4,413
Road freight transport activity [billion tkm]		2,346	2,534	2,511	2,501	2,519

Source: TRT.

4 Employment impacts of CAD

4.1 Summarised findings of employment impacts of CAD

The employment impact of the introduction of CAD technologies varies widely by the scale and scope of technology adoption, as can be seen in the figures in Table 4.1. These figures depict the change of employment in 2050 compared to 2020 and therefore include some other trends, such as increasing general transport demand and increasing productivity in manufacturing. They therefore have to be set into context. Generally, we expect significant employment declines in transport services driver employment, while other jobs in transport services are not as directly impacted and act as a stabilising force. In manufacturing, construction and other services, the demand for new, more valuable vehicles and components, as well infrastructure, results in job growth. This is, however, not enough to offset much larger job losses in transport services.

Table 4.1 Employment changes EU27, in thousand jobs

	Transport Services						Manufacturing [in CAD relevant sectors][27]		
	Passenger			Freight					
	2020[28]	2035	2050	2020[29]	2035	2050	2020	2035	2050
Scenario 1	2,122	+91	-46	4,508	+1,749	-2,302	9,190	-164	-168
Scenario 2	2,122	+91	-87	4,508	+1,431	-2,620	9,190	-164	-196
Scenario 3	2,122	+89	-265	4,508	+1,104	-1,247	9,190	-162	-239
Scenario 4	2,122	+89	-157	4,508	+899	+549	9,190	-163	-256
Employment in 2020 represents absolute employment in thousand jobs.									
Employment in 2035 and 2050 shows the employment change compared to 2020 in thousand jobs.									

Source: M-Five.

In passenger transport services, a variety of classic and automated modes coexist and compete with each other. Employment slightly increases before automated modes enter the market, but then decreases mostly because of job losses in bus and taxi traffic. Job losses are relatively strong in scenarios 3 and 4 (12.5% and 7.4% less over 2020 values) with spreading shared services. However, emerging automated transport services are also capable of creating a lot of new jobs, especially when ride-sharing grows at the expense of private car traffic. Automation takes place mostly in private car in scenarios 1 and 2 with a private focus, resulting in less severe losses in bus and taxi employment (2.1 to 4.1% loss over 2020).

Freight transport services experiences stronger growth in demand for employment driven by increased transport demand. This is followed by a much sharper decline in employment as vehicle fleets are rapidly transformed with new automated and cost-saving[30] vehicles. Employment levels are 52% lower in 2050 compared to 2020 in scenario 1 and even 58% lower in scenario 2. Depending on when and how rapidly this transformation unfolds, it is possible for the traffic volume

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[27] Employment in CAD-relevant manufacturing sectors includes employment in the vehicle, electronics, computers, and communication manufacturing sectors.

[28] 2020 results have been calibrated to match empirical data, but some adjustments had to be made to account for differences in scope. We calibrated public transport to 80% of the country level data from Transport in Figures (2016), not aiming at the full values because they include urban rail while this study does not. Transport in Figures data does not include taxi employment, so we used data from an EU report to calibrate taxi employment: Grimaldi, CERTeT Università Luigi Bocconi, Wavestone (2016).

[29] 2020 results for freight transport have been calibrated to match Transport in Figures 2016 data, including both road freight transport and postal and courier data.

[30] Replacing drivers with CAD technology eliminates one of the largest cost factors in freight transport. Automated vehicles also allow for more energy efficiency.

boost to employment to dominate job losses from CAD driver replacement, as can be seen in scenario 4.

Apart from general declines in transport services employment in most scenarios, we also expect a significant restructuring of the remaining jobs and skill requirements. IT jobs are set to grow rapidly. In passenger transport, stewards will be on many automated vehicles to provide customer services and possibly security as well as other tasks. In freight transport, we expect a transition period between traditional drivers and fully autonomous vehicles, when mobility operators supervise level 4 trucks and light-duty vehicles. There is possibly also an increasing role for staff in control centres, both in passenger and freight transport services.

Manufacturing employment is gradually declining over time due to improving productivity[31], declining importance of manufacturing industries and a shrinking labour force in several European countries. However, CAD-relevant sectors are dampening this trend, as employment increases with CAD becoming more important. With the roll-out of automated vehicles, employment increases as vehicles become more valuable (with more high-value components) and fleet renewal accelerates[32], driving up vehicles sales especially in scenario 1 and 2 with fast uptake of CAD.

Similar to the manufacturing sectors, the decrease in employment in the construction sector is also dampened by the introduction of CAD. Construction directly benefits from investments in CAD infrastructure. Being quite dependent on general economic activity, this sector is also boosted indirectly by GDP growth induced by the introduction of CAD and high vehicle sales.

In order to gain a complete overview of the employment impacts of CAD technologies, it is necessary to consider indirect, i.e. second-round effects. The transition to automated transport accelerates growth through a boost to fleet renewals, higher value vehicles and infrastructure and facility investments. This not only affects the manufacturing and services sectors described above, but also increases aggregate demand in the economy as a whole, which indirectly drives employment. Rising GDP and its positive indirect effects on employment can partially compensate for the lost employment in transport services. However, it is not enough to offset the large job losses completely.

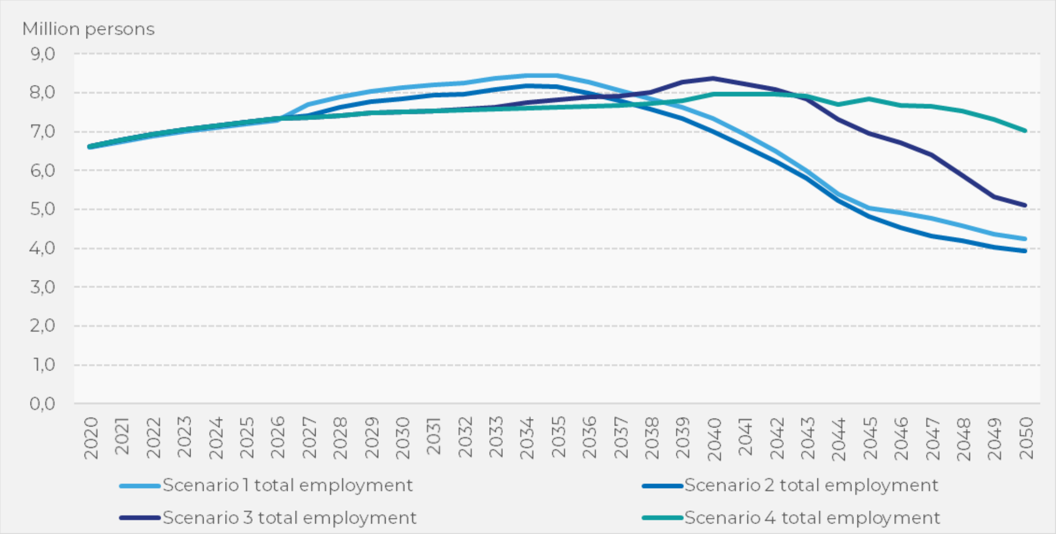
4.2 Transport services employment

Total transport services employment declines in all but one scenarios examined for this study. These aggregates are dominated by freight transport services developments, as their employment is much larger and the impact of CAD technologies on them is much more rapid. General employment trends are therefore largely driven by when and how rapidly CAD vehicles are adopted in cargo fleets. Developments in passenger transport services play a much smaller but still significant role. The dynamics of adoption are more complex in passenger compared to freight transport services. They may largely affect private cars and leave passenger transport relatively unaffected, transform passenger transport or even shift significant amounts of traffic from private car traffic to new forms of mobility services.

[31] This means that the same level of output can be produced with fewer inputs and less employment, mostly driven by technological advances.

[32] New vehicle purchases are an outcome of the Scenario Model. See chapter 3.3 for the development of the fleet. Generally, demand for autonomous vehicles as a breakthrough technology at accessible price is substantial. On supply side, there is room to increase capacity and hence production in the automotive industry.

Figure 4.1 Employment of passenger and freight transport services, EU27



Source: M-Five.

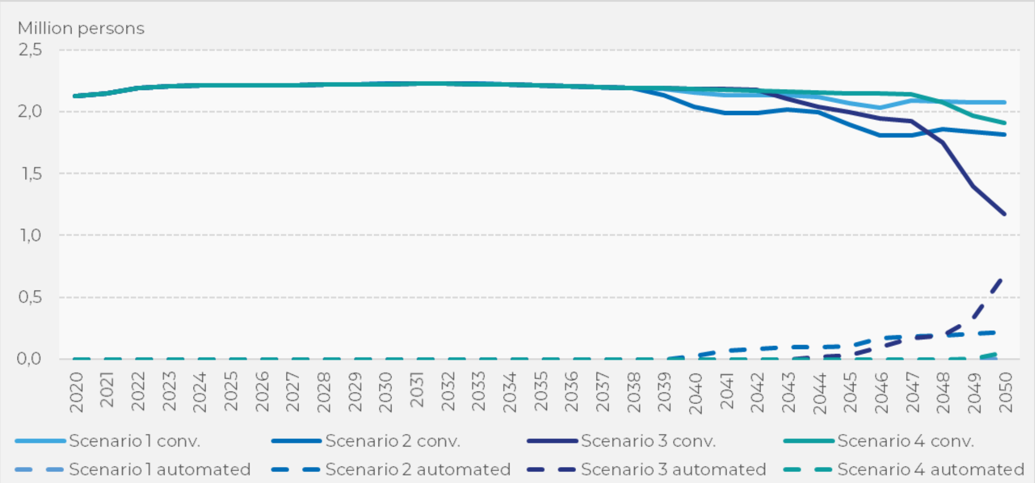
4.2.1 *Passenger transport services employment*

The landscape of passenger transport services is more complex than in freight transport, with various kinds of transport services coexisting and competing with each other, particularly closer to 2050, the end of the time period considered for this study. Automated services start emerging in the late 2030s or mid-2040s, depending on the scenario, and displace some demand for non-automated services. This transition is depicted in Figure 4.2, with dashed lines for all automated services and solid lines for all non-automated services.

Figure 4.2 depicts the emergence of automated buses, automated taxis and automated ridesharing (which is conceptualised in this project as an extended, more dynamic taxi services with various passengers and differing pick-up points and destinations, somewhat akin to a shuttle). All of these services emerge only when SAE level 5 automation is available, as we expect them to be feasible only at this level.

We will examine the specific kinds of transport services below, starting with the emergence of automated modes and moving on to their impact on the employment of traditional services.

Figure 4.2 Transition to automated transport in passenger transport services, EU27

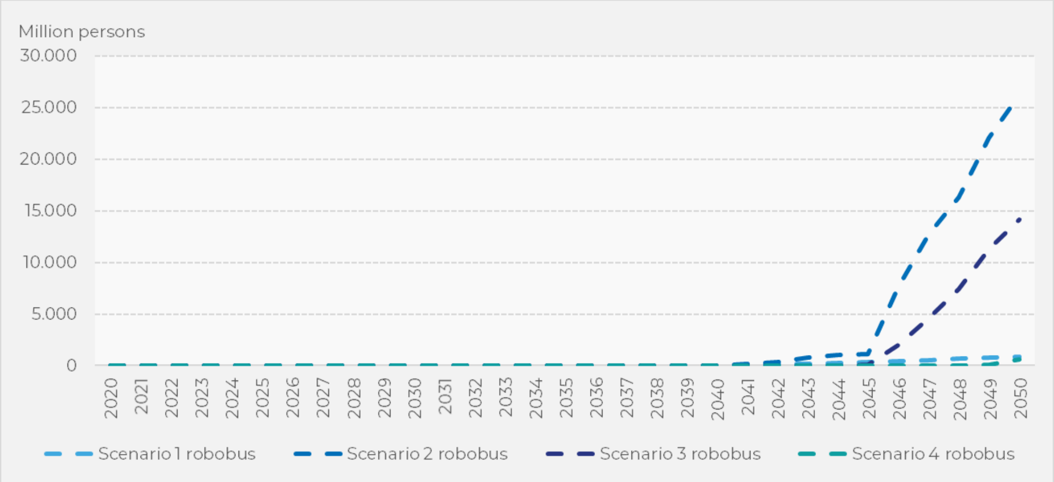


Source: M-Five.

Emerging automated passenger transport services

Automated buses start emerging from around 2040, with pilot projects in the early years. A more significant roll-out begins in the mid-2040s in some of the scenarios, while others do not see any development beyond pilot status by the end of the time period considered for this project. The scale of the roll-out is very small, never reaching more than just over 26,000 employees (note that the axis scale is very different from most other figures in this chapter). In scenario 2 we actually see automated buses taking up a significant share of the bus market, with around 10% of bus transport demand in some of the technologically more progressive member states. But with most countries lagging behind this development and since automated buses are only around half as employment intensive as conventional buses, employment figures on the EU level remain very small.

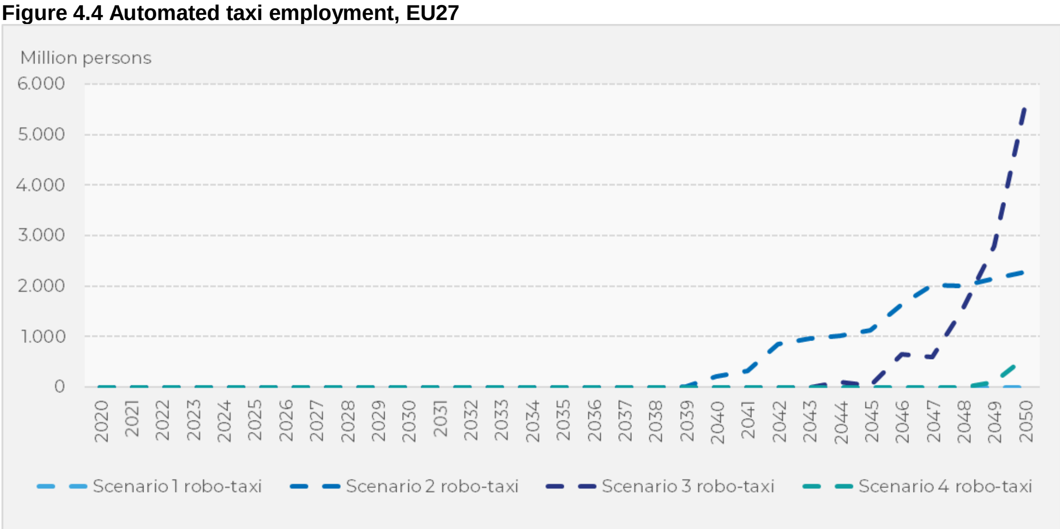
Figure 4.3 Automated bus employment, EU27



Source: M-Five.

For automated taxi services we also see only very limited development, reaching a maximum of only 5500 jobs created by 2050. In scenario 1, this service does not emerge at all – in this scenario, automation affects only private car traffic but not passenger transport services. In all cases with some emergence of automated taxis they are clearly overshadowed by ridesharing services.

Figure 4.4 Automated taxi employment, EU27

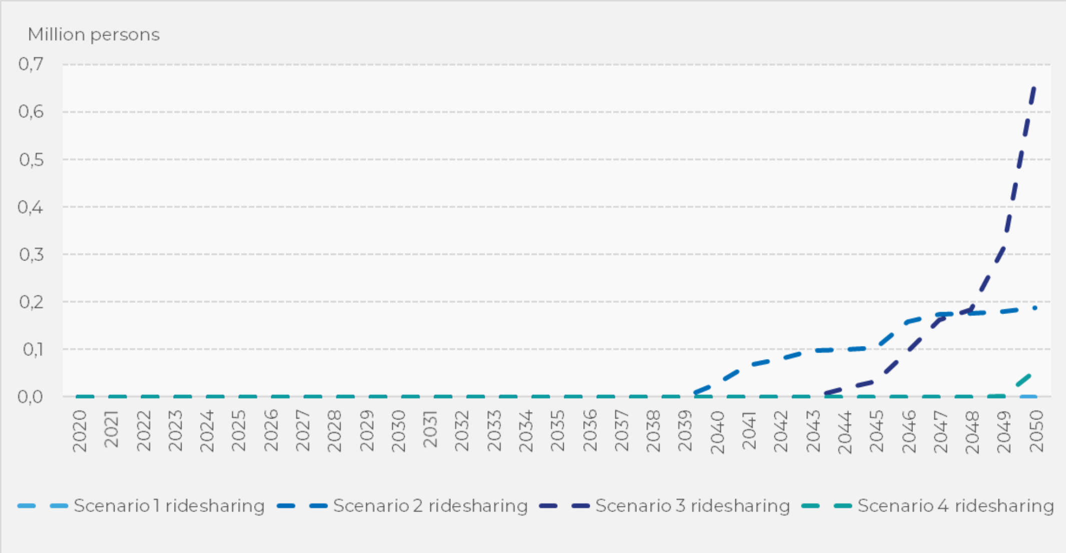


Source: M-Five.

The dynamics of ridesharing employment appear to follow a very similar pattern as automated taxis, but on a very different scale. Employment reaches figures in the hundreds of thousands in some of the scenarios and the traffic demand behind this development is the main driving force behind the impact on established transport services described further below.

In scenario 3, we see employment created by ridesharing reach 660,000, an impressive figure given that no drivers are required at SAE level 5. Almost 200,000 IT staff and 220,000 stewards make up much of this job creation. Another significant job group is maintenance with around 130,000 jobs. The development behind this surge is not only quantitatively, but also qualitatively different from the other scenarios and the other dynamics affecting transport services: This scenario depicts the possibility of a significant amount of travelling that was previously done with private cars is taken up by ridesharing by the end of the 2040s. This means that the overall size of the passenger transport sector grows by drawing more customers to this new transport service. This is important to keep in mind when evaluating the relative magnitudes of employment of different services in scenario 3.

Figure 4.5: Ridesharing employment, EU27



Source: M-Five.

Impact on driver-based passenger transport services

Let us now examine how these autonomous transport services affect established services. A basic finding of the Scenario Model simulation is that we are not looking at separate markets for buses, with conventional buses competing primarily with automated buses, and car-based markets, with conventional taxis competing against automated taxis and ridesharing. Instead, we see dynamics crossing these boundaries, as will be shown below.

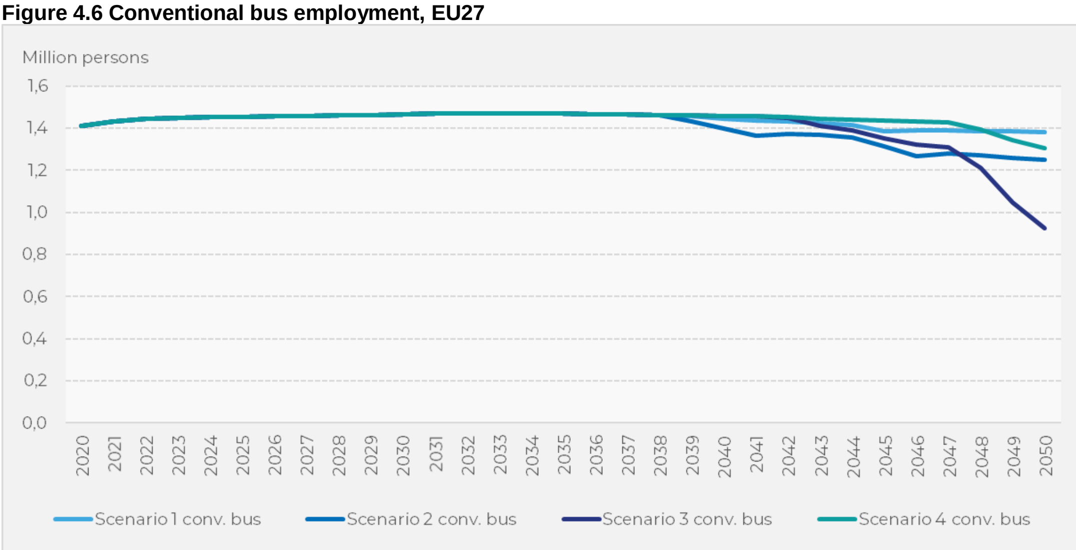
Buses make up a very large share of current transport services employment and their development therefore is a major impact on overall employment in the sector. Bus transport demand declines due to competition from automated transport services. This follows an increase in demand that sees bus employment peak in the early 2030s around 50,000 jobs higher than the 2020 level. Overall job losses in the period from 2020 to 2050 vary widely from just under 30,000 to 488,000.

As we have seen above, automated buses are not projected to take up large shares of the bus market in any of the scenarios. In the strongest showing of automated buses in scenario 2, they create around 26,000 jobs, while 160,000 conventional bus jobs are lost. In the scenario with the most rapid job losses (488,000 in scenario 3), automated bus employment reaches only 14,000.

Even accounting for the much lower employment intensity of automated buses, their emergence is not nearly a sufficient explanation for the decline in overall bus employment.

What we see instead is that transport demand for conventional buses reacts most strongly to the rise of ridesharing. As ridesharing becomes technologically feasible, the greater flexibility of free routing and relative affordability due to ride pooling makes this service more attractive to some people who currently travel by bus. This is the story behind scenario 3, in which, as we have seen above, ridesharing surges. It replaces not only taxi demand and private car traffic, but also a significant share of bus traffic demand.

Figure 4.6 Conventional bus employment, EU27

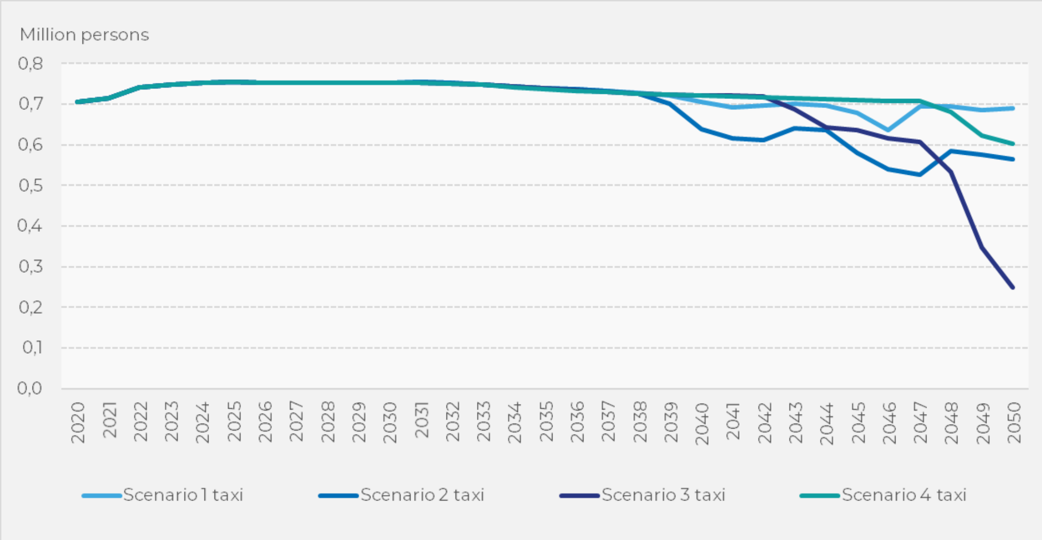


Source: M-Five.

In the taxi market, we also see employment declines that vary quite widely depending on the scenario. In the least severe case, job losses compared to 2020 account for 17,000, but in most cases, they exceed 100,000, reaching a maximum of 457,500 jobs lost in scenario 3. This is less in total numbers than the decline in bus employment, but represents a loss of almost two thirds of conventional taxi employment before the rise of ridesharing.

Carsharing remains very small in our projections, with EU employment levels between 2000 and 4500 in 2050. It actually loses market share in most of the scenarios and therefore has a decreasing and small significance in the transformation of passenger transport. Like other services, it loses jobs most rapidly when the rise of ridesharing is the strongest.

Figure 4.7 Conventional taxi employment, EU27

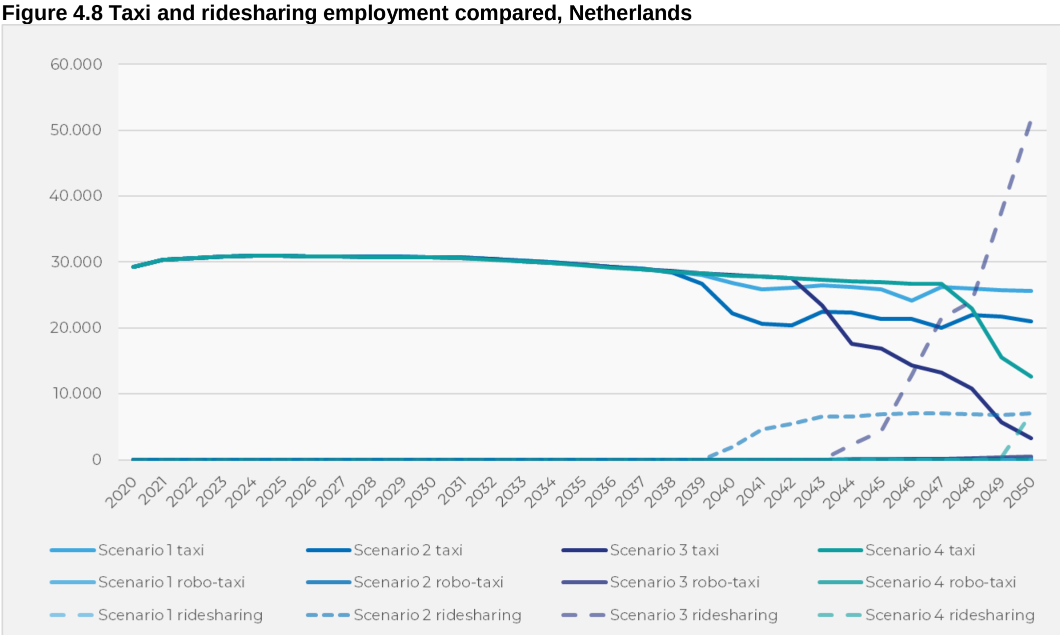


Source: M-Five.

As taxis are a much more direct competitor to ridesharing (which is basically an extended, pooled taxi service), their losses are much more severe in relative terms than the losses of the bus sector. This is most obvious in the forerunner countries, which experience earlier and much more rapid roll-outs of automated services. Looking at the example of the Netherlands in Figure 4.8, we see that in scenario 3 (grey lines) taxis with human drivers are about to disappear by 2050. Their employment declines from around 30,000 in the mid-2030s to only 3300 in 2050, with a similar pattern in the other forerunner countries. This means that most of the remaining taxi market in the EU is actually outside the forerunner countries.

Ridesharing employment, meanwhile, far exceeds previous taxi employment, despite not employing any drivers and therefore being much less employment intensive than taxis. This is a result of ridesharing being used by people who previously travelled by bus or private car.

Figure 4.8 Taxi and ridesharing employment compared, Netherlands



Source: M-Five.

Employment growth and decline of passenger transport services is summarised in Table 4.2. Not depicted are developments in private car traffic, because they are not transport services and do not create any direct employment. However, they are important parts of the dynamics behind some of the numbers. In scenario 1, automation of passenger vehicles largely takes place in private car traffic, while automated taxis and ridesharing are not assumed to enter the market in this case. In scenario 3, as we have seen, the growth of ridesharing benefits to a large extent from a shift of traffic away from private car traffic towards ridesharing.

Table 4.2 Employment development of passenger transport services, 2020 to 2050, EU27

Employment by mode (number of jobs)	Auto-mated Bus	Auto-mated Taxi	Ride-sharing	Bus	Taxi	Car-sharing	Total
Scenario 1	869	-	-	-29,713	-17,001	246	-45,599
Scenario 2	26,282	2,285	188,745	-160,409	-142,593	-904	-86,595
Scenario 3	14,182	5,529	663,429	-488,333	-457,526	-1,912	-264,631
Scenario 4	563	570	55,005	-107,785	-104,271	-609	-156,527

Source: M-Five.

In conclusion, we can clearly see that ridesharing is the major transforming force of passenger transport. Its growth far exceeds other automated services and it results in potentially rapid reductions in bus and taxi employment – up to a loss of 34.6% of 2020 bus employment and 64.8% of taxi employment in scenario 3.[33] Important to note is also that the overall decline in bus and taxi employment in itself is not a sufficient indicator of total employment in the sector. While in scenario 2 job losses in bus and taxi traffic are around 50% higher than in scenario 4, net job losses are actually smaller than in scenario 4 because of much stronger growth in ridesharing employment.

Job categories in passenger transport services

General trends in driver and non-driver employment

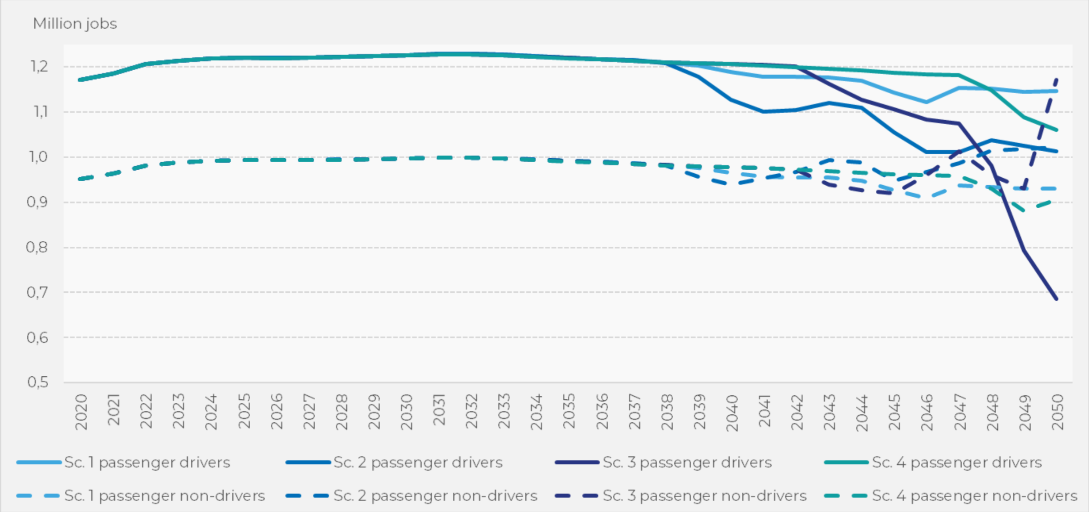
There is some transition in the tasks necessary to maintain the modern passenger transport system described by the scenarios. Traditional driver jobs will be significantly reduced. In contrast to freight transport services described below, we do not foresee any automated passenger transport services at level 4. Therefore, there is also no need for mobility operators similar to those in level 4 freight vehicles, who have to be ready to intervene in rare situations that level 4 automation technology is not able to handle. In other words, we expect a relatively abrupt transition from traditional drivers in buses and taxis to fully autonomous buses, taxis and ridesharing, without the transitional mobility operators of level 4 automation. With only limited and gradual growth in automated services, though, the overall impact on the labour market is also limited.

The general picture depicted in Figure 4.9 is of non-driver jobs acting as stabilising force on overall employment while driver employment is significantly reduced in most scenarios. Automated services do not employ drivers, but still require a range of administrative and other tasks similar to traditional services – as well as some new job positions, which are subsumed under job categories created for current transport services (such as stewards in the operations category). The normal dynamic with a simple replacement of traditional with automated services is therefore that driver employment is reduced, while other employment stays roughly on the same level. However, the transition is often not as simple as that, so we have to make a few qualifications. They concern the

[33] In scenario 1, bus and taxi employment are reduced by 2.1% and 2.4%, in scenario 2 by 11.4% and 20.2% and in scenario 4 by 7.6% and 14.8%.

employment intensity of automated services and the general level of passenger transport services demand.

Figure 4.9 Driver and non-driver employment in passenger transport services, EU27



Source: M-Five.

Employment intensity of automated modes

Employment intensity of automated services is mostly determined by the composition of passenger services and efficiency developments. In general, we assume automated passenger services to become more efficient over time in their employment requirements. In the initial phases (pilot phase, limited roll-out) they require additional staff for extensive customer service and stewards to accompany people while they are starting to get used to automated services. Over time, this requirement for additional assistance fades. We also assume to see further efficiency gains mainly due to three reasons: First, companies offering automated services are generally more tech-savvy than traditional companies and are thus likely to also introduce some additional automation technology in their offices. Second, tasks previously employing significant numbers of staff no longer have to be carried out – mainly the management of large numbers of drivers, including hiring and training them as well managing schedules. Third, as automated services grow rapidly, not all administrative tasks have to multiplied, as some of them are relatively independent of the scale of the service – especially when many processes are automated.

The intensity of non-driver employment is also affected by the composition of transport services. For example, the increase in scenario 2 non-driver employment is largely driven by a shift to ridesharing, which is more non-driver employment intensive than the buses it displaces, to some extent. Ridesharing requires the management of a large number of vehicles compared to bus traffic and its employment is modelled based on traditional taxis, which are very employment-intensive.

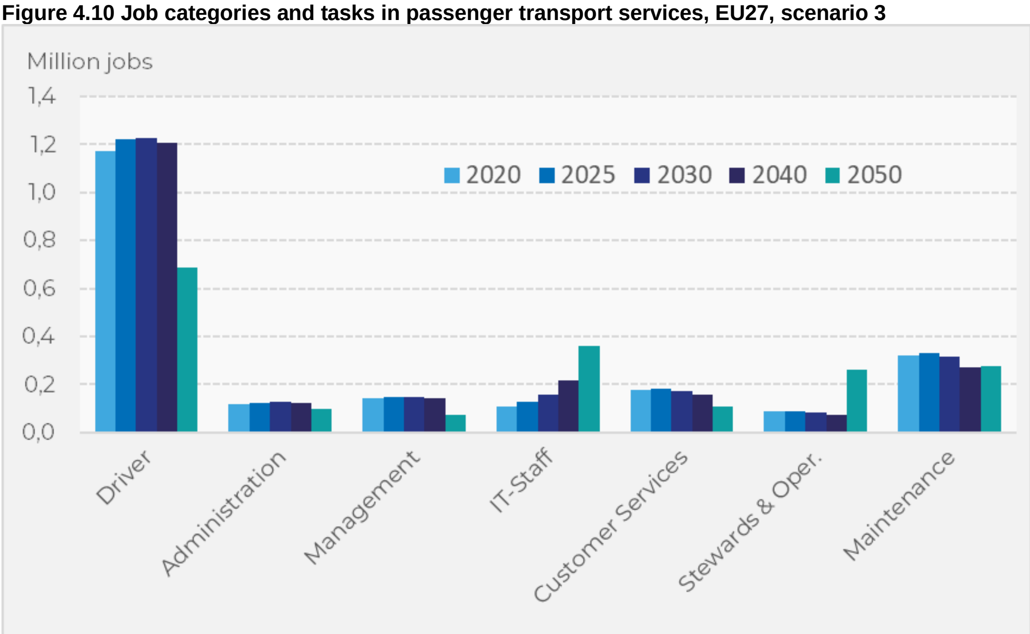
Finally, to understand the dynamics in Figure 4.9, we need to consider the underlying developments in overall passenger transport services demand. In scenario 3, ridesharing expands rapidly at the expense of private car traffic, among others, and thus significantly increases overall transport services demand as well as non-driver employment. In scenario 4, on the other hand, traditional passenger transport services decline before automated services start taking off. We therefore see a yellow dashed line that parallels the decline in driver employment as traditional services decline. Later on, there is an uptick in non-driver employment when automated services enter the market on a significant scale.

Tasks and job categories

The structure of jobs and tasks required changes over time. One of the most striking features is the rise in IT staff required to handle advanced automation technology. Most other tasks (administration, management, customer services, maintenance) experience some reductions caused by moderate decreases in overall employment and some efficiency gains.

There is also a significant increase in the number stewards employed in automated vehicles. This uptick is quite strong when compared to the market share of automated services – traditional services are still quite dominant in all scenarios. In the scenario with the strongest development of automated services, the number of stewards grows rapidly, to a level of around one third of traditional drivers (see Figure 4.10).

Figure 4.10 Job categories and tasks in passenger transport services, EU27, scenario 3



Source: M-Five.

Scenario 3 represents the maximum disruption of passenger transport employment considered in this study. As can be seen in Figure 4.10, driver jobs decline by almost a half, while IT and steward jobs grow rapidly. On the other hand, it is also conceivable that there will not be much change in the structure of jobs. In scenario 1, automated transport is adopted in private car traffic but does not heavily affect passenger transport services.

Steward employment

The employment of stewards is not new in the passenger transport services system. But it is set to expand rapidly with the rise of ridesharing (to a lesser extent also in automated busses and taxis)[34] and play an important part facilitating this transition. We therefore take a closer look at them in this section. What this job will look like in detail is still quite open, but in general we expect the job scope to revolve around the provision of information, security and cleanliness. Job profiles may vary substantially by region or companies within the same region.

Stewards will take on some of the side (non-driving) tasks of drivers, such as information and assisting passengers buying tickets. The need for a sense of security may increase when sharing a small vehicle (cars in the case of ride-sharing) with strangers. Cleanliness may also fall into the

[34] We expect up to around 220,000 stewards in ridesharing, while the maximum for steward employment in automated buses is 11,000 in scenario 2 and much smaller for automated taxis.

area of responsibility of stewards as vehicles are no longer indirectly supervised by drivers and/or conductors.

The spatial organisation may take several forms. Stewards may be on the vehicle permanently if this is required by law or strongly preferred by passengers. Especially in the early phases, this is likely to be important in order to establish public trust and acceptance in autonomous passenger transport services. They may also be on the vehicle only during certain parts of the trip or times of the day or night, depending on service and security requirements. Some stewards may also work predominantly in mobility stations.

Stewards for the emerging automated modes will not be involved in active driving as the modes are defined as SAE level 5 and therefore do not have any steering devices. They may, however, be able to intervene in less direct ways, such as through voice commands or much simpler steering devices or IT applications. While this may be useful operationally, the larger significance is probably in helping to establish trust and public acceptance of autonomous services.

4.2.2 *Freight transport services employment*

Basic dynamics and context of freight transport services

In freight transport services, we generally see a much more unitary transformation. Once CAD technologies become available and affordable, they will be gradually adopted to make heavy-duty vehicle (HDV) und light-duty vehicle (LDV) fleets more efficient. This process is more rapid than in passenger vehicles because HDV and LDV fleet renewal is much faster. Vehicles are typically used quite intensively, often travelling several hundreds of kilometres every day and therefore have be to be replaced after shorter lifespans than less intensively used passenger vehicles. Another factor is that decisions on which vehicles to use are heavily influenced total cost of ownership (TCO), potentially inducing rapid fleet replacements due to small cost savings per kilometre.

As a result of these dynamics, the patterns in the uptake of CAD technologies in freight transport follow similar trajectories across the different scenarios. The main difference is when this transformation commences and which point we arrive at in 2050.

As mentioned above, this transformation has to be seen in the context of an earlier expansion in freight transport demand, resulting in significantly increased employment peaking around the 2030s (depending on the scenario). In one of the scenarios this growth effect is larger than the loss of driver jobs, meaning that projected employment in 2050 is higher than in 2020.

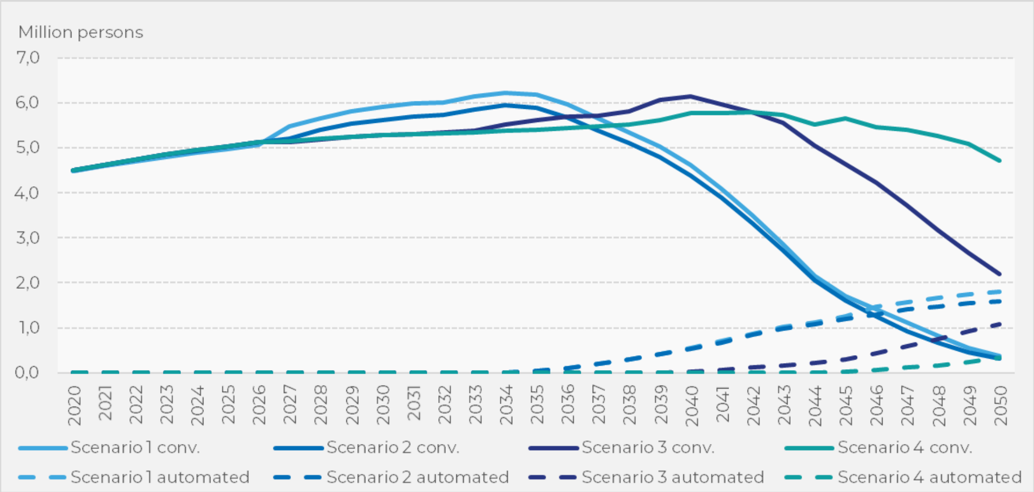
Impact on driver-based freight transport services

The transformation to automated vehicle fleets can proceed quite rapidly, with job losses of around 2 million every 5 years starting around 2035 und vehicles with human drivers largely phased out by 2050 (Figure 4.11). The decline is quite rapid in general. It accelerates around 2040 as more countries join the transformation process, while the curve somewhat flattens around 2045 as the forerunners have largely completed the transformation (more on this further below).

It is, however, also possible that there is only a slight transformation, as shown in scenario 4 (yellow line). In this case, a small number of forerunner countries introduce automated vehicles, while most countries continue running their fleets completely with human drivers, for the time period considered in this project. Scenario 3 is between the two extremes, with automated vehicles being introduced later than in scenarios 1 and 2 but later than in scenario 4.

A common feature in the scenarios is that labour demand actually increases due greater transport demand. This results in around 1.5 million more jobs at the peak of the curve, at some time between the mid-2030s and mid-2040s depending on the scenario. The need to expand employment while rapid job losses in the future are clearly a prospect poses a particular challenge in freight transport services.

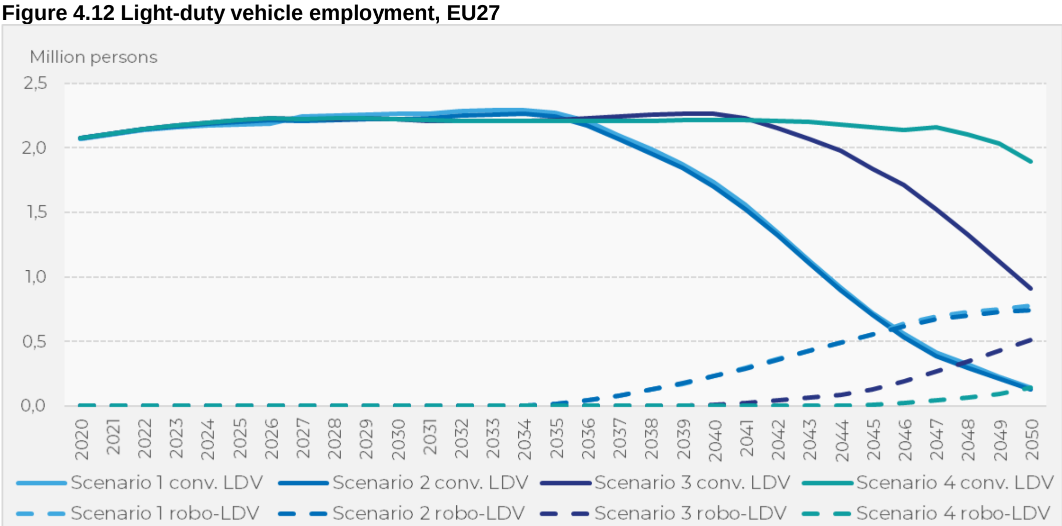
Figure 4.11 Freight transport employment, EU27



Source: M-Five.

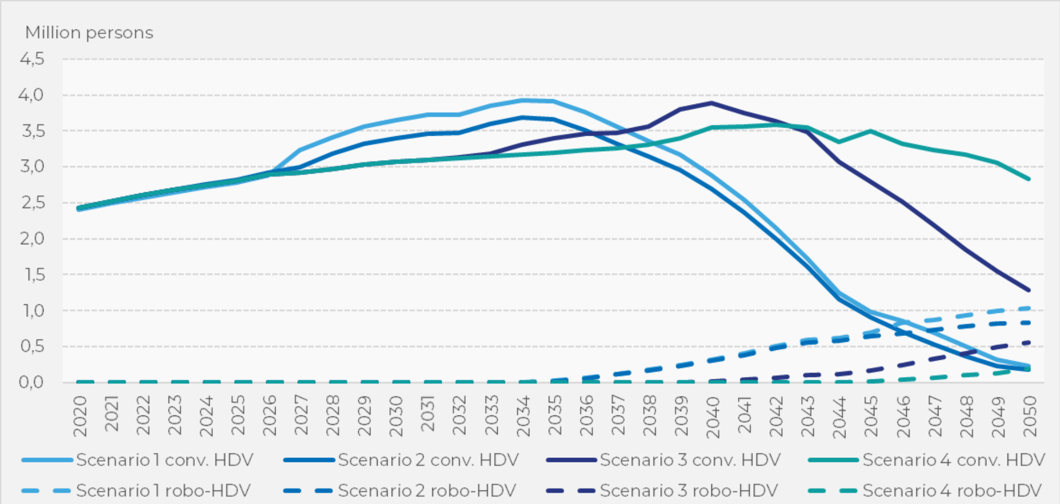
The dynamics of the transformation are quite similar in light-duty and heavy-duty vehicle fleets and therefore do not require much separate explanation (Figure 4.12 and Figure 4.13). Again, we see the employment impact of fleet replacement starting in the mid-2030s in the earliest and most rapid transformation scenario. The curves have a similar shape in both types of vehicle fleets, with the transformation accelerating in the early 2040s and decelerating in the late 2040s as some countries have completed the process of fleet renewal.

Figure 4.12 Light-duty vehicle employment, EU27



Source: M-Five.

Figure 4.13 Heavy-duty vehicle employment, EU27



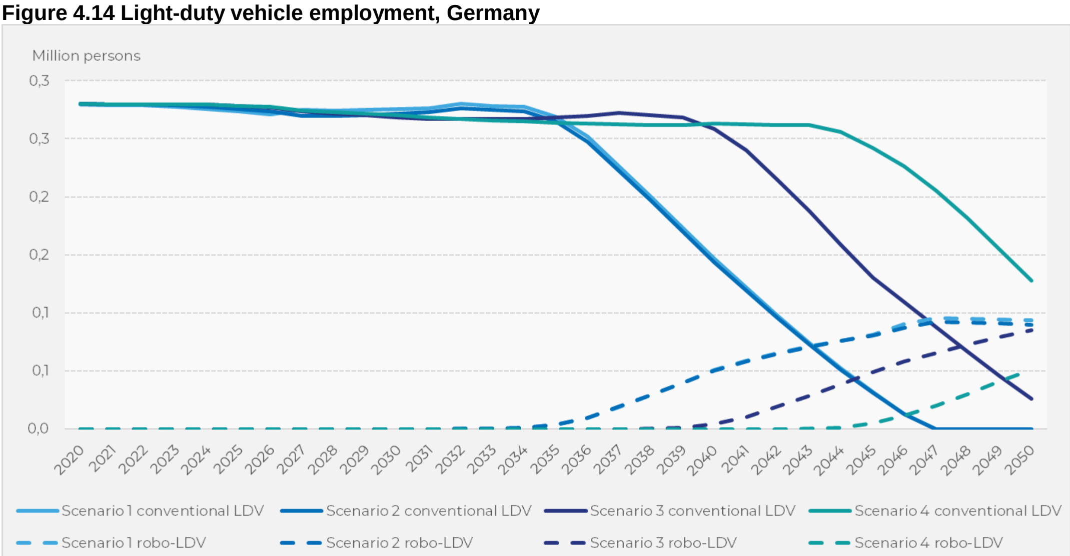
Source: M-Five.

Regional differences: forerunner and follower countries

Differences between EU member states can be significant. Forerunner countries such as Germany (Figure 4.14) experience an early transformation, beginning in the mid-2030s in scenarios 1 and 2, with a steady decline in conventional vehicles from then on. The transition is basically complete by 2047. The dynamics for heavy-duty vehicles are quite similar, but with conventional HDV employment somewhat above zero at 2050.

Scenario 3 assumes an introduction of CAD technologies a few years later, but approaching a complete transition to automated vehicles around 2050. In scenario 4, we saw only a slight decline in employment on the EU level, although in the context of transport demand that is continuing to grow. In forerunner countries the transition is much more advanced than the EU average, with a reduction in traditional LDV employment by over 50%.

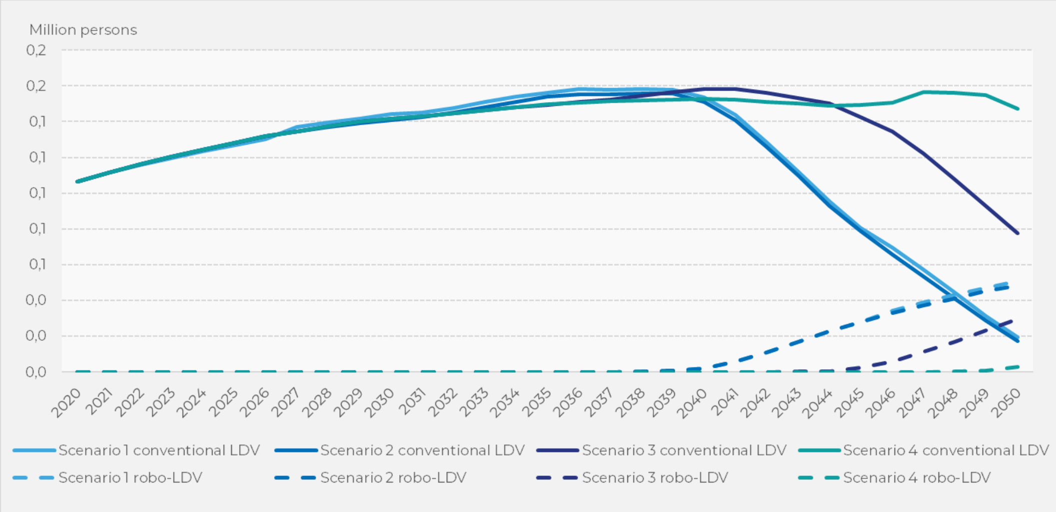
Figure 4.14 Light-duty vehicle employment, Germany



Source: M-Five.

In contrast, in countries with somewhat later development, the introduction of automated vehicles starts only around 2040, as in Romania's example (Figure 4.15). The transformation in the strongest scenarios, while also quite rapid, does not quite result in a complete disappearance of vehicles with human drivers by 2050. It is even conceivable that the fleets are almost completed unaffected by CAD technologies, with only a very slight up-take in 2050 and a slight decrease in employment of conventional vehicles (scenario 4). Again, the dynamics are quite similar for heavy-duty vehicles.

Figure 4.15 Light-duty vehicle employment, Romania

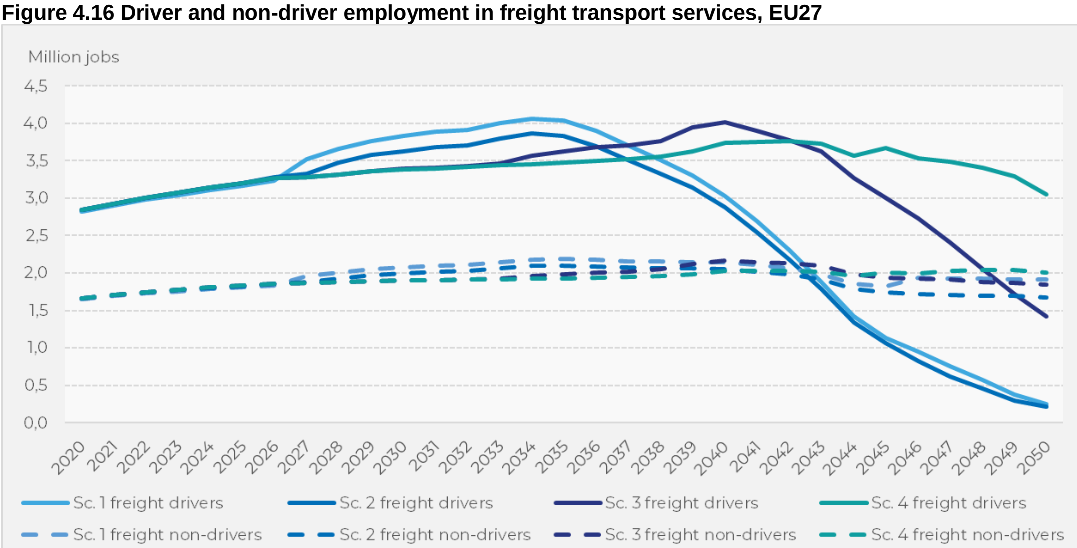


Source: M-Five.

The evolution of jobs and tasks in different automation levels

The widespread adoption of CAD technology of level 4 and 5 will rapidly reduce traditional driver employment. Level 4 represents a transitional period, with traditional drivers largely obsolete but human intervention necessary in some rare occasions unforeseeable by the technology of level 4 automation. At level 5, neither drivers nor the mobility operators of level 4 will be required. Non-driver employment is expected to stay relatively stable but significant changes will take places in the tasks and skills required.

Figure 4.16 Driver and non-driver employment in freight transport services, EU27



Source: M-Five.

Requirements for driving activities as well as other tasks related to freight transport are set to change significantly at automation levels 3 to 5. Starting at level 3 with the introduction of platooning on highways, the need for active driving can be significantly reduced. The impact on employment requirements is probably limited, though, and has not been implemented directly in the model. Much larger employment impacts, as well as changes in tasks and skills required, are expected with level 4 and level 5 vehicles, when little or no active driving will be required by human drivers, or mobility operators / logistics operators, as they may be more appropriately referred to. We will discuss them in more detail below.

Mobility operators – transition from traditional drivers to fully autonomous vehicles

The end point of the transition in driver and mobility operator employment is level 5 automation. At this level, by definition, the vehicle is fully autonomous and can properly drive in and react to all kinds of environments. This means that human driving or intervention is no longer required. It will actually not even be possible, because a typical level 5 vehicle has no steering devices. The only possible restriction we see is regulatory requirements limiting self-driving vehicles with no human on board. In general, though, we assume that nobody will have to be present in a level 5 vehicle as there is quite simply nothing for them to do there.

The main point of interest is therefore on mobility operators in level 4 vehicles. At level 4, vehicles can drive autonomously in most environments and situations, with human operators only required to intervene in rare unforeseen situations. This opens up a whole range of options on how to employ people, specialised on vehicle operation or combining tasks, working in a vehicle or remotely. We mainly see three kinds of mobility operators.

Specialised on-vehicle mobility operators

Mobility operators could be similar to traditional drivers that are working in the vehicle and mainly focused on driving tasks. This means that mobility operators in this sense of the term will be inactive most of the time, apart from rare exceptional situations that cannot be handled by the level 4 vehicle. Inactivity of this length comes with risks of attention drift and sleepiness. On the other hand, optimal focus will make operators well prepared to handle situations in which they actually have to intervene.

Specialised remote mobility operators

In a similar way to military drone operators today, freight vehicle operators could monitor and steer vehicles remotely. Enormous efficiency gains could be made in this way: Operators would no longer have to travel to their vehicle and make long trips around Europe far away from their home. Significant time used to transfer drivers to vehicles could therefore be saved, while also making the job enormously more attractive and family-friendly. Taking these time savings into account, one remote mobility operator could take on the jobs of more than one traditional driver.

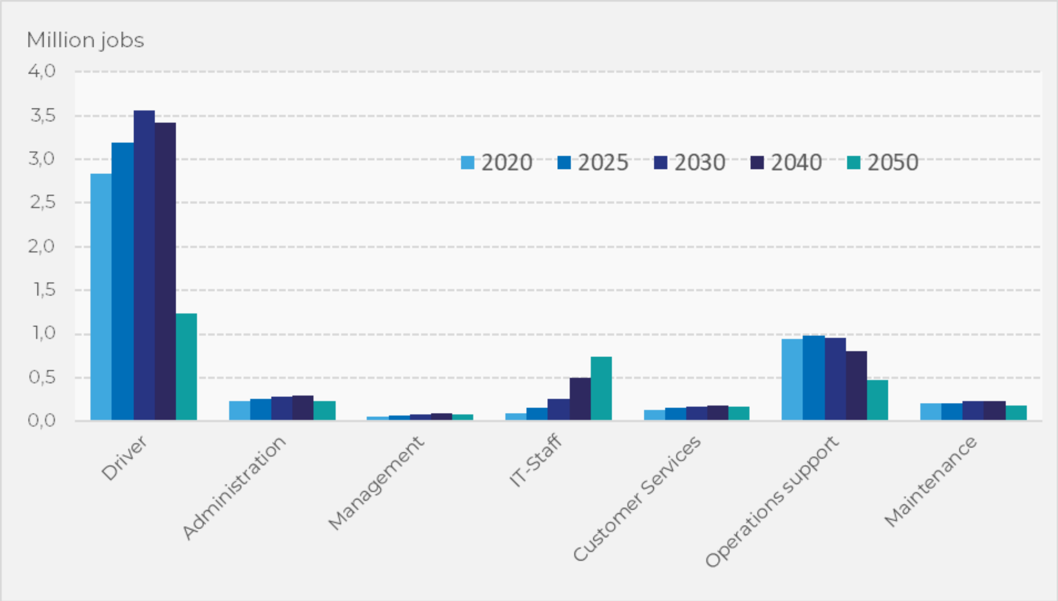
Vehicle-office fusion mobility operators

A final option is for mobility operators working in the vehicle to take on other tasks that are currently office-based. This comes with the risk of diverted attention, potentially obstructing quick reaction when human intervention is necessary. However, attention and preparedness for emergency are a challenge in all options for level 4 mobility operators and working on other tasks is not necessarily worse than not being active at all. Working on office-related tasks requires the operator to maintain a general level of focus and attention and on-vehicle workspaces could be arranged in a way to allow the operator to have the highway in their field of vision. Adjusting the intensity of the office work could allow operators to notice unusual and threatening features in their environment.

Tasks and job categories

As we have seen before, traditional driver employment will increase due to growing transport demand and then rapidly decline as drivers are replaced by technology. We see significant changes in non-driver tasks that are summarised in Figure 4.17.

Figure 4.17 Job categories in freight transport services, EU27, average of all scenarios



Source: M-Five.

The most striking feature is the rapid growth in IT staff. This is caused by both vehicles and interaction between company and the mobility operators or autonomous vehicles will become more heavily based on IT. We see remote mobility operators (explained above) as part of this category. If they turn out to be the main model of mobility operation, we may see an even stronger growth in IT.

Operations support is another task with significant changes. This category mainly includes warehouse management and logistics. As this is probably not more challenging to automate than driving tasks, we also expect significant efficiency gains here. On the other hand, since we do not have a specific category for mobility operators, they could be seen as part of this category. However, since we do not expect them to be the dominant model for mobility operators, we do not see net growth in this category. In other words, we do not see gains of employment from mobility operators in this category to dominate job losses due to automation.

The rise of vehicle-office fusion mobility operators would transfer some tasks from offices to vehicles, including mainly administration, customer services and operations support. In this context, we have two opposing forces affecting general efficiency and employment numbers: on the one hand, more advanced technology will make many of the tasks easier, requiring less human work. On the other hand, vehicle-based work on these tasks will come with less intensive focus for safety reasons.

Finally, for management and maintenance, we do not expect major changes. Maintenance tasks will be somewhat reduced as a result of the transition to zero-emission vehicles.

To conclude this section, we can see that the dynamics of the adoption of automated vehicles are quite similar, with relatively rapid fleet renewals setting in once CAD technologies become available and competitive. The uncertainty lies mainly in when this transformation will commence, which could be any time between the mid-2030s and mid-2040s. Another open question is the way level 4 vehicles will be operated and related to that the development of specific task requirements.

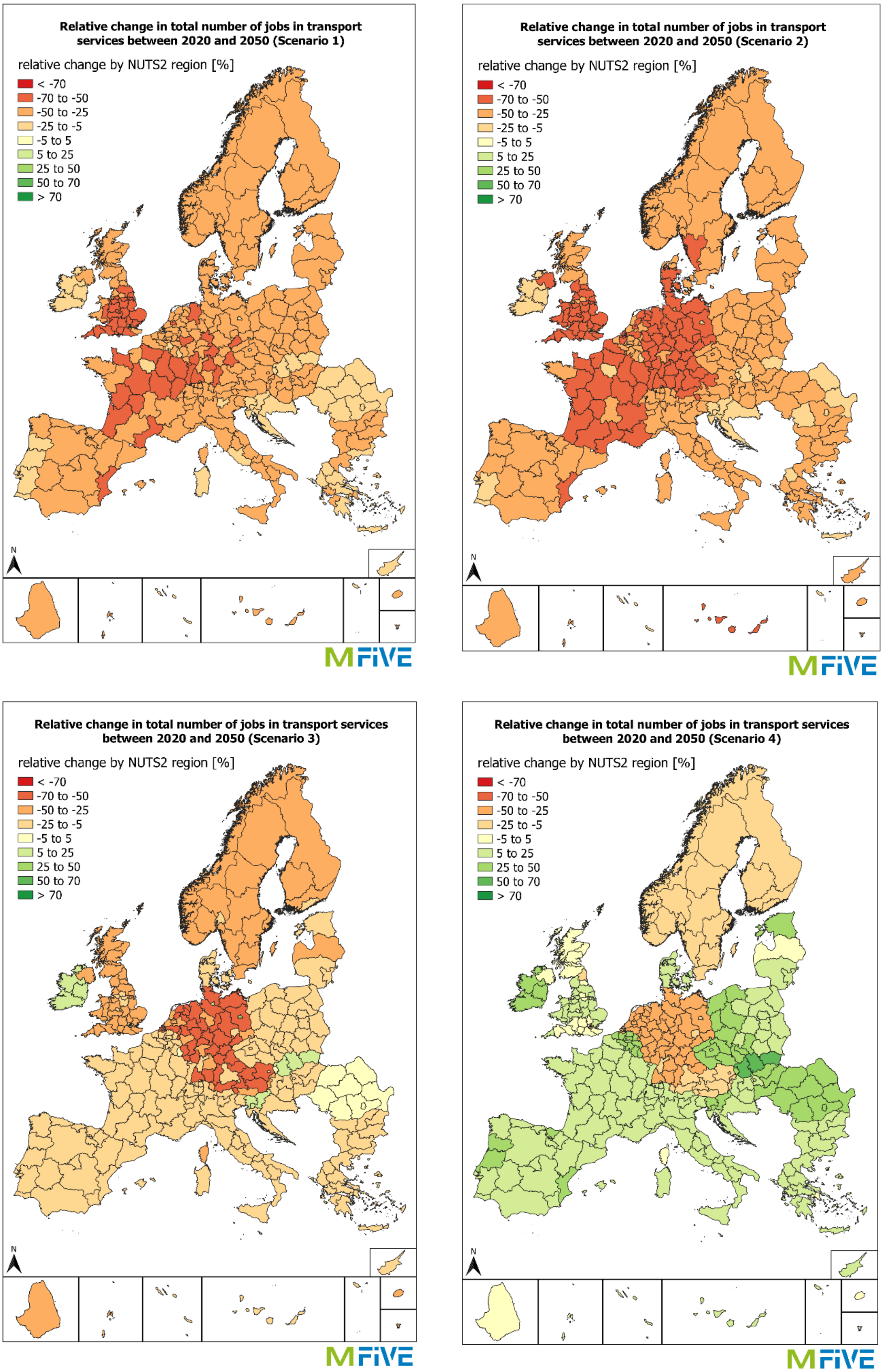
4.3 Regional distribution of transport services employment

To examine the regional distribution of employment impacts, we have broken down national results to NUTS-2 regions across Europe. The approach to develop the regional keys is described in Annex C. Regions vary quite widely in size, population and employment levels. As a result, we decided to mostly evaluate relative changes as a percentage increase or decrease between 2020 and 2050.

As described above, overall employment impacts are to a large extent determined by developments in freight transport services because they have much larger employment to begin with and because they are impacted much more rapidly and extensively than passenger transport services. This is also generally true for the regional impact of CAD technologies.

Freight transport also expands much more rapidly than passenger transport services. The relative job impact of transport demand expansion and displacements due to CAD technologies is the most important explaining factor behind most of the clearly observable features of the maps in this section. Transport demand expands most strongly in Slovakia, Slovenia, Ireland and Romania, resulting in relatively positive job development in these countries. Other countries, such as Germany, experience very little growth in transport demand (see also Figure 4.14 and Figure 4.15 for a comparison of Germany and Romania). Figure 4.18 depicts the impact of both passenger and freight transport services for all scenarios.

Figure 4.18 Relative change of jobs in transport services, European regions, all scenarios



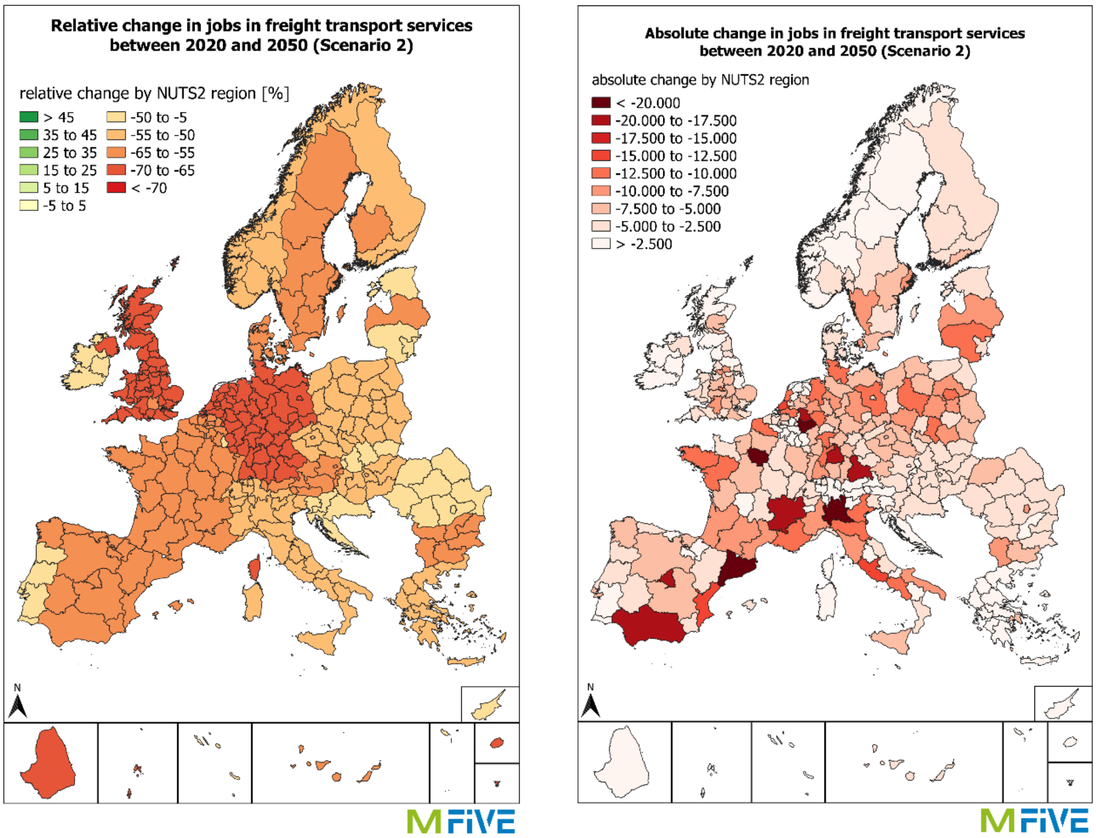
Source: M-Five.

All countries are affected by significant job losses in scenarios 1 and 2, when automated vehicles transform freight vehicle fleets almost completely, resulting in the replacement of most drivers in freight transport. The countries with the strongest losses are those that combine severe reductions as a result for CAD freight transport with relatively limited expansions of freight transport demand until the 2030s.

In scenario 3, we see the combined effects of a medium intensity transition in freight transport services and the most significant disruptions in passenger transport services, with ridesharing in particular displacing traditional taxis and buses. Negative job development of traditional passenger transport and freight transport is dominant in the numbers behind most of the regions, but there is a regional variation due to ridesharing. Most notably, major urban regions around Berlin, Munich, Hamburg and Vienna experience less severe job losses than regions around them. For many other urban centres, this distinction is not visible due to the composition of the respective regions, combining both urban and large rural areas. The variation is more clearly visible in Figure 4.20.

In scenario 4, there are more transport services jobs in most regions in 2050 than in 2020 due to significant transport demand expansion, overcompensating for CAD-induced job losses. Exceptions to this overall trend are regions that see limited demand expansion and therefore job growth combined with rapid introduction of CAD vehicles with the associated rapid job losses.

Figure 4.19 Relative and absolute change of jobs in freight transport services, European regions, scenario 2

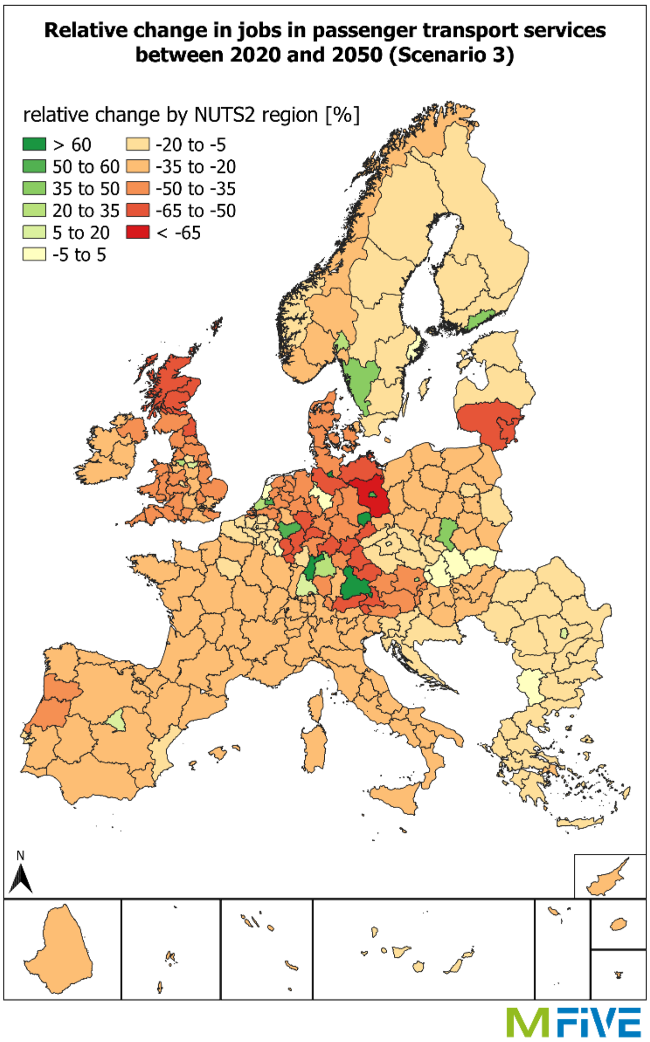


Source: M-Five.

One of the scenarios with the strongest CAD transition in freight transport services is shown in Figure 4.19. As pointed out above, we see the strongest employment reductions in countries that rapidly and extensively adopt automated HDVs and LDVs and that have seen relatively limited expansions in their freight transport demand up until the 2030s. On the other hand, there are countries in which the dynamics are opposed: strong demand expansions and limited adoption of CAD vehicles. Interestingly, we see that, for example, Bulgaria is affected by much more severe job losses by 2050 compared to 2020 than Romania. This is largely due to freight transport employment in Romania expanding much more strongly until the 2030s than in Bulgaria.

For passenger transport services, the map in Figure 4.20 shows an overview with a lot more variation than freight transport developments. Scenario 3, shown here, describes by far the strongest impact of CAD on passenger transport services, mostly because of the rise of ridesharing displacing bus and taxi employment. While the losses in traditional services are relatively equally distributed in urban and rural regions, ridesharing employment is more concentrated in major urban centres. This variation is quite clearly visible in Germany, but not as much in many other countries – probably mostly due to the combination of urban and rural areas in larger regions in most of Europe.

Figure 4.20 Relative change of jobs in passenger transport services, European regions, scenario 3



Source: M-Five.

4.4 Employment in manufacturing sectors and construction

4.4.1 Sectoral employment figures

The sectoral[35] employment results show the impacts stemming from the manufacturing of vehicles and providing necessary CAD-infrastructure.

See Table 4.3 on the short, medium and long-term impacts of CAD on employment for scenario 1 as an example. Annex C includes tables and figures for all scenarios. In addition to absolute employment in persons, the tables show percentage changes against the baseline as well as against the base year 2020. The former enables to identify the impact of CAD in future changes of employment, the latter provides an indication of the level of change compared with today. In general, the change compared with today is more significant than the impact of CAD.

Table 4.3 Sectoral employment of EU27 in relevant sectors, Scenario 1

Scenario 1	Sectoral Employment in Persons				% Change to 2020			% Change to Base		
Sector	2020	2025	2035	2050	2025	2035	2050	2025	2035	2050
Vehicles	4,362,470	-23,786	-103,626	-115,411	-0.55%	-2.38%	-2.65%	-0.02%	0.00%	0.96%
Electronics	1,824,612	6,805	11,464	58,830	0.37%	0.63%	3.22%	0.32%	0.14%	1.78%
Computers	283,394	-5,879	-14,540	-21,221	-2.07%	-5.13%	-7.49%	0.05%	0.28%	1.16%
Communication	2,720,366	-20,225	-57,653	-90,529	-0.74%	-2.12%	-3.33%	0.03%	0.16%	0.28%
Construction	14,162,688	-117,812	-394,131	-664,744	-0.83%	-2.78%	-4.69%	0.07%	0.00%	0.63%

Sectoral employment in 2020 represents absolute employment in persons.
Sectoral employment in 2025, 2035 and 2050 shows the employment change compared to 2020 in persons and in %.
In addition, changes to Baseline in 2025, 2035 and 2050 are displayed in %.

Source: M-Five.

Manufacturing employment is declining in all scenarios over time in all relevant sectors (but Electronics) due to an increase in productivity[36], declining importance of manufacturing industries and a decline in labour force for several European countries. However, CAD-relevant sectors are dampening this trend, as employment increases with CAD becoming more important. The rise in sectoral employment for Electronics reflects the rising importance of the respective sector. CAD even enforces this trend in scenario 1.

Scenarios 1 and 2 are defined by a fast uptake and show considerable employment gains compared to baseline. Scenario 3 (with a focus on shared mobility,) also shows an increase in employment compared to baseline, although not as strongly. Here, the demand for autonomous vehicles is lower as a higher share of population relies on shared mobility services without owning a car. Scenario 4 shows hardly any changes within the study horizon as CAD deployment is assumed later in time.

The following figures present the time profile of sectoral employment from 2020 until 2050 for the major sectors affected by CAD. The impact of CAD scenarios usually becomes more visible after 2035 or even after 2040 only when the diffusion of CAD into road transport accelerates in the scenarios. Some sectors, such as vehicles or electronics sectors, can depend directly on the changes induced by CAD (e.g. increase in investment) and less on general economic performance of a scenario. Other sectors may depend on both direct impacts of CAD and indirect impacts

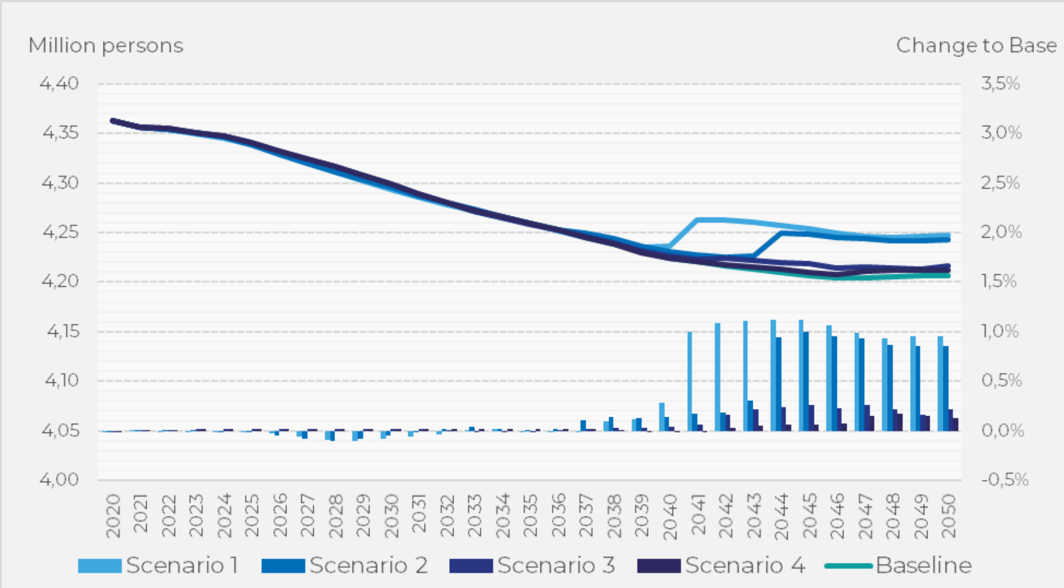
[35] For an overview about the sectors in ASTRA and their corresponding NACE sectors, see Annex C.

[36] Productivity is a measure of the efficiency of production. It is expressed as the ratio of output to input. An increase in productivity implies that the same level of output can be produced with fewer inputs, such as people employed. Several factors drive long-term productivity: investment in physical capital, innovation in the form of new technologies, products or new corporate structures and their diffusion, workforce skills, as well as competition that improves innovativeness and allocation of resources to most efficient firms. Notable future technological trends include ICT technology, automation, artificial intelligence, machine learning, virtualization, network building etc.

transmitted via changes of overall economic performance. The latter holds for the construction sector, which directly benefits from investments in CAD infrastructure but also from improvements of general economic performance such that other sectors or households increase their demand.

In scenario 1 and 2, vehicle production and hence employment in the EU27 vehicle sector is higher than in the other scenarios (see Figure 4.21). In both scenarios, vehicles with higher automation level enter the market at greater number and at an earlier stage, which cause higher purchase expenditures for vehicles. In the early years, sales of electric vehicles increase, which are less employment-generating than combustion engine vehicles. Employment will fall slightly compared to the baseline before 2030. In the following years, the increasing demand for CAD vehicles and CAD components creates a rise in employment.

Figure 4.21 Sectoral employment of EU27 in the vehicle sector (all scenarios)

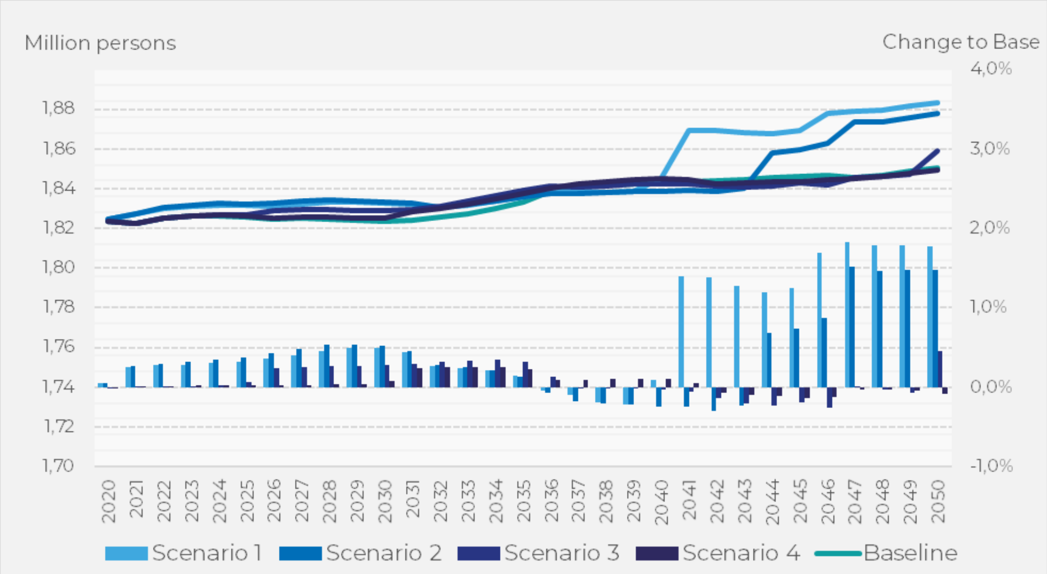


Source: M-Five.

The electronics sector will maintain its importance in the future and shows an increasing employment trend for the baseline as well as for the scenarios. With faster uptake of CAD and a higher demand for autonomous vehicles (scenarios 1 and 2), sectoral employment increases further compared to baseline. The same reasoning of higher purchase expenditures of CAD vehicles explained above also applies to the electronic sector. In addition to CAD-relevant components for on-board equipment the electronics sector also produces components necessary for CAD infrastructure.

Scenarios 3 and 4 show less value added and hence less employment in the electronics sector. The higher demand for busses and mobility services cannot compensate the reduction in demand for cars. In addition, CAD components become cheaper over time and create less value added. This holds especially for CAD-relevant components of the electronics sector such as driver assistance systems.

Figure 4.22 Sectoral employment of EU27 in the electronics sector (all scenarios)



Source: M-Five.

As the computer sector produces CAD relevant components for on-board equipment, it also benefits from a faster uptake of CAD technologies and a large number of vehicles sold, albeit to a lesser extent than the vehicle and electronics sectors. Other affected sectors, such as trade & repair, show similar effects of CAD on sectoral employment as the computer sector. As on-board components of communications (e.g. V2X) have already been fully developed with automation level 3, the communication sector does not benefit from a further CAD uptake in the same extend as the other CAD-relevant sectors. A cellular network is required for the operation of CAD vehicles, but it is not fully included in the calculation of CAD employment effects in the communication sector, as it cannot be exclusively assigned to CAD. The construction sector is involved in the construction of CAD infrastructure and of new production facilities for CAD components. Further, it is a sector that benefits from the general improvement of economic performance in the scenarios resulting in a damped decline in sectoral employment.

The NEMESIS model supports the finding that a strong CAD ramp-up has a positive effect on sectors producing autonomous vehicles and CAD-components as well as CAD-relevant infrastructure. Annex C provides detailed model results for the NEMESIS model as well as a comparison between the two economic models.[37]

4.4.2 Regional distribution of manufacturing

Regional organisation of the manufacturing employment explained above will be far from equal. Relevant industries are concentrated in several regions, while other regions or even entire countries may not see significant manufacturing employment gains at all. In this section, we will briefly describe how a few selected regions are likely to benefit from the development of CAD. This selection is of course not exhaustive, as there are other regions with important suppliers of important components and new regions may join the industry as new companies are set up or as technology companies from other regions or continents invest in them. Further information and sources are outlined in Annex C.

Focus regions of CAD manufacturing are likely to include the regions with innovative vehicle manufacturers (OEMs). Depending on their success in developing and selling advanced

[37] The comparison of sectoral employment not only includes manufacturing sectors and construction but also aggregate results on the transport service sector.

autonomous vehicles, these regions will benefit from increased OEM employment and probably also increased activity of suppliers. As examples, we will briefly look at Île-de-France, Upper Bavaria and Stuttgart region.[38]

CAD-related sectors in Île-de-France (NUTS code FR10) employ around 700,000 people, centred on OEMs PSA and Renault as well as major suppliers such as Valeo (which holds nearly 300 CAD patents). Transdev, a public transport provider headquartered in Paris, is already quite involved in activities in the context of CAD. There are also several engineering service providers employing tens of thousands of people. Upper Bavaria (DE21) and in particular Munich is home to major OEMs (BMW, Audi, Traton), but is also known as the "Isar Valley" (aspiring to resemble Silicon Valley) for its diverse and vibrant technology environment. This includes software companies, AI start-ups and microelectronics producers. Together with suppliers including Continental and Siemens Mobility, total employment in CAD-related sectors is around 500,000. The stage is also set for future testing and development of CAD vehicles with the Highway test site *A9 Digital Motorway Testbed* from Nuremberg via Ingolstadt to Munich. Stuttgart (DE11) region is home to over 700,000 employees in CAD-related companies. Bosch, one of the world's leading suppliers of CAD components, is headquartered in this region, as are the OEMs Daimler and Porsche. In a way similar to Upper Bavaria, CAD research and development is also set to be facilitated by the "Test Area Autonomous Driving Baden-Wuerttemberg".

Suppliers of CAD components are concentrated in several regions across Europe. While Noord-Brabant (NL41), centred around Eindhoven in the Netherlands, has some OEM employment (DAF Trucks), it is more notable for its semiconductor producers. They include NXP Semiconductors with over 30,000 employees as well as smaller companies, such as Dream Chip Technologies. Stockholm (SE11) is the headquarter location of Autoliv, a company offering safety technology for vehicles. There are also several start-ups in the city with a focus on connected and automated driving. Dresden (DED 2) is a major centre of the microelectronics manufacturing, with nearly 300 companies in the industry and around 40,000 employees. They include US semiconductor producer *GlobalFoundries*, employing 16,000 people. The region also has several test sites for CAD.

4.5 Employment impact from economic growth

In order to gain a complete overview of the employment impacts of CAD technologies, it is necessary to consider indirect, i.e. second-round effects. The transition to automated transport accelerates growth through a boost to fleet renewals, higher value vehicles and infrastructure and facility investments. This not only affects the manufacturing and services sectors described above, but also increases aggregate demand in the economy as a whole, which indirectly drives employment.[39]

Higher economic growth may also facilitate the transition to new skill requirements and help ameliorate some of the negative consequences of the introduction of CAD (job losses). As a

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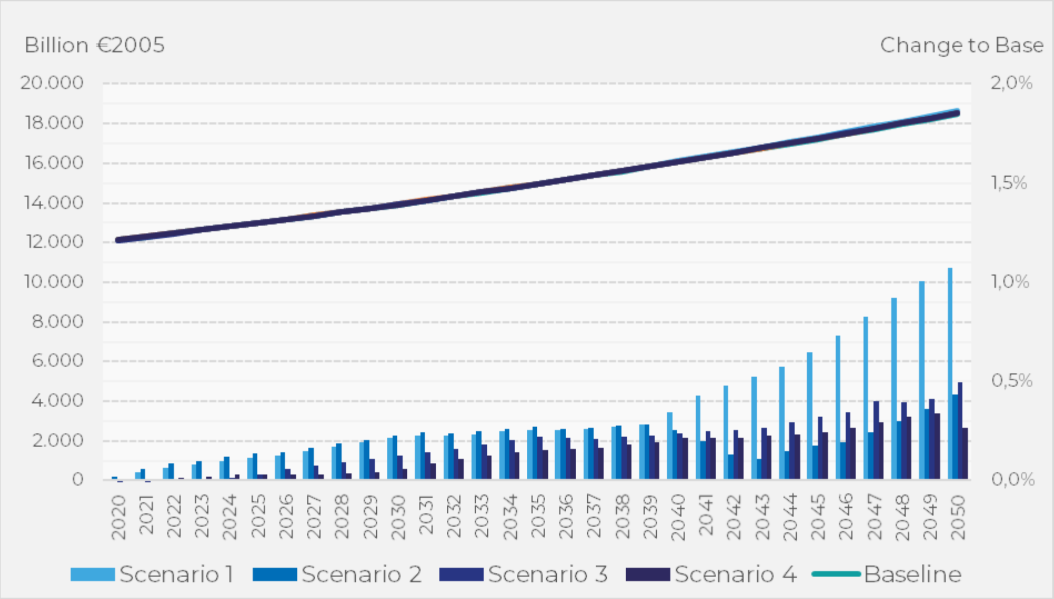
38 The selection of regions is exemplary only and is not meant to be nearly exhaustive. We selected regions with an approach combining top-down and bottom-up considerations: For a top-down screening and overview, we used EU Cluster Reports and other European platforms to identify industrial regions of particular relevance – selecting for overall economic potential in a first step and transport industries in a second step. In a bottom-up, selection and validation approach we selected cluster regions with high concentrations of CAD-related patents and company headquarters. For this final selection step, we used the "CAM Innovation Index" of the Center of Automotive Management, as well as M-Five's RE-MOB data base.

39 The effect is based on increasing incomes of people employed in the sectors that are directly affected, whether through more employees or higher salaries. These higher incomes will be spent on a wide range of products and services in other sectors. In order to meet this increased consumption demand, employment in the indirectly affected sectors is also set to increase.

prospering economy increases potential government revenue creation, governments will be in a better position to respond to the challenges that come with CAD. Increased revenues could be used for investment support, retraining efforts for laid-off driver, or unemployment benefits.

Figure 4.23 shows the development of the overall economic performance presented by the gross domestic product (GDP). The baseline reflects the EU Reference Scenario 2016. Tables with exact figures on the development of GDP for EU aggregates as well as at country level are in Annex C.

Figure 4.23 Development of GDP of EU27



Source: M-Five.

In general, the figure shows a steady increase in GDP for all scenarios that is larger in some scenarios than in others. In reference, the average annual growth rate of GDP for EU27 in the years 2020 to 2050 is 1.25%. The uptake of CAD changes the development of GDP slightly compared to baseline.

In scenario 1, the EU27 average annual growth rate of GDP between 2020 and 2050 is 1.29%. For the other scenarios, the impact of CAD is positive, but less pronounced as in scenario 1. The increase in demand for automated vehicles and necessary investments in production facilities and infrastructure stimulates the economy. Both investment as well as consumption of transport are highest in scenario 1 with a fast CAD uptake and focus on private passenger transport. Scenario 2 and 3 show a similar GDP development, but different driving factors. Scenario 2 demonstrates a higher importance of transport consumption due to a fast and private CAD uptake. In scenario 3, CAD has a positive impact on GDP due to the investments required for sharing services. These drive GDP especially after the 2040s and compensate for the lower numbers of vehicles sold. Scenario 4 shows a similar, albeit time-delayed, profile.

Table 4.4 presents the effects of CAD on total employment in the EU27 for all scenarios.

Table 4.4 Total employment of EU27 (all scenarios)

	Total Employment in thousand jobs				% Change to 2020			% Change to Base		
Scenario	**2020**	**2025**	**2035**	**2050**	**2025**	**2035**	**2050**	**2025**	**2035**	**2050**
Baseline	199,114	-1,913	-5,739	-10,248	-0.96%	-2.88%	-5.15%	0.00%	0.00%	0.00%
Scenario 1	198,986	-1,821	-5,495	-10,769	-0.92%	-2.76%	-5.41%	-0.02%	0.06%	-0.34%
Scenario 2	198,989	-1,768	-5,513	-10,966	-0.89%	-2.77%	-5.51%	0.01%	0.05%	-0.45%
Scenario 3	198,981	-1,801	-5,586	-10,449	-0.90%	-2.81%	-5.25%	-0.01%	0.01%	-0.18%
Scenario 4	198,981	-1,808	-5,646	-10,169	-0.91%	-2.84%	-5.11%	-0.01%	-0.02%	-0.03%

Sectoral employment in 2020 represents absolute employment in thousand jobs.
Sectoral employment in 2025, 2035 and 2050 shows the employment change compared to 2020 in thousand jobs and in %.
In addition, changes to Baseline in 2025, 2035 and 2050 are displayed in %.

Source: M-Five.

Rising GDP and its positive indirect effects on employment can partially compensate for the lost employment in transport services. However, it is not enough to offset the large job losses completely. The roll-out of CAD decreases total employment in all scenarios compared to baseline in 2050.

The two economic models, ASTRA and NEMESIS, agree on the finding that total employment develops negatively due to the introduction of CAD. When CAD arrives early and unrestricted on the market, the negative impact on total employment is more severe as more jobs will be lost in transport services. Detailed modelling results of NEMESIS and a comparison with ASTRA are presented in Annex C.

Both models show similar aggregated effects of employment, but respond differently to the respective economic drivers. ASTRA responds stronger on the productivity effect of investments into CAD. Developments in NEMESIS are driven by transport cost decrease of CAD improving competitiveness and exports.

5 Other social impacts of CAD

5.1 Summarised findings of social impacts of CAD

The introduction of CAD is expected to have far reaching employment impacts in the road transport sector and beyond, as indicated in the previous chapter. These demand-related effects, in turn, are anticipated to have various social impacts. Namely, it is forecasted that CAD will affect skills and competencies requirements for various occupations in the transport sector; it also has the potential to alter the gender balance in the sector, the age distribution of employees (in particular drivers and their future counterpart – mobility operators), and their income levels. Finally, the implementation of CAD is also likely to have some implications for the sector's cross-cutting issues, which include the shortage of drivers currently experienced in Europe and social inclusion in the road transport, both from an employment and a customer perspective.

Table 5.1 provides an overview of the anticipated impacts of CAD, while the following sections offer a more detailed analysis for each of the impacts.

Table 5.1 Main social impacts

Social impact category	Main impacts
5.2 Impacts on changing skill requirements	
Drivers	• For freight vehicles up until SAE-level 4, mobility operators will be needed, either on-board or remote controlled. These operators require a different skillset than conventional drivers, since this involves a shift from manoeuvring vehicles (traditional vehicles) to supervising the automation systems (CAD vehicles). In addition, these mobility operators can take up several non-driving tasks (e.g. customer service); • In contrast to freight transport, no automated passenger transport services at SAE level 4 are foreseen. Therefore, there is no demand for mobility operator skills in passenger transport. Drivers can possibly be reallocated to different, more customer-oriented professions within the sector; • For SAE-level 5 vehicles, no drivers will be required.
Other professions	• For the other professions, there is a general shift towards more IT-related skills, which is also reflected in the growing demand for IT-staff relative to the other (non-driving) professions.
5.3 Impacts on professional and socio-economic characteristics	
Drivers' age distribution	CAD is expected to lead to a decrease in conventional driver employment and an increase in the need for mobility operators. This increase might attract some younger employees as automation will require a new set of skills and is expected to change the nature and pace of the work, which in turn is likely to make it more appealing to a younger demographic.
Gender	The transport sector in general and the driver profession in particular are male dominated. The introduction of CAD has the potential to influence the gender distribution in the sector as the use of automated vehicles makes some jobs more accessible to women as well. On the other hand though, the implementation of CAD increases the need for more IT-related skills, whereas both STEM education and jobs still suffer from a gender gap.
Income	Overall, as CAD is associated with an increase demand for ICT/IT skills and overall higher qualification levels, which are more in demand on the labour market as well as more transferable, it can be stipulated the effect on income will be positive.

5.4 Impacts on cross-cutting issues	
Driver shortages	The introduction of CAD will not substantially alter the high demand for professional drivers in the short- to medium-run and thus it will not resolve the problem of the shortage of drivers for this time period. On the other hand, though, in the long-run CAD can potentially alleviate the problem of shortage of drivers to a (much) higher degree. The extent to which this will be the case depends on the scenario considered.
Social inclusion	• From an employment perspective, the introduction of CAD has potential to increase the accessibility of the mobility operator profession for persons who, due to specific conditions (e.g. reduced mobility), are not able to control conventional vehicles; • From a consumer perspective, the introduction of CAD is expected to benefit persons with reduced mobility by increasing their mobility and travelling independence; • When CAD becomes affordable, sharing a vehicle, and thus paying for the actual use of the vehicle rather than for a privately-owned car is more economical, and could provide easily accessible low-cost mobility for low-income people.
5.5 Social Impacts based on new business models	
Impacts of new business models	• Competition on the market of taxi services will likely get more intense when the robo-taxi operator enters the market. If most taxis are robo-taxis without any staff on board, availability taxi services suitable for special groups may be reduced (e.g. passengers who need assistance with boarding or leaving the vehicle); • Line based public transport can be provided at lower cost with automated shuttles with no staff on board, especially in case of thin passenger flows (e.g. night-time or suburban environment). This increase in productivity can be used by public transport authorities e.g. to increase service coverage or frequency; • Highly automated or fully autonomous trucks will lower the cost of road freight per ton kilometre. On routes where automated driving is feasible, conventional trucking companies may be displaced or forced to adopt automation. The market shares of other transport modes, such as rail may also be affected; • The cost of last mile delivery will be reduced. In the long term, online retailers may have an increased need to partner with an e-commerce platform or automated vehicle operator to be able to provide last-mile delivery at competitive price. Online shopping may become more attractive; • Automated vehicle has potential to become a place for consumption of entertainment, use of online services or a work space, such as a mobile office. A long commute from home to work by car will also be perceived as less inconvenient, and commuters may compensate this by accepting a longer distance between home and workplace. The distance to be travelled by car is no more limited the fatigue of a human driver, and private car becomes even more attractive option for long trips and a stronger competitor of long-distance public transport such as rail and bus services.
New working environment	• A highly automated or fully autonomous vehicle will likely be used as a temporary or secondary office space. This new work environment will be introduced to a large number of professions; • If driving is no more part of the work, the length of the working day is no more limited by the legislation that restricts the maximum number of driving hours in a day or minimum duration of breaks. Variation in the length of work shifts may therefore increase in some professions; • In case of public transport and robo-taxis, automated vehicles are likely to require supervision and sometimes remote operation by a human user. These tasks are likely to be performed by a 'control tower'. The control tower will be a new work environment but its characteristics are difficult to predict as long as its role is not fully defined; • In case of trucks, driving task may be reduced or eliminated, but a human user may be needed on board for other purposes such as to deter crime against the vehicle or cargo

	and to perform security related and administrative tasks related to logistics. The cabin of a truck may become a combination of a mobile office, security control room and a hotel room.

Source: Ecorys, VTT.

5.2 Impacts on changing skill requirements

5.2.1 Drivers

This section presents the implications of CAD technologies on changing skill requirements for drivers up until SAE level 4. The reason for this is that for SAE level 5 vehicles, no drivers will be required.

Passenger transport

Within passenger transport, fully automated buses, taxis and ridesharing will only emerge after SAE level 5 has become available. As such, after the introduction of automated forms of passenger transport, conventional drivers will need to be reskilled and reallocated towards other professions. In the metro sector, there have been experiences with reallocating drivers to in particular steward occupations.

Experiences with reallocating metro drivers in the transition towards autonomous metros

Stakeholders[40] from the passenger transport sector provided some examples on how metro drivers have been reallocated to different functions at control centres or along the line, which could serve as a prospect of how drivers could take up different jobs within the sector:

- In Budapest, metro drivers had been reallocated as station dispatchers;
- In Milan, with the automated driverless metro, stewards are now located along the line with customer service tasks and aid recovery systems in case of incidents;
- In Madrid, the prior model of station management foresaw four different functions which are today covered by one function: the station supervisor.

The experience of operators that manage both Full Automated Operations (FAO) and conventional metro lines shows that automation facilitates improved customer service at equal staffing levels. Customers are more satisfied with fully automated lines, an outcome that cannot be solely attributed to the novelty factor, as satisfaction rates remain consistently high after years of operation. Asides from the perception of a more technological and reliable system, the increased presence of visible and interactive staff contributes to customer satisfaction because of three key aspects:

- Closer to the customer: “unlocked” from their cabins, multi-skilled and versatile roving staff is visible and closer to passengers, thereby contributing to a better travel experience;
- Affordable and attractive customer care: at equal staffing levels, there is a potential to improve customer service: face-to-face customer information and assistance, faster intervention on “small asset failures” (resetting escalator or platform screen doors, cleanliness etc.);
- Security: with equal staffing, the more visible presence of staff in a FAO line is a major element supporting an increased feeling of security (UITP 2019).

Freight transport

The introduction of CAD technologies up until SAE level 4 in freight transport encompasses a switch from conventional to automated transport, affecting the occupation of driver. Drivers of automated vehicles, which will be called “mobility operators”, thus require different skill sets than conventional drivers. A 2016 study by the Michigan Department of Transportation (MDOT) and the

40 Input provided by UITP (05-08-2020).

Centre for Automotive Research (CAR) describes a shift from manoeuvring vehicles to supervising the automation systems and monitoring the environment, as was also confirmed by several stakeholders (MDOT & CAR 2016).

An important issue here is whether the mobility operator will be present in the vehicle, or remotely from a control centre. Stakeholders indicate that they currently anticipate mobility operators to still be present in most instances, in particular on public roads, whereas in certain confined spaces they see the potential of an operator working remotely from a control centre. As such, the following types of mobility operators are distinguished as presented in section 2.1.1:

- Specialised on-vehicle mobility operator;
- Specialised remote mobility operator;
- Vehicle-office fusion mobility operators.

Skill requirements for mobility operators

For this mobility operator, the following future skill changes are anticipated[41,42]:

- Operating all types of AV, except fully self-driving vehicles, will require supervision and selective intervention skills;
- It will also require an understanding of the capabilities and limitations of automated features;
- As driving functions become shared between mobility operators and automated systems, human operators will need to improve their coordination, cooperation and collaboration skills. Most importantly, mobility operators will need to maintain a constant level of awareness of the performance of the AV and the environment, while, at the same time, performing secondary tasks;
- Finally, will need to master the techniques of transition from automated to manual driving, for instance when arriving in terminals and transferring the vehicle from road to ship.

In addition, it is expected by stakeholders that mobility operators that are present in the vehicle will also need to develop non-driving skills, such as:

- Mobility operators that are not driving could take up additional tasks such as administrative work;
- In general, mobility operators will need to obtain more skills on the legal implications of driving an automated vehicle, for instance regarding driver liability in case of an accident caused while driving in 'autopilot' mode.

It is expected that skills required for CAD (up until level 4) will vary at different stages of the journey. Highway driving, often comprising minimal variations, might be more suitable for high degrees of automation (also considering developments such as truck platooning). Driving in cities, navigating through complex streetscapes, on the other hand might require in some cases a higher degree of human presence in the vehicle (Bissell et al. 2018).

Skills depreciation due to automated driving

Paradoxically, CAD might make it more difficult for mobility operators to intervene in case of an emergency, which is due to the following:

- Automated vehicle operators will experience a degradation of their conventional driving skills – both dexterity as cognitive, which may reduce their ability to intervene (Cunningham & Regan 2015);

41 It is expected that there will be a gradual transition from the conventional driver to the mobility operator. Here, we describe the end state of the mobility operator profession, which will disappear once SAE-level 5 is rolled out.

42 The focus in this section is on those skills that are introduced or change as a result of the introduction of CAD. For a comprehensive overview of work tasks and transversal (non-driving) work tasks, see the profile that was developed in the framework of the FutureDRV study. This profile gives an overview of all tasks a future driver will need to perform under SAE level 4 to adequately perform its job (www.project-futuredrv.eu).

- Acting as a supervisor reduces the operator's workload, which may cause the operator to become bored or perform secondary tasks, hence also affecting its awareness. In case of a system failure, the sudden need to intervene might lead to an unexpected and potentially unmanageable increase in workload (MDOT & CAR 2016).

Expected development of the transition from conventional drivers to mobility operators

The timeline and extent of the transition from conventional drivers to mobility operators is dependent on the introduction of CAD technologies. Based on this, policy measures can be designed in such a way that by the time the new technologies are introduced, sufficient drivers have been upskilled to mobility operators.

For freight transport, scenarios 1 and 2 show the strongest transition from conventional drivers towards mobility operators. In these scenarios, an early introduction of CAD technologies is seen around 2035, leading to a rapid decline in demand for conventional driver skills to almost 0 around 2050 whereas demand for mobility operator skills emerges (as discussed in section 2.1.1, no net effect for mobility operators can be provided). In scenario 3, the introduction of CAD technologies is expected around 2040, leading to a likewise rapid decline in demand for conventional driver skills although still substantial at 2050. Last, in scenario 4 it is seen that there is a slow uptake of CAD technologies, leading to only minor decline in demand for conventional driver skills and only minor demand for mobility operator skills.

For passenger transport, automated vehicles start emerging around late 2030s or mid-2040s depending on the scenario. Overall however, there remains a substantial demand for conventional driver skills by 2050. In contrast to freight transport, no automated passenger transport services are foreseen at level 4, which means that for passenger transport we do not assume any demand for mobility operators. However, as discussed there is potential for passenger transport drivers to be reallocated to different steward functions at control centres or along the line.

5.2.2 Other professions

The effect of CAD on the skills and competencies required for specific non-driver occupations is less clear-cut than in the case of drivers, which is also reflected in the relative lack of attention for the effect of CAD on these professions in literature. Nevertheless, overall automation and digitalisation in general and CAD in particular is expected to increase the demand for more highly qualified workers. In particular, there will be a need for more IT skills (Alonso Raposo & Ciuffo, 2019 and WIN, 2017). The sections below provide an overview of whether and how CAD is expected to impact several non-driver occupations in the transport sector.

IT professionals

The introduction of CAD is expected to lead to a new type of an IT profession, i.e. a hybrid one that combines IT related skills and competencies as well as knowledge and understanding of relevant processes (such as traffic control and management) and expertise in modelling (e.g. traffic models) (Pettigrew, Fritschi, & Norman, 2018).

Similarly, CAD is also expected to lead to high demand for engineers with cross-functional skills, who can work on interconnected automotive systems. Such engineers will become more multi-disciplinary and the skills required will include: math, physics, artificial intelligence (AI), machine learning, robotics, data science, and software. [43]

[43] DeNisco Rayme, A. (2019), Self-driving cars will create 30,000 engineering jobs that the US can't fill. TechRepublic. See: https://www.techrepublic.com/article/self-driving-cars-will-create-30000-engineering-jobs-that-the-us-cant-fill/#:~:text=The%20rise%20of%20self%2Ddriving,Detroit%20Mobility%20Lab%20(DML).

Third, as the large volumes of data produced by the vehicles will need analysing, managing, and utilising for future development, the need for knowledge and competencies related to data management and analysis (i.e. data science related skills) will increase as well. [44]

Two new and high-skilled IT-related occupations were identified by the SKILLFUL project (2017) as 'emerging' as a result of CAD:
- System analysts – analysing the interaction between road and vehicle; and
- Electronic technicians and software engineers – developing custom software to respond to the sophistication of vehicles' electronic and digital features.

Management
With regards to skills for management staff, no clear-cut effects on skills are anticipated in literature. However, in line with the predictions for other professions, the importance IT and ICT related skills is expected to increase.

Customer service
The introduction of CAD and likewise technological advancements require customer service clerks to obtain more IT-related skills in order to be able to use communications technology and information systems (e.g. to dispatch autonomous vehicles). As such, it is anticipated that customer service clerks will require basic numeracy skills, software skills and understanding of hardware (e.g. tablets) and peripherals (Cedefop 2020a). At the same time, social and behavioural skills remain the most important skill for customer service clerks.

Some additional effects of the introduction of CAD on the customer service clerk occupation can be differentiated between passenger and freight transport:
- Within passenger transport, in the initial phases (pilot phase, limited roll-out) CAD requires additional staff for extensive customer service and stewards to accompany people while they are starting to get used to automated services, also considering the absence of a driver in the vehicle. This may allow for an integration of the profession into a single-worker operation combining both steward operations, attending, security and customer service. Thus, this may increase demand for a more diverse skillset within customer service clerks;
- Within freight transport, the introduction of CAD has the potential to provide more digitalised forms of service to its customers (thereby reducing demand for human customer service clerks), through e.g.[45]:
  - Route optimisation;
  - GPS tracking;
  - Virtual assistant support;
  - Autonomous delivery.

Stewards, operations, and customer support
For this category, the most notable effect of CAD is expected to entail the integration of several operations support (e.g. steward, and customer service) into one single-worker occupation, especially in the initial phases of the introduction of CAD in passenger transport.

For operations support in freight transport, no clear-cut effects on skills are anticipated in literature as a result of the introduction of CAD.

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44 Stacy, P. (2016), Driverless Cars Will Create New Jobs, Not Destroy Them. Lexis Nexis. See: https://blogs.lexisnexis.com/insurance-insights/2016/09/driverless-cars-will-create-new-jobs-not-destroy/.

45 Hyken (2019), Four Ways Self-Driving Cars Will Improve Customer Service. See: https://www.forbes.com/sites/shephyken/2017/02/25/four-ways-self-driving-cars-will-improve-customer-service/#704a548a2938.

Maintenance

Automated vehicles will not be only driverless but also "connected" and remotely controlled. As safety increases due to CAD, demand for collision repair will decrease whereas more emphasis will be placed on predictive maintenance. This is specifically for ride-sharing cars, robo-taxis and other types of cars that are (in theory) on the road 24/7, and therefore undergo more wear and tear[46]. Additionally, greater emphasis will be placed on software programming and data management[47].

The digital transformation (CAD are part of) in maintenance may lead to the facilitation of work as sensors make maintenance work much more predictable and work requirements more transparent. Examples from public transport companies show that a gain of time and a more efficient way to work may result from the possibility that assets are controlled and even reinitiated remotely. Where the metro operates nearly 24/7, maintenance work must be carried out in a tight time frame. This process might become more flexible with digitalisation.

For maintenance personnel, this transition will thus require a higher level of IT skills (compared to traditional mechanics with traditional vehicle repair skills) (Thierer & Hagemann 2015), such as the ability to diagnose faults in automated systems and fix them accordingly, or to be able to implement, operate and maintain automated systems.

Administration

The most significant effect of CAD on administrative staff is arguably the forecasted higher need for remote-support staff for self-driving vehicles.[48] In other words, there will be a substantial increase in the demand for specialised remote mobility operators, who in freight transport particularly will largely replace traditional drivers. This increase is expected to translate into new skills requirements for administrative personnel (or re-trained drivers) that will enable them to understand and operate complex IT infrastructure and systems. Therefore, digital skills and ICT literacy competencies will play an increasing role in this occupation.

Manufacturing

The introduction of CAD will see manufacturing increasingly transitioning into a tech industry/sector, wherein an emphasis will be placed on high level IT skills that include competencies related to software engineering, AI, machine learning, and cyber-security.[49]

Construction

No major changes are foreseen in the construction sector with regards to the skills and competencies required, with the exception of potentially higher IT/ICT literacy levels.

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[46] Eliot (2019), Rack 'em up: driverless cars surprisingly will be a boom for the auto repair market. See: https://www.forbes.com/sites/lanceeliot/2019/04/29/rack-em-up-driverless-cars-surprisingly-will-be-a-boon-for-auto-repair-market/#4bdae587207b.

[47] Rohra (2019), Rethinking the future of auto repair for self-driving vehicles. See: https://www.automotive-iq.com/autonomous-drive/articles/rethinking-the-future-of-auto-repair-for-self-driving-vehicles.

[48] DeNisco Rayme, A. (2019), Self-driving cars will create 30,000 engineering jobs that the US can't fill. TechRepublic. See: https://www.techrepublic.com/article/self-driving-cars-will-create-30000-engineering-jobs-that-the-us-cant-fill/#:~:text=The%20rise%20of%20self%2Ddriving,Detroit%20Mobility%20Lab%20(DML).

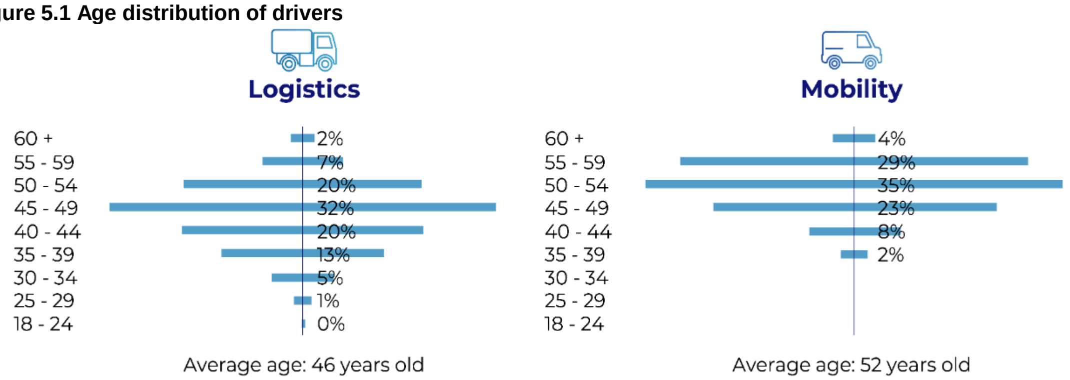
[49] Meril, A. (2020), 4 unexpected ways autonomous cars could change the auto industry. 2025 AD DRIVEN BY DRIVERLESS. See: https://www.2025ad.com/4-unexpected-ways-autonomous-cars-could-change-the-auto-industry.

5.3 Impacts on professional and socio-economic characteristics

5.3.1 *Impacts on drivers' age distribution*

The population of drivers and vehicle operators is aging and over one-third of those employed are 50 years and older. More specifically, according to a survey conducted by IRU in 2019, in logistics companies only 6% of the drivers were below the age of 35, while almost two out of three (61%) is 45 and older and as such expected to retire within the next 20 years. The situation for mobility companies was even more striking; according to the survey results no drivers were below the age of 35, and 91% is expected to retire within the next 20 years.

Figure 5.1 Age distribution of drivers



Source: IRU survey of drivers year: 2019.

In line with this, Cedefop forecasts that out of the 9.7 million drivers and vehicle operators employed in the EU, approx. 5.2 million will leave their existing jobs as a result of either transitioning to a different job (e.g. in the case of logistics many drivers move to another profession at the age of 55 given the demanding nature of the work) or exiting the labour market due to retirement. The substantial number of retirees will result in high replacement needs for this occupation (Cedefop 2020b). These replacement needs to be combined with the net increase in new jobs created vs. jobs lost, which can be observed for all four scenarios up to (at least) 2035, will result in a high total number of job openings in the short- to medium-run and potentially provide room for younger workforce to enter this occupation.

However, given the current rather severe shortage of drivers in many European countries, which is only forecasted to increase further in the short- to medium-run[50], and the relative lack of interest in this occupation among younger employees (i.e. for conventional drivers) as well as low birth rates it is highly likely that many of the job openings will remain unfulfilled (IRU 2019).[51] As a result, in the short- to medium-term the age distribution of employed drivers and mobility operators is not expected to decrease. More specifically, it is expected that in the upcoming years the average age of drivers will increase approximately by one year every two years (IRU 2019).

On the other hand, in the long-term and in particular for the years 2040-2050, all four scenarios predict a substantial decline in conventional driver employment and an increase in the need for mobility operators. Considering that automation will require a new set of skills and is expected to change the nature and pace of the work, this is expected to make the mobility operator profession more appealing to a younger demographic (IRU 2019).

[50] ETF (2020), ETF and IRU urge EU to address unprecedented driver shortage in road transport industry. See: https://www.etf-europe.org/etf-and-iru-urge-eu-to-address-unprecedented-driver-shortage-in-road-transport-industry/.

[51] Kulikowska-Wielgus, A. (2019), Every fifth truck driver position in Europe is vacant. Soon, there could be twice as many. Trans.INFO. See: https://trans.info/en/every-fifth-truck-driver-position-in-europe-is-vacant-soon-there-could-be-twice-as-many-131212.

5.3.2 Impacts on gender distribution

In 2018, only 4.4% of all drivers and vehicle operators in the EU were women. For freight transport specifically, we see an even smaller share of only 3% women in 2018. In passenger transport 13% of drivers were female. The main reasons for this underrepresentation of female drivers are difficult working conditions (e.g. long periods away from home and a physically demanding job as due to loading and unloading), lack of security (including discrimination and having to stay in insecure parking areas in the case of truck drivers), the high cost to obtain a driver's license, complex regulatory requirements and the poor image of the profession (IRU 2019).

Within the different non-driver occupations, large differences are observed within the EU. Whereas in 2018, females consist for 71% of total customer service clerks (Cedefop 2020a) they make up only 16.4% of ICT professionals (Cedefop 2020c) and 4% of all electro engineering workers (e.g. workers in vehicle maintenance) (Cedefop 2020d).

As stated by UITP, "overall, having a diverse workforce is directly linked to innovation and creativity, which translates into better customer experiences, improved service quality and stronger branding. More Public Transport companies are starting to look at diversity and inclusion as a source of competitive advantage. Joint recommendations from UITP and the International Transport workers Federation (ITF) encourage diversity of labour in the transport sector, to improve the functioning and the efficiency of the services for passengers by better representing the diversity of the passengers" (UITP 2020a).

There are several developments that could enhance female participation in the transport sector, as well as barriers for increased female participation:

- First, the anticipated increasing importance of customer orientation / relations (within passenger transport especially in the initial phase) is expected to benefit the attractiveness of the profession for females. There are several examples of transport companies that have benefited from more women in their workforce, i.e. due to their communications skills and interaction with customers (Ecorys, ISI-Fraunhofer, Panteia & PwC, 2018);
- Second, the possibility of operating vehicles remotely (up from SAE level 4 in freight transport) from a control centre takes away some of the barriers for females to take up jobs in the transport sector (i.e. long days on the road, irregular working hours and safety issues);
- On the other hand, the literature does not conclude that CAD makes it more attractive for women to operate such automated vehicles. More specifically, it is shown that women show lower levels of willingness to use automated cars than men (Rice & Winter 2019). Furthermore, women are more likely to associate anxiety with automated cars rather than pleasure, whereas for men automated cars are more likely to be associated with pleasure (Hohenberger *et al* 2016). These studies however solely focus on operators taking place in the vehicle, remote-controlled vehicle operations are not taken into account - it can be expected that willingness differs between sitting in the vehicle and operating the vehicle from remote.

As such, it is shown that the introduction of CAD provides both opportunities as well as barriers to a more gender balanced road transport sector. Stakeholders indicate they see automation as an opportunity to attract a more female workforce[52]. However, as one interview participant mentioned, there are also other (non-CAD) measures required to increase the gender balance in the sector. Improving and sustaining integration at all levels of women in the transport sector requires a package of activities and initiatives, among them recruitment policies, qualification and training

[52] As was discussed during a workshop with IRU (07-07-20).

opportunities, policies to promote work-life balance, health and safety, equality in wages, gender stereotypes, etc. (UITP 2020a).

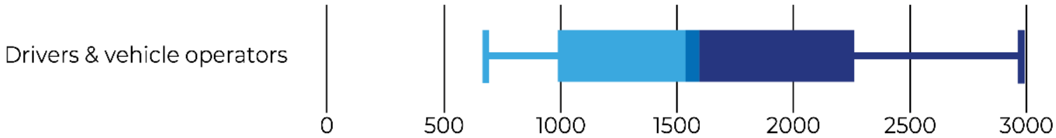
5.3.3 Impacts on income levels

Overall, as CAD is associated with an increase demand for ICT/IT skills and overall higher qualification levels (including higher education), it can be stipulated the effect on income will be positive. That is, the income levels of most or even all affected occupations in the transport sector are expected to increase as these occupations will be characterised by higher skill levels that are also more in demand on the labour market and are also transferable to other sectors.

Anticipated impact of the introduction of CAD on income of drivers and vehicle operators

The median monthly gross income for a driver / vehicle operator in the EU is estimated at €1,567 in a range of between €677 to €2,978, as illustrated in Figure 5.2.

Figure 5.2 Range of gross monthly income in 2017



Source: European Union Statistics on Income and Living (SILC).

In the coming years, the wages of drivers might go up as driver shortages are forcing employers to increase renumeration in order to attract new employees.[53] However, some efforts undertaken so far to improve the income of drivers (in particular freight drivers) had proven unsuccessful and exposed some of the difficulties and barriers face by the transport sector in this regard following primarily from the high degree of cross-border mobility among drivers.

In 2015 Germany has introduced a nationwide minimum wage, which was also meant to be applicable to all individuals working in the country's territory. However, following strong opposition from Polish transport companies and the government (which considered the measure to be "discriminatory and disproportionate" given the much lower wage levels in Poland), foreign truck drivers were exempt from this minimum wage requirement.[54]

Similarly, in 2016 France introduced a minimum wage for the road transport sector to protect its declining road haulage sector against competition from Eastern and Central European countries. However, the European Commission has taken legal action against the application of this measure systematically to all international transport operations, regardless of the time spent by the driver in a Member State, could potentially restrict the free movement of goods and the freedom to provide services (DG MOVE 2019).

The introduction of CAD has the potential to increase the average income of drivers given the (small) substitution effect of conventional drivers with automated drivers. More specifically, the transition from conventional to automated driving results in a higher demand for ICT literacy and more skills related to creativity and resolution and to the gathering and evaluating of information; it also results in a lower demand for more 'elementary' skills. As the former are associated, on average, with higher education and qualification levels than the latter and are overall more in demand in the increasingly digitalised labour market, it is expected that the income of automated

[53] Knowler, G. (2019), Europe truck rates rise even as demand slows. JOC. https://www.joc.com/trucking-logistics/europe-truck-rates-rise-even-demand-slows_20190507.html?destination=node/3606216.

[54] EUBusiness (2015), Germany suspends minimum wage for transit truckers. https://www.eubusiness.com/news-eu/germany-poland-wage.znx.

drivers will go up compared to the current levels of income of conventional drivers (Alonso Raposo, & Ciuffo 2019). Overall, the extent of the increase in the income of mobility operators will vary and largely depend on the tasks and responsibilities required of the operated and consequently the types of qualifications needed. To illustrate, the anticipated salary increases for an operator who is required to only supervise an automated vehicle will be rather small, while the raise for an operator who will also take up a client facing role will be more substantial.

It is important to note though that his potential increase in the income of drivers is subject to some constraints. More specifically, currently the driver profession is rather low in the occupational hierarchy and therefore has a low bargaining power, which would allow negotiating better wages (ETF 2018). What is more, the employers within the driver occupation are often small to medium sized enterprises, which cannot afford raising wages (World Bank & IRU 2017).

5.4 Impacts on cross-cutting issues

5.4.1 Driver shortage in road transport

As mentioned in the previous section, currently the transport sector in Europe is subject to a severe shortage of drivers. More specifically, as of 2019 the supply of drivers in the road freight transport sector met only 79% of the employment demand, resulting in a shortage of 21%. Put differently, slightly over a fifth of all driver jobs in this sector remained unfulfilled. It is worth mentioning that, for certain countries this shortage was much more severe than in Europe on average. To illustrate, according to IRU's driver shortage statistics, in 2019 the unsatisfied driver demand for logistics companies in Romania amounted to 50%, while the unsatisfied demand for mobility companies in Germany equalled 41%. The supply of bus and coach drivers met 81% of the demand, resulting in a shortage of 19% (IRU 2019)

Driver shortage is only expected to intensify in the upcoming years, primarily as a result of high rates of retirement, combined with difficulties to find replacement employees for the retirees, and an expected continued strong demand for freight transport (in the short- to medium-term).The difficulties in finding new employees who can replace those that retire are driven by (i) the profession's low reputation, which makes it challenging to attract young and female employees; (ii) financial and legal barriers to accessing the driver profession; and (iii) low birth rates, which negatively impact the generational replacement rates. The lack of interest in the profession among younger generations is evident by the fact that according to the IRU survey of drivers, logistics companies had on average 4% of driver apprentices while mobility companies had 3%.

The shortage of drivers is also unlikely to be resolved by hiring foreign nationals given the challenges associated with doing so, which include legal barriers of hiring non-EU nationals, languages difficulties, and the high costs associated with obtaining a driver's license.

Overall, while the introduction of CAD is expected to lead to significant job losses, in particular for conventional drivers in freight transport (see Figure 4.11), it is argued that automation *per se* will not substantially alter the high demand for professional drivers in the short- to medium-run and thus it will not resolve the problem of the shortage of drivers. According to IRU, this problem needs to be tackled instead by (i) improving the image and reputation of the profession; (ii) improving the working conditions of drivers; and (iii) attracting a more diverse workforce, which includes women and youth. It is important to note, though, that CAD can provide some new opportunities that can facilitate the achievement of the three aforementioned objectives. That is, greater reliance on technologies can make the driver profession more innovative and dynamic, which in turn can make it more attractive and appealing to a wider, more diverse group of individuals (IRU 2019; Alonso

Raposo, & Ciuffo 2019). Moreover, automation will change the skillset required to perform the job and require higher qualification levels (in particular with regards to ICT skills). As the future mobility operators are likely to have higher qualification levels and more transferable skills than current conventional drivers, they are also likely to have a better position on the labour market and therefore benefit from improved working conditions.

The increase in the profession's attractiveness or popularity is expected to be more pronounced in the case of remote mobility operators and less so in the case of on-vehicle operators. This expectation is related to the fact that the latter occupation type will still suffer from some of the challenges that are associated with the conventional driver profession and which make it unappealing. These challenges include, but are not limited to, spending long periods of time on the road and away from home as well as having to spend the night in unsecured locations.

On the other hand, in the long-run CAD can potentially alleviate the problem of shortage of drivers to a (much) higher degree. The extent to which this will be the case depends on the scenario considered. That is, if a maximum or intermediate uptake of CAD is assumed (Scenario 1 or 2 respectively), the demand for conventional drivers in freight transport is expected to decrease to almost zero. While some increase in the demand for mobility operators is also forecasted for these scenarios, the magnitude of this increase is relatively low. Thus, the drop in demand for conventional drivers will not be compensated with the rise in demand for mobility operators (as illustrated in Figure 4.11). This in turn implies that by the year 2050 the issue of the shortage of drivers issue will no longer persist.

A different picture emerges when considering Scenarios 3 and 4, which respectively assume a moderate and low uptake of CAD. That is, under Scenario 3 conventional truck drivers will still be needed by the year 2050, albeit not to the extent they are now. More specifically, for this scenario the demand for truck drivers will persist in "follower" countries, while in "forerunner" countries the situation is more likely to resemble the one described for Scenarios 1 and 2. Therefore, the extent to which the implementation of CAD will be able to resolve driver shortage in "follower" countries will depend on whether the supply of conventional drivers will be able to meet the new (lower) levels of demand in these countries. However, current projections suggest that the shortage in the supply of drivers will only become more severe in the upcoming years (considering the ageing driver population and the fact that the retired drivers are unlikely to be fully replaced by younger individuals) (IRU 2019). Thus, it is likely that the supply of drivers in the "follower" countries will still be unable to meet the lower projected demand for drivers by 2050.

Finally, as Scenario 4 assumes a slower rate of CAD uptake (compared to Scenario 3), while also distinguishing between "forerunner" and "follower" countries, it is fair to assume that the shortage issue will also persist (and will likely to be greater in magnitude) in particular for the latter group of countries.

5.4.2 Social inclusion in and through road transport

The literature does not provide insights into the extent to which CAD will increase the possibilities for persons with reduced mobility to take-up jobs as mobility operators. However, the shift in tasks from a driver manoeuvring vehicles to a mobility operator supervising automation systems has the potential to increase the accessibility of the job for persons who, due to specific conditions, are not able to control conventional vehicles. This was also indicated by two interview respondents from public transport operators, who indicated that there is potential for the inclusion in the labour force of persons with disabilities.

From a consumer perspective, there is more information on the ability CAD has to contribute to a more inclusive society. First, several studies (Johnson *et al*. 2017) highlight the possibilities CAD has to benefit persons with reduced mobility (e.g. disabled people, older people, non-drivers). In current situations these groups are dependent on others (family, friends, government, other providers etc.), but with the introduction of CAD (i.e. in case of fully autonomous vehicles, SAE level 5) they should be able to increase their mobility and travelling independence – which in turn could also enhance their possibilities of taking up employment further away from home.

Second, the possibility of sharing automated vehicles might also contribute to a more inclusive society. Sharing a vehicle, and thus paying for the actual use of the vehicle rather than for a privately-owned car is more economical, and could provide "easily accessible low-cost mobility for low-income people" (Johnson et al. 2017). Of course, this is conditional on whether CAD vehicles will become an affordable alternative to conventional vehicles (and thus will represent a significant share of total vehicles). The sharing or collaborative economy was estimated to account for EUR 26.5 billion in revenues in 2016 in the EU and has grown over the past year (Technopolis, VVA & Trinomics 2018). This trend is expected to continue, therefore it is likely to also affect CAD, however simultaneously cars will continue to remain status symbols and those who can afford them will buy them.

On the other hand, stakeholders indicate human interaction as well as assistance is an important aspect of social inclusion. Considering that a substantial share of e.g. taxi services consist of public services (e.g. bringing elderly to the hospital), it is anticipated that demand for services with a human element will remain despite the introduction of CAD. For instance, if a passenger uses a wheelchair, this passenger needs to be assisted in boarding the vehicle and the wheelchair must be secured to the vehicle during transport. It was also confirmed in an interview with a taxi operator, stating that it is key to maintain services provided to persons with reduced mobility when CAD has become mainstream.

5.5 Social impacts based on new business models

5.5.1 Description of new or different business models

The focus of this section is on business models, which have the potential to affect the market of transport and markets of other goods and services and therefore have an impact on industry and society. The work started by identifying main business cases enabled by CAD. These business cases were then described as value networks. This allowed us to identify the key stakeholders in the business case. When identifying the key stakeholders, the first task was to identify the focal company that is likely to have market power and to exercise control over other stakeholders in the supply chain described as value network. In addition, the stakeholder that owns an automated vehicle in each of the business cases was identified as a key stakeholder. The business model of the focal company or other key stakeholder was then described using the service business model canvas.

Five main business cases were identified for connected and automated driving (Table 5.2). Full descriptions of business cases B1–B5, as well as the business models of key stakeholders and their impacts on markets of products and services are available in Annex H[55].

[55] Annex H also provides an overview of sources used for the analysis.

Table 5.2 Main business cases related to CAD

Business cases		Business case characteristics		
Number	**Name of business case**	**Vehicle owner**	**Focal company**	**Comments**
B1	Highly automated vehicle as a robo-taxi	Robo-taxi operator, affiliated with automated vehicle manufacturer	Automated vehicle manufacturer	Trials going on
B2	Automated shuttle providing a local public transport service	Automated shuttle operator	Automated shuttle operator, public transport authority	Trials going on
B3	Long-haul goods transport with a highly automated vehicle	Automated truck operator, affiliated with automated truck manufacturer	Automated truck manufacturer, integrated logistics company	Under development, most likely to appear first between logistics hubs such as harbours and cargo terminals
B4	Local goods delivery with an automated vehicle	Automated vehicle operator, affiliated with automated vehicle manufacturer	E-commerce platform or consignor	Starting trials, e.g. groceries or pizza delivery in local community by a robot or a light highly automated vehicle
B5	Privately owned highly automated vehicle	Private car user	Automated vehicle manufacturer	Under development but not on the market yet, corresponds to the current paradigm and culture of vehicle ownership

Source: VTT.

B1: Highly automated vehicle as a robo-taxi

In business case B1, a highly automated vehicle is operated as a robo-taxi. At least in the beginning, the operator of the robo-taxi is likely to be integrated with the automated vehicle manufacturer. When integrated (e.g. in the same company or group of companies) they will form a focal company having substantial control over suppliers (tier1 and tier2 suppliers of the automated vehicle manufacturer) and at least some market power towards customers. In the long term, the relationship between automated vehicle manufacturer and the robo-taxi operator will probably evolve towards relational value chain (in which “buyers and suppliers engage in complex interactions” creating “mutual dependence and asset specificity”) or a relation of a buyer and a turn-key supplier. When new technology becomes more mature, the buyer and supplier will be better able to express their request as written contracts (to “codify their requests”), transactions will become less complex and supplier capabilities are likely to increase. These three factors are likely to facilitate development of supply chains from hierarchical and captive supply chains towards relational and modular supply chains. The robo-taxi operator will be a new entrant on the existing market of taxi services, and it will face competition with other taxi operators. In addition to the participating in the market of taxi services, the robo-taxi operator has also other opportunities for realising revenue. These include, for example, partnering with an airline or rail transport operator to provide door-to-door journeys and establishing collaboration with a Mobility as a Service (MaaS) platform.

B2: Automated shuttle providing a local public transport service

In business case B2, an automated vehicle is used to provide a local public transport service. It is assumed that this corresponds to operation of an urban or suburban bus line with an automated vehicle[56]. The relationship between the automated shuttle manufacturer and the automated shuttle operator is likely to be similar to the relationship between automated vehicle manufacturer and the robo-taxi operator described in business case B1. The automated shuttle operator will be a new entrant in the market of urban public transport services and face competition with conventional bus companies. Alternatively, an existing bus operator may establish collaboration with an automated shuttle manufacturer to provide line-based public transport with automated shuttles. In many cities, the market of bus services has only one major buyer – the local public transport authority which manages the ticketing system of public transport used in the region or city and sells tickets to travellers. It therefore has the characteristics of a focal company even though it is a non-profit stakeholder. Transport authorities responsible for public transport need to comply with legislation on public procurement. In most cases, the selection of a bus operator is to large extent based on the offered price.

B3: Long-haul goods transport with a highly automated vehicle

In business case B3, automated vehicles are used to transport goods over a long distance. The business case includes two companies with the characteristics of a focal company. First, integrated logistics companies typically own the relationship with the end customer (consignor or cargo owner). Second, they also have large networks of subcontractors such as trucking companies which provide services on the individual legs of the transport route from door to door. On the other hand, the automated truck manufacturer integrated with the automated truck operator may also exhibit the characteristics of a focal company. This applies to situations in which the technology of automated trucks is still evolving fast, only few suppliers of new technology are available, few or no written specifications are available to describe the product, and automated trucks have not 'become a commodity'. The automated truck operator will be a new entrant on the market of long-haul goods transport services. It will therefore face competition with conventional truck operators. Alternatively, a conventional truck operator may establish collaboration with an automated truck manufacturer to provide transport services with automated trucks. Automated trucks will also compete with rail transport on routes where a rail connection and suitable rail terminals are available and with inland waterways and short sea shipping on routes where both road and maritime transport connections are available. According to a recent estimate, the costs of road freight per ton kilometre may be reduced by 29–45% due to automated vehicles. In an analysis carried in the US, fully autonomous trucks have been estimated to reduce the demand for rail freight by 19–45%.

B4: Local goods delivery with an automated vehicle

In business case B4, automated vehicles are used to provide local goods delivery services (e.g. groceries, pizza or medicine). At least in the beginning, the automated vehicle manufacturer will be closely integrated with the automated vehicle operator. When acting together, they will have certain characteristics of a focal company in the supply chain. On the other hand, the customers of the automated vehicle operator are likely to be able to substitute the service of the automated vehicle operator (e.g. by using a conventional delivery company or organising delivery with their own vehicles). The customers of the automated vehicle operator may also have substantial market power themselves (e.g. major e-commerce platforms or supermarket and restaurant chains with large market shares) and will have a direct relationship with the end customer. In case of groceries, it was assumed that the goods supplier (a supermarket chain or other major retailer) would be a key stakeholder and a focal company in the business model.

[56] In the main results, shuttles are considered as a sub-group of ridesharing.

Privately owned highly automated vehicle

In business case B5, highly automated vehicles will be privately owned or provided as a service by the vehicle manufacturer. The business case corresponds to the current paradigm of vehicle ownership which includes both cars owned or leased by consumers and other car users. As in the current situation, vehicle manufacturers maintain or establish their dealer networks which not only sell or lease new vehicles to consumers but provide vehicle maintenance services and spare parts. The vehicle manufacturer retains its position as a focal company in the value network. It is currently not certain how the costs of accidents caused by highly automated vehicles will be covered. Possible outcomes include continuation of the current model in which the vehicle is owned and insured by the user or a business model in which the vehicle manufacturer provides the vehicle as a service and takes also responsibility for accidents (e.g. by self-insuring). In the latter case, the vehicle manufacturer would likely be responsible also for vehicle repairs and maintenance in a way comparable to vehicle leasing contracts already offered today by financing companies affiliated with vehicle manufacturers. The vehicle manufacturer would likely use its own dealership networks to organise tasks related to vehicle maintenance and repair or outsource these tasks to independent vehicle repair shops with sufficient capabilities. Only spare parts and materials provided by the vehicle manufacturer would be used in vehicle maintenance. Over the long term, revenues of aftermarket spare part manufacturers and independent car parts wholesalers and retailers may be reduced. The need for motor insurance with third party liability coverage may also decrease if the driver is not controlling the vehicle most of the time or not at all.

5.5.2 Potential social impacts of these business models

After the value networks of the business cases and the business models of key stakeholders had been described, it was possible to identify the impacts of the business models on markets of products and services. A description of the method is provided in Annex I.

B1: Highly automated vehicle as a robo-taxi

It was assumed that a robo-taxi can operate without a human driver on board, and this can be expected to reduce the cost of a taxi ride more than automation increases the capital costs of providing the service. When a new participant with a lighter cost structure enters the market of taxi services, competition on the market of taxi service can be expected to get more intense. On the other hand, a taxi ride is a complementary product to many long-distance public transport trips (e.g. air, rail or long-distance bus), as the taxi ride may be the only transport option for the last mile, or it may be preferred by the traveller. Reduction in the cost of the last mile part of the journey may make transport options based on public transport more attractive. Potential beneficiaries include rail operators, airlines and long-distance bus companies. Third, taxi service provided by robo-taxi may act as a substitute of a trip by local public transport (e.g. bus or train). Ridership of local public transport services may be affected especially when ticket prices are high, public transport connections are infrequent or inconvenient or when more than one person travels together. Establishing a robo-taxi service requires (i) access to new technology and (ii) sufficient number of vehicles to allow monitoring and operation of vehicles to be carried out in an efficient manner by a control centre. From economic efficiency point of view, the optimal size of a robo-taxi operator may be larger than the optimal size of a conventional taxi company. With increasing company size, the market power of the taxi operator may increase. In case of robo-taxis operating without any staff on board, there will be no personnel who would be capable of assisting a passenger to board or leave the vehicle or to assist a passenger with special needs (e.g. the earlier mentioned example of passenger that use a wheelchair which must be secured to the vehicle during transport). Similar requirements may also be related to transport of persons belonging to vulnerable groups (e.g. unaccompanied minors who need to be escorted to their destination). If robo-taxis without any staff onboard cover most of the supply and demand of taxi services, large share of taxis available will be unsuitable for these groups of travellers. Unless action is taken by the robo-taxi operator or the regulator of taxi services, availability of taxi services suitable for special groups may be reduced. However, as explained in Section 5.4.2 on social inclusion, the demand for human assistance in taxi services is likely to remain, considering that a substantial work for taxi services comes from public services. Safe operation of highly automated and fully autonomous vehicles (SAE4 and SAE5) is likely to require changes to physical infrastructure (e.g. safe harbours where an automated vehicle can be safely stopped by automation) and roadside systems (mobile network connectivity, C-ITS, positioning etc.). More demand will be created for construction, equipment installation and ICT services. This applies to all five business cases for CAD.

B2: Automated shuttle providing a public transport service

In future, line-based public transport can be operated at lower cost with automated shuttles with no human driver onboard. This applies especially to situations with thin passenger flows such as low-density environments and off-peak times (e.g. night-time). The increase in efficiency may be used by public transport authorities to improve service coverage, increase frequency or to reduce ticket price paid by the traveller. When the vehicle has no driver or other staff on board, ticket control and controlling access to the vehicle can no longer be based on methods requiring manual work, and appropriate electronic ticketing and access control systems will be needed. Moreover, not every vehicle will have staff available for tasks related to security of passengers and prevention of vandalism. Monitoring the security of passengers and detection of possible incidents of vandalism will probably be carried out by the control centre ("control tower") monitoring a fleet of automated shuttles, and mobile security patrols may be needed in the area where automated shuttles are operating (private security company or police). In case of a breakdown of the vehicle or any failure of the automation system, the vehicle will have no driver or other staff who could inform and assist the passengers or to warn other road users. Breakdowns of automated shuttles and failures of the automation system need to be managed in a way which ensures the safety of passengers and other road users. This is likely to require a control centre with an advanced software platform as well as a mobile technical support team which may be provided by the vehicle operator itself or an external service provider (in a way similar to contractors maintaining elevators or vehicle towing companies). In geographical areas and periods of low demand, automated shuttles can potentially serve as feeders to rail stations or other public transport lines (e.g. tram). The accessibility of rail stations or other public transport terminals is likely to improve. For operators of tram, heavy rail or trunk bus lines, this involves an opportunity to increase their revenue and number of passengers.

B3: Long-haul goods transport with a highly automated vehicle

A highly automated truck is capable of transporting goods without a human driver on board. This means also that there is no human user on board managing the shipping documents or capable of presenting them for inspection when necessary, and the company operating an autonomous truck, or its customer, must have an information system which is capable of handling electronic freight documentation (e.g. electronic waybills). Digitalisation can therefore be expected to accelerate in road freight sector. This creates new business opportunities for software and ICT services companies.

When highly automated or fully autonomous trucks are introduced, the cost of road freight per ton kilometre will likely be reduced. Highly automated or fully autonomous trucks will therefore have a cost advantage over manually controlled trucks on routes where automated driving is feasible. In the long term, some companies operating manual trucks may be forced to adopt automation or be displaced by companies with highly automated or autonomous trucks. In addition, highly automated and fully autonomous trucks will compete with rail and waterborne transport on routes where rail connections or waterways are available. According to an analysis carried out in the US, introduction of highly automated or fully autonomous trucks may reduce the market share or rail transport. In case of a conventional truck, the presence of a human driver is likely to deter crime against the vehicle and its cargo (e.g. theft of cargo), and a human driver is capable of detecting, reporting and sometimes preventing security incidents. In case of highly automated or fully autonomous trucks, other solutions will be needed. These may include electronic alarm systems, other systems protecting the vehicle or mobile security patrols responding to detected incidents. This will potentially create a new market for ICT system developers and private security companies.

B4: Local goods delivery with an automated vehicle

Local goods delivery with a highly automated vehicle does not require a human driver onboard. In other words, the time based variable cost of delivery services based on automated vehicles is lower than the corresponding cost of delivery services provided by a vehicle and a human driver. Local goods delivery implemented with an automated vehicle may have a positive gross margin at lower prices than delivery service provided with a conventional vehicle and a human driver. The cost of providing local delivery service for goods ordered online or offline (e.g. groceries, medicine or pizza) can be expected to be reduced. This also means that competition may become more intense in local and last mile delivery services.

An online retailer with capability to use automated vehicles for delivery will probably have lower shipping costs than other online retailers and will therefore have a competitive advantage. When the cost of local delivery is reduced, online shopping will also become more attractive when compared to shopping trips to retail shops (e.g. supermarkets or shops in shopping malls). The potential impact on supermarkets, other retailers and shopping malls is hard to predict.

The owner of the goods (e.g. an online shop) needs to establish collaboration with an automated vehicle operator or an e-commerce platform to benefit from the lower delivery cost enabled by automated vehicles. At least in the beginning, these options are likely to be available to large or mid-sized online or physical retailers. In the long term, online retailers may have an increased need to partner with an e-commerce platform or automated vehicle operator to be able to provide last-mile delivery at competitive price.

B5: Privately owned highly automated vehicle

In a highly automated or fully autonomous vehicle, vehicle occupants do not need to focus on the driving task most of the time (SAE4) or at all (SAE5). The time used for driving in the past will be available for secondary activities e.g. work or entertainment. This means that the automated vehicle has potential to become a place for consumption of entertainment, use of online services or a work space such as a mobile office. A long commute from home to work by car will likely also be perceived as less inconvenient. In practice, commuters may compensate this by accepting a longer distance between home and workplace. An increase in road capacity will be needed, and property prices may be affected. In case of an automated car, the distance to be travelled by car during one day will also not be limited by the fatigue of a human driver like in case of a non-automated vehicle. Relative attractiveness of traveling by car may increase for trips that can be travelled by car in a time accepted by the traveller but are perceived to be exhausting to drive. Therefore, private car becomes an even stronger competitor of long-distance public transport such as rail and bus services, and the market of long-distance public transport services may be affected. In addition, an automated vehicle can potentially be used in a more flexible way than a manually controlled vehicle. For example, a highly automated or fully autonomous car used for commuting to work may be used for other purposes by somebody else in the same household during the working day. This applies to situations in which the car is capable of moving on the road network without a driver (SAE5 vehicle or SAE4 vehicle with remote operation). The need to have more than one car in the same household may be reduced. Fully autonomous (SAE5) and highly automated vehicles (SAE4), that are remotely operated, will be available as a transport mode also for groups which are now 'captive users' of public transport. Revenue of public transport and taxi services may be reduced, especially in situations in which highly automated or fully autonomous privately owned vehicles compete against infrequent conventional bus services and conventional taxis.

When the vehicle is only occasionally or never controlled by a human driver, it will be more and more difficult to attribute liability for any accidents to the negligence of the human driver. Over the long term, the need for motor insurance paid by the owner of the vehicle may decrease (the liability part). However, the vehicle manufacturer remains exposed to product liability. Possible outcomes include e.g. insurance taken by the vehicle owner (the current model), personal injury and accident liability coverage provided by the vehicle manufacturer (e.g. by self-insuring) or a no-fault regime for compensating the cost of traffic accidents.

A fully autonomous vehicle (SAE5) does not need a human driver for transporting goods from one point to another, even though loading and unloading by a human person may be needed. This means that goods ordered online can be picked up from seller’s shop or warehouse without the buyer being present (e.g. groceries or medicine), and the buyer does not need to use his or her time for the trip. The number of trips to supermarkets and shopping malls may decrease, and this applies especially to consumers with limited time budget. In the long term, a new retail concept may evolve.

5.5.3 New work environments and work patterns

First, highly automated and fully autonomous vehicles can be operated without an intervention by human user most of the time (SAE4) or at all (SAE5). This allows the human user to be involved in other activities, such as office work. On the other hand, travelling from one place to another is likely to remain as a regular activity in many businesses. It therefore seems possible that a highly automated or fully autonomous vehicle will be used as a temporary or secondary office space which will be introduced to a large number of professions. Automated driving is also likely to affect professions in which most of the work is carried out at customer’s premises, and a usual working day involves visiting multiple locations (e.g. delivery and installation of large household appliances, equipment maintenance contractors etc.). If autonomous vehicles (SAE5) are introduced, driving will not be a part of the work anymore, and length of the working day is no more limited by the legislation that restricts the maximum number of driving hours in a day or minimum duration of breaks. Variation in the length of work shifts may therefore increase.

In case of public transport and robo-taxis, automated vehicles are likely to require supervision when operating on roads and in urban environment. It seems likely that the supervision and possible remote operation of a number of automated vehicles will be carried out by a ‘control tower’. While the tasks of the control tower can be foreseen to certain extent, the role of the control tower is still an active research topic. The control tower will be new work environment but its characteristics as a workplace are difficult to predict as long as its role is not fully defined.

In long-haul freight transport, there will be much less (SAE4) or no (SAE5) need for driving after highly automated or fully autonomous vehicles have been introduced. However, a human person on board the vehicle may be required for certain purposes such as to deter theft of valuable cargo, to respond to security incidents and to guard the vehicle when it needs to be stopped in an unprotected place (e.g. outside the gates of a harbour or cargo terminal). It is possible that management of vehicle and cargo documents and administrative work related to logistics may be carried out by the person on board the vehicle in addition to security related tasks. In summary, the tasks carried out by the driver would become much more diverse in this scenario, and the cabin of a truck would become an office, a security control room and a hotel room.

PART 3:

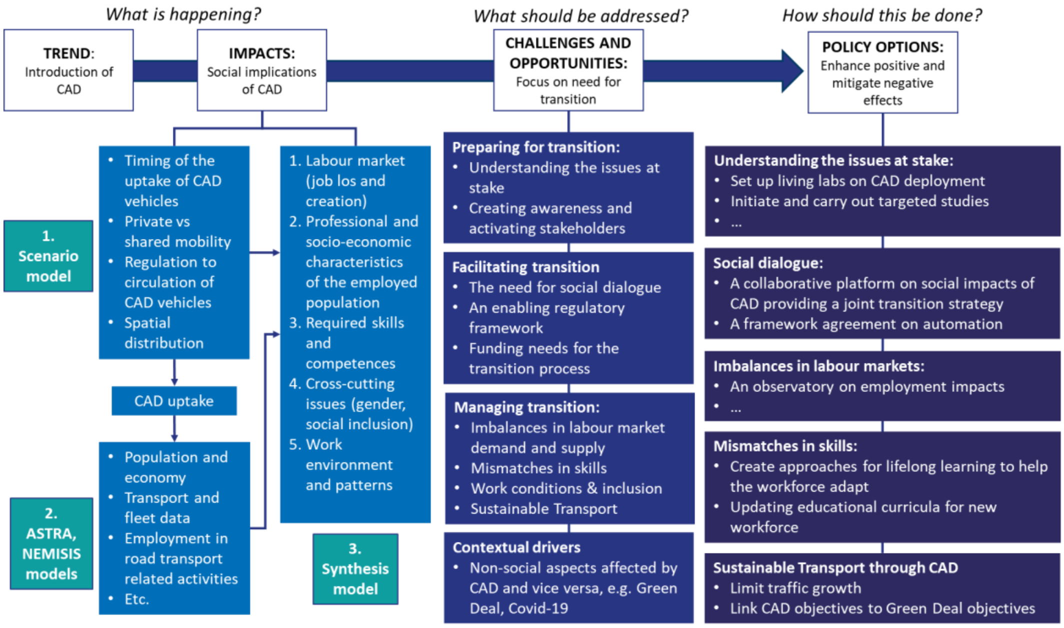
Policy options towards a social roadmap for Connected and Automated Driving

6 Policy Options for CAD deployment

The deployment of CAD technology on our roads is expected to create many social challenges and opportunities. Therefore, it is important to properly understand these challenges and opportunities and define policy options for timely action to safeguard and enhance the positive effects and avoid or mitigate the negative effects of CAD on employment and other social impacts.

The development of the policy options is based on the assessment of impacts and the challenges and opportunities caused by these impacts. The sequence, starting with the introduction of CAD, based on different scenarios (Chapter 3), followed by the impacts (Chapter 4 and 5), leading to challenges and opportunities, providing the basis for defining policy options, is presented in Figure 6.1.

Figure 6.1 Sequence leading to policy options



Source: Ecorys.

In the following sections, we describe the challenges and opportunities (Section 6.1) and the policy options (Section 6.2). These policy options will then be operationalised by placing options in a timeframe and allocating tasks and responsibilities to stakeholders in Chapter 7.

6.1 Challenges and opportunities

CAD related challenges and opportunities in the road transport sector are looked at from two angles:

1. Challenges and opportunities in the social domain resulting directly from the introduction of CAD (Section 6.1.1);
2. Contextual drivers such as challenges and opportunities for the transport sector not directly linked to CAD, but which may affect the introduction of CAD or vice versa (Section 6.1.2).

6.1.1 *Challenges and opportunities as a result of introduction of CAD: focus on transition*

Road transport is a crucial sector for the European economy, not only because of the connectivity it provides for people and goods, but also because of the employment it creates across the EU. In 2020 about 4.5 million people are employed in road freight transport and 2.1 million in its passenger equivalent across the EU[57]. As captured in chapter 4 (Figure 4.1), the introduction of CAD has a profound impact on the demand for jobs in the road transport sector, especially in freight transport. At the same time, a shift in demand for jobs can be seen, providing opportunities for other road transport related job categories. Moreover, as a result of CAD deployment, jobs will be created in the construction industry and additional jobs are generated in the manufacturing industry, notably in electronics, computer and IT sectors developing and producing the CAD technology. Besides these labour market changes, Chapter 5 indicates additional social changes, for example in skills required, gender balance, age distribution and income levels. All these changes contribute to a changing employment and social landscape in road transport and related industries. This landscape changes over time, with the speed of change varying per scenario.

The road transport sector is to face the challenges and opportunities to adapt to this changing landscape and the key word in this process is transition. Transition needs to be prepared, facilitated and managed, as illustrated in Figure 6.1. As the transition in road transport services does not happen today, but will unfold in the coming decades, the coming period should be utilised to prepare for the impacts of the CAD transition. Relevant challenges and opportunities are described below, grouped under the above-mentioned transition domains. These three transition domains are partially overlapping[58], however they provide a framework to conceptualise the necessary steps and group policy measures.

The Commission so far has played an active role (and will continue to do so) in preparing, facilitating and managing the transition process by developing policies such as the Mobility Packages, strategies, roadmaps and communications; creating a platform for interaction between stakeholders; preparing and adjusting relevant legislation; developing standards; and funding relevant research and innovation projects[59].

Preparing for transition

In preparing for transition, emphasis is placed on better understanding the impacts, their interrelationships and related challenges and opportunities, as well as creating awareness with stakeholders involved in the transition process. These aspects can be considered as pre-conditions for transition. In fact the transition can also lead to many positive aspects such as growth, innovation, new technologies and business models thus competitiveness, and more efficient road transport supporting climate mitigation. However, without properly understanding the issues and without sufficient awareness and willingness to act of stakeholders involved, these positive aspects of the transition could be hampered.

Understanding the issues at stake

The deployment of CAD has been studied intensively and results have been reviewed in our study[60]. Already relevant mechanisms for exchange on important issues, for example the Cooperative, Connected and Automated Mobility (CCAM) platform[61], have been put in place in

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57 According to our modelling results, as presented in Table 4.1.

58 For example, adjusting legislation could also be seen as preparing for transition.

59 This project is an example of how the Commission is funding a project aimed at better understanding employment implications of the introduction of CAD.

60 See Annex D (Literature review).

61 The CCAM Single Platform was set up as a joint initiative by DG MOVE, DG GROW, DG CNECT and DG RTD. It consists of an informal group of both private and public stakeholders and its aim is to advise and support the EC in the area of open road testing and making the link to pre-deployment activities as well as to coordinate CCAM research, piloting, testing and

order to better understand the deployment of CAD, and the impacts thereof. Stakeholders, including Member States, industry, unions, and the Commission actively collaborate in this process, taking into consideration various perspectives.

On the subject of understanding the employment implications of the introduction of CAD, a number of studies has been carried out, as presented in Annex D (literature review). This has resulted in a better understanding of social aspects, for example on the required skills of workers and related training needs. It is important to build on the results of these studies and continue to develop the knowledge base, for example by setting up living labs, providing practical insights in CAD deployment impacts. Furthermore, mechanisms to monitor social impacts should be developed, for example by preparing groundworks for an observatory on socio-economic impacts of CAD, providing a basis for monitoring whether impacts take place as expected, while also being able to assess the effects of policy measures.

Creating awareness and activating stakeholders

Having consulted with many stakeholders in this study, it appears that the awareness of expected employment and social impacts and consequences thereof, strongly varies between stakeholders. Amongst some stakeholder categories, for example SMEs, there is lack of awareness of these impact and consequences, obviously not contributing to an active approach towards transition.

Consequently, there is a challenge in creating more awareness amongst stakeholders that play a role in the transition process, for example by providing information, for example by documentation, websites, organising events, or other awareness raising activities. Furthermore, expert platforms and working groups, could be created such as a collaborative platform on the social impacts of CAD.

Facilitating transition

Catalysts need to be put in place to facilitate the transition process. Part of this concentrates on setting up collaboration mechanisms between stakeholders. To this end, automation and its employment and social impact should be placed on the social dialogue agenda. Ideally, a common strategy towards transition would be developed. Moreover, an enabling regulatory framework, addressing social aspects related to CAD introduction should be created. For this, legislation, including EU Directives and Regulations, need to be fit for purpose and existing legislation need to be reviewed and adjusted where needed, while new legislation may need to be developed. Finally, funding is needed for managing the transition process.

The need for social dialogue

The deployment of CAD could potentially have adverse effects for workers, as mentioned above. Social contracts need to be updated to reflect the new requirements for workers, especially considering that the deployment of CAD can result in the displacement of workers. These risks and uncertainties can lead to frustrations among workers and conflict between social partners if not addressed. Social dialogue is needed to mitigate those risks. The transition has to be participatory and social partners should make use of existing dialogues to discuss the upcoming transition and create a shared narrative on how to tackle it. A collaboration platform on social impacts of CAD could facilitate this process, as well as a Framework Agreement on Automation.

An enabling regulatory framework

A changing work environment will not only require an adaption of the social contract, but is likely to also require an adaption of the regulatory framework. Policy makers will need to review current

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deployment activities. For more information, see: https://connectedautomateddriving.eu/mediaroom/european-commission-launches-ccam-single-platform/.

social legislations in light of the changes caused by CAD. These reviews should be based on evidence in order to create legislation fit for purpose (see also the section on understanding the issues at stake). Therefore, first, a mapping exercise would be required to make an inventory of what legislation should be reviewed.

In road transport, there are specific areas that would need to be reviewed[62]:

- The legislations governing driving and rest time periods;
- The legislations setting out requirements for skill levels of professional and also private drivers.

Regarding driving and rest time periods, the Regulation (EC) No 561/2006 provides a common set of EU rules for maximum daily and fortnightly driving times, as well as daily and weekly minimum rest periods for all drivers. Furthermore, Directive 2002/15/EC lays out provisions concerning the hours of work in road transport in order to ensure both the safety of transport and the health and safety of the persons involved. Finally, Regulation (EU) 165/2014 on Tachographs ensures the proper recording and monitoring of driving times. These legal documents would need to be reviewed based on the changing role of the driver[63]. Moreover, the absence of drivers in fully automated vehicles would require different rules, as obviously rest times do not apply to robots[64]. More information is needed on how long people could work safely at different stages of automation. First results have been gathered in tests with CAVs (Heikoop et al, 2019), however, it is still unclear what stress levels and workloads operators of automated vehicles would be exposed to.

Legislations for required skill levels of drivers, such as Directive 2003/59/EC regulate the training of professional drivers. In regard to private drivers, Directive 2006/126/EC introduced a harmonised licence model and further minimum requirements for obtaining a license across the EU. In both cases, the introduction of CAD could warrant a review of these directives in due time to ensure that training requirements keep up with the gradual progress in automation. For example, even in a scenario with increased levels of automation (up to SAE4 level), there may still be situations in which the vehicle requests the human driver to take over. Drivers will then be required to take over in the most difficult situations while at the same time having less driving experience. Therefore, for the sake of safety precautions there might actually be a need to require more frequent training of drivers as compared to today.

In reviewing these directives (and possible others), harmonisation across the EU will be important to consider in order to facilitate the deployment of CAD.

Making funding available to manage the transition

Upon developing a strategy for managing the transition, including an action plan to deliver this strategy, an indication of required funding could be established. This is to be matched with available funds at sector, Member State and EU level.

Managing transition

As the deployment of CAD is a dynamic process, which will take place over a longer time period, managing the transition is a continuous and situational process. Continuous, as the transition will be based on a gradual change of the vehicle fleet, resulting in different impacts over time, shaping the process as a transition pathway. Situational, as transition depends on factors, such as location, timing and market segments. Managing the transition focuses on matching supply to changing demands in the labour market, as dynamics in both the supply and demand side can lead to

[62] Other areas could include data, physical and digital infrastructure, and standardisation. Whether this should be included is to be established in the mapping exercise, as mentioned in the text.

[63] Vehicles that require drivers to mainly monitor and intervene only in certain situations.

[64] Periodic checks of the functioning of software and hardware might be needed, but that is not covered in driving and rest time.

shortage or oversupply of workers in certain professions in road transport and related industries. Moreover, required skills develop over time and challenges related to skill mismatches need to be addressed, either through retraining existing workers or adjusting curricula of future workers. In order to deal with the current driver shortage, workers need to be attracted to the sector, opening opportunities for a more diverse workforce, including young and female workers and overall improving working conditions. An important challenge in managing the transition, is to promote sustainable mobility solutions and reduce externalities.

Imbalances in labour market demand and supply

One of the main challenges that road transport is facing is a shortage in the supply of drivers[65]. Current policies are trying to address this by making the sector more attractive (also for a more diverse workforce – see in the next sections). The deployment of CAD will affect the situation by changing the demand for drivers, at least in the long run. In managing the transition for labour market demand and supply, policy makers need to consider the following aspects:

1. The current driver shortage of 21% in freight and 19% in passenger road transport;
2. The age composition of the drivers' labour force, with an average age of drivers in freight transport of 46 and in passenger transport of 52, resulting in many retiring in the coming years[66];
3. The stark reduction in demand caused by the introduction of CAD starting in some scenarios for freight as early as 2035 and for passenger from 2040 on. The reduction will especially be felt in freight road transport.

Combined, these aspects create a challenge for policy makers to manage this transition by creating more supply of workers in the short-term and medium, while managing the phasing out of older drivers and the replacement with a younger workforce that needs to be made ready for the upcoming transition caused by CAD.[67] Moreover, potentially, policy makers might also have to consider measures for transiting and retraining displaced workers into other professions.

Beyond drivers, CAD will also affect demand and supply in various other professions related to road transport. These can be summarised in the following developments:

- In passenger transport, an increased need for on-board stewards and staff for control centres from 2040 on to fulfil customer relations and safety tasks on automated vehicles;
- Across road transport, an increased need for IT specialists to maintain and operate automated vehicles and infrastructure from 2035 on;
- In manufacturing, an increased need for engineers in vehicle and electronics manufacturing in scenarios 1 and 2;
- In construction, building the needed infrastructure will require sufficient construction workers, including technicians to handle the electronics component of CAD infrastructure.

Mismatches in skills required as a result of introduction of CAD

Closely related to the challenge of labour demand and supply imbalances, is the challenge skill mismatches in the workforce. Overall, the deployment of CAD technology is expected to increase the average skill level of workers in road transport, but it will also reduce the importance of some skills (e.g. manoeuvring vehicles) while increasing the importance of others (IT related and social skills) Specifically, policy makers need to consider three main points:

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65 See Section 5.4.1. for more details on driver shortage.

66 See Section 5.3.1.

67 For example, considering that the CAD transition will take place from 2035 on (in terms of reduced demand for labour), one third of the current workforce being 50 years or older will likely have retired by then, while at the same time, companies need to fill the current shortage of drivers with young entries whose career will include a transition from driver to what we describe as mobility operator.

1. A shift from driver to mobility operator requiring workers to become more adept in IT skills, but also in monitoring and intervention skills;
2. A potential shift in responsibilities for drivers towards more administrative and/or customer related tasks;
3. Overall the increased need for ICT and engineering skills to build, maintain, and operate the vehicle fleet and infrastructure.

Especially the first two points will require to build on flexible approaches, such as lifelong learning to allow drivers to adapt to the changing requirements over time, as the traditional driver skills will only gradually become less relevant. On-the-job training will also ensure that skills that will be less used over time (e.g. manoeuvring vehicles) do not depreciate and drivers are still able to intervene in emergencies (which will be relevant for up to SAE level 4). Policy makers will also need to consider the retraining of drivers (especially in freight transport) into other professions (e.g. logistical experts, traffic managers) with the introduction of fully autonomous vehicles (SAE level 5 and for freight in some cases level 4) possibly phasing out many drivers. In light of point three and in preparing the future workforce, there is also merit in considering the needs of the future workforce in terms of skills and adapt existing curricula (more IT and customer relations skills) as well as promote educations in fields where there will be future demand such as ICT and engineering, traffic control and logistics.

Work conditions and attractiveness of the sector

The introduction of CAD is also an opportunity to improve working conditions, as well as to attract younger workers and more women to the profession. Currently, road transport is a male dominated profession with only 4.4% of vehicle operators being female[68]. The sector is not seen as very attractive and therefore struggles with attracting new workers. However, the transition towards CAD could improve working conditions and thereby make the profession more interesting to a wider audience by:

- Raising the required skill levels and thereby possibly increasing salaries, but also the employability of workers (affecting negatively talent retention);
- Requiring a broader skill set (e.g. customer relations, ICT) and thereby attracting people from different educational backgrounds;
- Making the profession less physical demanding;
- Making working hours more flexible with continuous progress in automation and the possibility of remote operations (better consideration of work-life balance).

Nevertheless, attracting a more diverse workforce will require flanking policy measures. Moreover, CAD might make road transport even less interesting for prospective workers, due to the uncertainty that automation causes in the future labour demand. If this uncertainty is not addressed, then this opportunity might turn into a challenge, as even less people will be inclined to pursue a career in road transport, which would be a problem with increasing demand in the short-term. A forward looking policy would acknowledge the transition and provide career paths with a broad knowledge base that would allow branching out into different fields in transport. Moreover, in terms of improving the gender balance, while the need for social skills might attract more women, ICT skills are currently also male dominated and research has shown that men are more positive about CAD as a technology[69]. Again without proper flanking measures such as promotion of education, road transport might remain a male dominated profession. Finally, remote operations and the need of ICT or customer relation skills over physical skills, might also allow more people with disabilities to enter the profession (see also next paragraph).

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[68] See Section 5.3.2.
[69] See Section 5.3.2.

The effects of CAD on social inclusion

The impacts on social inclusion described in Section 5.4.2 as well as in Section 5.5.2 on the social impacts of new business models, highlight the potential of CAD being both an opportunity and a challenge when it comes to social inclusion. An opportunity, because on the one hand it can increase the possibilities for persons with reduced mobility to take-up jobs in road transport due to the shift to more supervising tasks. On the other hand, low-cost mobility provided by shared services, as well as by robo-buses could contribute to social inclusion by providing accessibility to low-income people and people in rural and underserved areas. Finally, CAD could also improve inclusion in society for persons with reduced mobility by increasing travelling independence allowing them to move more freely with less help of others. However, this also comes with a challenge, as this is only possible if CAVs are designed in a way to be accessible to persons with reduced mobility. In fact, it could become a challenge and lead to social exclusion in a scenario where most services are provided by robo-taxis or robo-shuttles with no driver or other staff on board and no accessibility measures to support person who needs assistance with boarding or leaving the vehicle.

Imbalances caused by a changes in regional automotive industry and transport service patterns

The regional analysis of automotive industry clusters, and a separate analysis of ICT industry linked with CAD technology, highlighted that their regional patterns differ (see Section 4.4.2). While the current conventional automotive industry is spread across a large number of clusters in various Member States (e.g. CZ, DE, ES, FR, HU, IT, SE, SK) the capability and the industry to develop and manufacture CAD technology seems to be much more concentrated in a few clusters in only a limited number of Member States (DE, FR, NL, SE). Thus as an additional challenge, the CAD transition is expected to some extent to relocate jobs in the automotive industry and create spatial mismatch in labour demand and supply.

This spatial mismatch can also be observed to some degree in transport services. Section 4.3 highlighted that the regions with the strongest losses are those that combine severe reductions as a result of automation with relatively limited expansions of freight transport demand until the 2030s. Depending on the scenario, countries like Germany, France, Austria and the United Kingdom are more severely impacted by reduction in employment. In scenario 3, where passenger transport employment is disrupted the strongest, we see also that major urban regions such as Berlin, Munich, Hamburg and Vienna (where a lot of ridesharing employment is expected to develop) experience less severe job losses than regions around them. However this distinction is not visible, for many other urban centres, due to the composition of their respective regions.

Promote sustainable mobility solutions and reduce externalities

If automated vehicles will be available at a relatively low cost, the demand for private mobility could be stimulated, leading to a significant increase in passenger transport activity. Depending on the scenario, car traffic could increase substantially by 2050[70], leading to increased congestion and high external costs for society, especially in urban areas. In order to address this challenge, shared mobility solutions should be considered. Shared mobility solutions or other measures, such as road pricing and taxation schemes, reducing passenger transport activity, would also contribute to delivering European Green Deal (EGD) objectives. The link to EGD objectives is further elaborated below.

6.1.2 *Contextual challenges and opportunities*

In a broader policy setting, going beyond the introduction of CAD, the road transport sector is facing challenges and opportunities, notably in providing safe, connected, and clean mobility. These

[70] This is estimated at 30% for scenario 1 and 10% or scenario 2.

contextual challenges and opportunities are not a direct result of the introduction of CAD, but are expected to affect the development and deployment of CAD and vice versa.

Two ground-breaking contextual changes are the EGD and the Covid-19 pandemic. The EGD is the top priority presented by the new Commission for the coming years, focused on making the EU's economy sustainable, by turning climate and environmental challenges into opportunities, and making the transition just and inclusive for all[71]. The transport sector, through modernisation and making the sector more sustainable, plays an important role in realising the EGD's ambitions. As such, it will affect the development and deployment of future transport solutions, such as CAD. Covid-19 is an external effect, which heavily impacts our lives in these days and in the period to come. Society has to deal with these Covid-19 related impacts now and in the future, which is sometimes labelled as "the new normal". Overcoming the pandemic and its effect will also provide opportunities to invest in a more sustainable and resilient transport system. As such, Covid-19 has the potential to accelerate the process towards a more sustainable Europe.

These two major contextual changes are described in more detail below; other contextual changes, such as shared mobility and new mobility concepts, such as MaaS, are briefly touched upon afterwards.

The European Green Deal

Climate change and environmental degradation are an existential threat to Europe and the world. Transport has the second highest GHG emissions, shortly after the energy industries, contributing 24.6% to the EU's total emissions in 2017. Transport is also the only sector where emissions continue to rise compared to 1990 levels. Road transport is above its 1990 emission levels and with 71.7% contributes by far the most to the total transport emission. Consequently, addressing climate change and decarbonisation are major challenges for road transport and a central theme in the EU Road Transport Strategy[72]. This is further emphasised by the European Green Deal, seeking at least a 90% reduction in these emissions by 2050.

CAD should have a positive contribution to climate objectives. This is also stated in the EGD, where automated and connected multimodal mobility, together with smart traffic management are identified to play an increasing role in providing new sustainable mobility services that can reduce congestion and pollution (European Commission 2019b). For example, big data analytics and new mobility services, such as shuttles and ride-sharing, should make transport more efficient. At the same time, as indicated in some of our scenarios, CAD could also result in an increased demand for private mobility, leading to an increase in passenger transport activity and potential trips of empty vehicles, with an adverse impact on the environment, as well as congestion and safety. Consequently, additional policy action is needed on how CAD is applied, emphasising concepts such as shard mobility, for CAD to contribute to climate objectives.

Furthermore, while CAD does not equal electromobility, there is still a clear link between both technologies, as in the medium to long run most vehicles will be electric, as well as autonomous. By 2035, when we see more and more autonomous vehicles entering the market, we would also expect that by then most new vehicles developed do not rely anymore on combustion engines. As indicated above, CAD is often associated with shared mobility and could lead to less private car ownership. The implementation of electromobility and shared mobility depends to a large extent on a combination of regulation, strategic choices made by the vehicle manufacturing industry and

[71] European Commission. A European Green Deal, Striving to be the first climate-neutral continent: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.

[72] Besides other themes, such as a well-functioning internal market; fair competition and workers' rights and digital solutions (see: https://ec.europa.eu/transport/modes/road/road-initiatives_en).

consumer preferences. The net environmental effect depends on how governmental and industrial policies will set up synergies towards making transport more efficient and stimulate shared and public mobility solutions.

Covid-19 and the impact of pandemics

Since early 2020, public health has become a major challenge. The Covid-19 pandemic has made it clearer than ever before, that the way we travel directly impacts our health. The pandemic has forced people to reduce their commuting and work from home, or where possible, switch to personal transport modes. According to estimates by the International Energy Agency, global road transport activity was almost 50% below the 2019 average by the end of March 2020 (IEA 2020).

The specific impacts vary, in public transport, ridership in cities dropped significantly, in many cases down to 85%, and has been recovering slowly, with only a handful of cities reaching 50% of their pre-pandemic ridership levels (UITP 2020b). According to numbers by IRU, European road passenger transport companies are expected to suffer on average revenue losses of 57% or EUR 80 billion in 2020. For urban and local bus and coach services the expected revenue losses are 42%, for taxi services 60%, intercity bus and coach services 70%, and for bus and coach services in tourism losses are expected to reach 82% this year. Road freight transport losses are expected to exceed EUR 64 billion (a reduction of 17%) in Europe in 2020 (IRU 2020). These severe impacts were caused by the general economic downturn reducing freight demand, by travel restrictions affecting both freight and passenger transport and by overall reduced demand in passenger transport due to the aforementioned changed working and mobility patterns.

Policy makers have responded by taking supportive measures, for example by providing financial support to public transport companies in order to maintain adequate levels of public transport services, despite the sharp reductions of ridership. Furthermore, exemptions on rules governing driving and resting times were approved in certain Member States.[73]

CAD deployment (level 4-5) and its employment and social impacts are expected to manifest themselves only after 2030-35. By that time, Covid-19 will most likely have subsided, however, its lingering effects, as well as possibly other pandemics, will continue to affect the transport sector, including the development and deployment of CAD. This is manifested in a number of ways. For example, during the crisis CAD development has slowed down through delays in setting up pilots or trials and through cuts in investment to favour short-term cash management (McKinsey 2020). Moreover, Covid-19 has affected transport and mobility patterns, with a possibly lasting impact, as shown in the delivery of daily goods, such as food items, and the development of e-commerce during the crisis, with people avoiding to go to supermarkets or restaurants. Also, the reallocation of road space and modal priority, in favour of pedestrians and cyclists, could affect the deployment of CAVs.[74], a reallocation that might be enforced by EGD policies. In other cases, CAD can be a solution for future pandemics, as was shown by self-driving shuttle trials that were repurposed for the transportation of Covid-19 tests in Florida.[75] Similar, in autonomous passenger transport, the absence of a driver would reduce infection risks for drivers, although there might be a need for additional cleaning personnel disinfecting vehicles.

The pandemic has also led to the introduction of new procedures in transport and mobility, such as taking the temperature of staff and in some cases passengers, social distancing rules in public

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73 COVID-19 led to a temporary relaxation in Member States for rules on driving time, breaks and rest periods in road transport. See: https://ec.europa.eu/transport/modes/road/social_provisions/driving_time_en.

74 LEVITATE (14 May 2020) Automated vehicles and COVID-19 – what we can learn from it. See: https://levitate-project.eu/2020/05/14/automated-vehicles-and-covid-19-what-we-can-learn-from-it/.

75 The Verge (6 April 2020) Supervised self-driving shuttles are moving COVID-19 tests in Florida. See: https://www.theverge.com/2020/4/6/21209964/self-driving-shuttles-covid-19-tests-florida-beep-jacksonville-navya.

transport, disinfection procedures creating new jobs related to cleaning vehicles, as well as closer cooperation between employees and their companies (for discussing safety in the workplace). Outside companies, it has led to a shift away in consumer behaviour from shared mobility and public transport to personal transport solutions, such as private cars, bikes and walking. It has also led to an increase in remote working and has repeatedly closed cross-border transport for both freight and passengers. Notwithstanding the (financial) support, layoffs in both passenger and freight transport could be expected as a result of the above-mentioned negative impacts on ridership numbers and turnover, as well as the reduced demand for freight transport. The effect in the medium and long run is uncertain. In a post Covid-19 era, some of these impacts are likely to disappear, others, such as changing mobility patterns, for example, due to remote working arrangements, may have a lasting effect.

Other challenges and opportunities

Climate change and Covid-19 are not the only contextual challenges or opportunities affecting road transport. There are many others, some of which were already addressed in Chapter 5, as well as in connection with the CAD related challenges and opportunities. Among these are the existing driver shortage, the gender imbalance and the issue of an ageing profession, as presented in Sections 5.3 and 5.4. Furthermore, CAD also has the potential to increase road safety and reduce accidents, which is an important reason to promote CAD. Finally, opportunities in the transport sector also come from other directions, for example from disruptive changes in technology, providing an entry to e-mobility solutions and changes in mobility patterns, for example as a result of the sharing economy (European Commission 2019c) and the implementation of MaaS solutions. CAD can be seen as an opportunity to facilitate the develop many of these new trends and vice versa.

6.2 Policy options to address challenges and opportunities

Many of the challenges and opportunities introduced in the previous sections are already recognised by the European Commission, resulting for example in the development of policy initiatives for a socially fair transition towards clean, competitive and connected mobility, as defined in the Low-emission Mobility Strategy (2016), which is the basis for three waves of legislative proposals, i.e. the Mobility Packages[76]. These initiatives jointly address many transport sector challenges and opportunities. However, specifically some of those linked directly to the introduction of CAD are less recognised. Therefore, we present in this section policy options to address the afore described challenges and opportunities.

Where the challenges and opportunities indicated what should be done to respond to the impacts, the policy options indicate how this can be done. We linked the identified challenges and opportunities to specific policy options in order to ensure that the proposed measures are comprehensive and address all aspects. A full overview on these linkages is presented in Annex I and each of the following sub-sections provides a short overview thereof.

[76] Europe on the Move - An agenda for a socially fair transition towards clean, competitive and connected mobility for all of 31 May 2017; Delivering on low-emission mobility – A European Union that protects the planet, empowers its consumers and defends its industry and workers of 8 November 2017; Europe on the Move – Sustainable Mobility for Europe: safe connected, and clean of 17 May 2018.

6.2.1 *Preparing for transition*

The policy options for the identified challenges and opportunities related to preparing the transition are presented in Figure 6.2.

Figure 6.2 Policy options for preparing the transition

Source: Ecorys.

PO-1: Set up a network of living labs on CAD deployment, focusing on employment and social impacts

In preparing for transition, and developing supporting policy measures and creating an appropriate regulatory environment, it is important to collect evidence at the early stages of deploying CAD. To this end, a network of living labs could be established at European level. Such a network could also connect the many ongoing CAD pilots within the EU[77].

The JRC, in "The future of road transport - Implications of automated, connected, low-carbon and shared mobility", recommends the development of such living labs to create the right environment in which innovative mobility solutions are tested and rolled out with the direct involvement of citizens (Alonso Raposo & Ciuffo 2019). Whereas the JRC has a broader agenda for testing mobility solutions, CAD deployment, and its employment and social implications, could well be placed within this approach. The key here is the ability to test new mobility concepts and the impacts thereof.[78] If successful, concepts can be rolled-out, if not successful, concepts can be further improved. Hence, the suggestion to develop a platform to facilitate the process of exchanging experiences between the living labs. It should be noted that the JRC has launched a call for expressions of interest to launch pilots for such living labs, for example by developing CAD related mobility services, such as door-to-door automated delivery, automated shuttles, and robo-taxis.[79]

PO-2: Initiate and carry out targeted studies creating better understanding of CAD related employment and social impacts

The topic of CAD deployment and related impacts has been researched extensively, as indicated in Annex D, resulting in better understanding and development of roadmaps and action plans,

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77 See Annex D (literature) for a list of ongoing CAD pilots.

78 Please note that for such testing, some adaptations of the legal framework of road transport to CAD is needed. For example, regulating in a harmonised way testing methodologies and the conditions for the use of CAD on the road, as well as addressing liability issues.

79 Call for expressions of interest - Pilot living labs at the JRC. See: https://ec.europa.eu/jrc/en/research-facility/living-labs-at-the-jrc/call-expression-interest-future-mobility-and-digital-energy-solutions.

addressing a broad range of stakeholders[80]. This specific study adds to this research, as well as other ongoing studies, such as one on the social dimension of the transition to automation and digitalisation in transport, focusing on the labour force (DG MOVE), which covers all transport modes[81].

There is an ongoing need to develop the understanding of the employment and social impacts of CAD deployment, which needs to be in a coherent way, involving multiple stakeholders, such as the industry, the social partners and the authorities, including the Commission. To this end, the CCAM Single Platform has been established, which advises and supports the European Commission through the coordination of CCAM research, piloting, testing and deployment activities with the goal to increase their efficiency and effectiveness, as well as integrate existing fora. One of the established working groups is responsible for coordination and cooperation of R&I. In addition, we identified 49 research projects on various CAD related topics in the EU[82], some covering social impacts, for example LEVITATE or SKILLFUL. Still, the better understanding of employment and social impacts needs to be placed on the R&I agenda and other stakeholders from within and outside the Commission such as DG EMPL and ETF need to be connected. A range of topics could be considered, for example:

- Preparing the groundwork for the observatory of employment and social impacts related to CAD deployment, as described below (KPIs, data sources, working arrangements);
- Deepening the understanding on the timing of CAD deployment as this determines the transition process (prepare, manage, facilitate)[83];
- Research into driver/mobility operator fatigue, stress levels, and workload at different automation levels;
- Create a common understanding on liability in vehicles at different automation levels;
- Analyse the impact of geographic mismatch on employment in Europe.

PO-3: Incorporate lessons learnt from the current Covid-19 pandemic

Covid-19 has uncovered inherent weaknesses and risks within our supply chains, including road transport. CAD alone will not solve this, as it requires a reorganisation of industries and their supply chains. Still, the impacts and lessons learnt from Covid-19 should be considered when deploying CAD. After all, resilience in supply chains and infrastructure and any disaster preparedness should be a priority when developing future proof transport solutions.

In the specific case of a pandemic, the way humans interact with their environment is the key problem, therefore changing the way we interact with our environment is an important factor in dealing with future pandemics. CAD has the potential to fundamentally change our mobility patterns and as such the way we interact with the environment, for example by increasing supply chain resilience and keeping goods and passengers moving through automated vehicles, without endangering people during a pandemic.

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80 For example, in the frame of the CARTRE project, a large selection of roadmaps and action plans, as well as pilots, projects and test sites were collected and analysed, providing an overview of what kind of actions and/or recommendations in general and for public authorities in particular are considered.

81 Results of this study are expected to become available at the end of October 2020.

82 See Annex D.

83 Stakeholder consultation revealed that massive CAD deployment is only expected to commence after 2030/2035+. Apart from upstream impacts on the R&I and manufacturing side, the major CAD impacts on employment will only appear with the CAD deployment in transport services. Thus some 10+ years remain to prepare for the transition to a mobility system with massive CAD deployment. To implement the appropriate measures at the right point of time will be important. If measures would come to early resources could be wasted, if too late workers, employers and citizens would have to adapt in a hasty and non-structured way. Therefore it is relevant to deepen the understanding on the timing of CAD uptake and thus on the timing of the preparatory measures. Ideally this will enable to design a structured transition pathway.

When pursuing shared and public transport solutions, additional health standards need to be developed for future passenger transport solutions, making shared and public transport safer in terms of avoiding the spread of diseases. For example, introducing standards for interior vehicle design that facilitate the introduction of barriers, disinfectants or ventilation systems that filter the air. Already, in-vehicle technologies, such as cabin disinfection, air purification, human machine interfaces, are being identified that can help mitigate spread of future diseases.[84] Further research to collect the lessons learnt and develop public health solutions for freight and passenger transport would be beneficial to facilitate the development of a resilient transport system.

PO-4: Organise awareness raising activities for stakeholders involved

Awareness of CAD deployment and its employment and social impacts is a precondition to managing the transition properly. This applies to all stakeholders involved, including transport companies, workers, authorities and society as a whole. In our study it has become clear that the level of awareness differs per stakeholder category. Where there is a general understanding that automation will come and affect the sector, awareness on employment and other social impacts is sometimes limited, for example with SMEs. Hence, the need to raise awareness, tailored to the needs of the stakeholders involved.

In order to raise awareness with the main stakeholders, an awareness raising campaign is proposed. Elements included in such a campaign are the following:

- Determine the target audience and needs: for the main stakeholders, the level of awareness of expected employment and social impacts needs to be determined and the way this affects the stakeholders. For example, companies and drivers need to understand the future demand for drivers (or mobility operators) and how that translates into job opportunities or reskilling perspectives. Whereas authorities would need to understand this process in order to develop programmes or initiatives supporting the transition. The earlier mentioned living labs could contribute to better understanding;
- Based on understanding of the needs, information packages need to be developed to support creating awareness;
- Information needs to be provided using the appropriate communication channels. This can be through events, such as conferences or webinars, or providing information in documents or brochures or though websites.

PO-5: Design a collaboration mechanism to manage the transition process

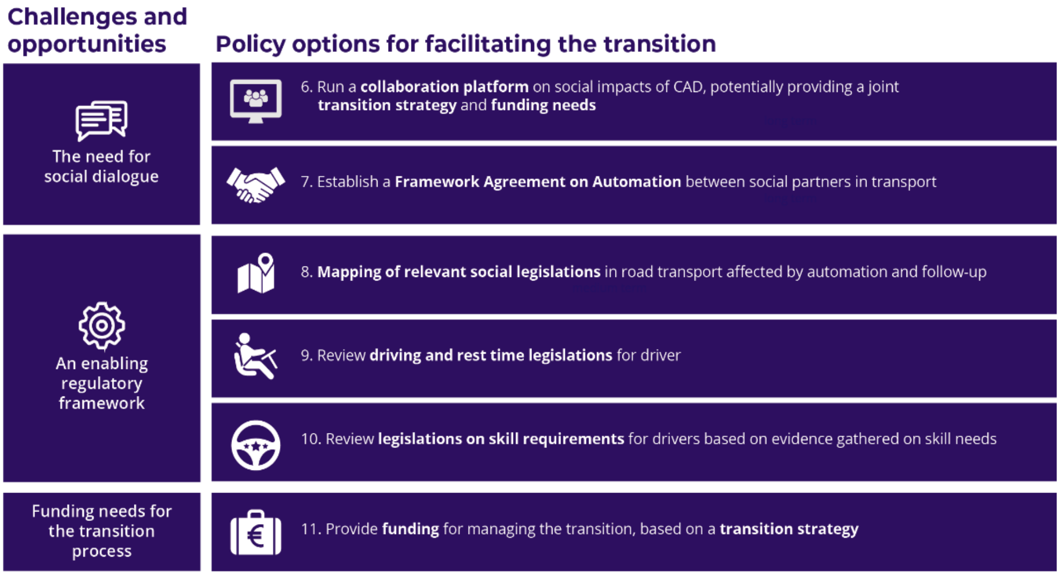
In order to prepare for transition, collaboration mechanisms between social partners and authorities is needed to be established to engage in discussions on social and regulator aspects. The discussion on how to shape this collaboration is to be initiated on short notice. This could be an initiative driven by public authorities, with support provided from the sector. Alternatively, this could be linked to an existing initiative. Laying the groundwork for the collaboration mechanism should be part of the preparation for transition. The section on facilitating the transition describes the platform for collaboration in more detail.

6.2.2 Facilitating the transition

The policy options for the identified challenges and opportunities related to facilitating the transition are presented in Figure 6.3.

[84] Gartner (29 June 2020) Gartner Identifies In-Car Technologies That Can Help Mitigate Spread of COVID-19. Available at: https://www.gartner.com/en/newsroom/press-releases/2020-06-29-gartner-identifies-in-car-technologies-that-can-help-.

Figure 6.3 Policy options for facilitating the transition



Source: Ecorys.

PO-6: Run a collaboration platform on social impacts of CAD

A collaboration platform on social impacts of CAD is to be established (see preparation activity on design of such a platform). This platform aims to engage stakeholders (public authorities, social partners) in a dialogue on the social impacts caused by CAD deployment, as well as ways to deal with these impacts and create a common understanding of the issues at stake in transition. The work of this collaboration platform should build on the results of existing work, including the identified policy options in this study.

Setting up such a platform could be a shared responsibility through a public-private partnership, involving relevant stakeholders and facilitating the creation of a joint strategy and funding needs. Alternatively, or possibly at a later stage, the platform could be linked to an existing initiative, for example the CCAM platform, with an additional working group on social impacts. The European Commission is expected to have a strong facilitating role.

The collaboration platform, whether organised as a separate industry led initiative or as part of a larger platform, would need to develop a common understanding of the needs for transition (see the section further above on understanding what is at stake). This could for example include adjustments in legislation, the need for adapting curricula and providing flexible re- and upskilling approaches or specific topics, such as liabilities of drivers.

Optionally, based on the developed understanding, the collaboration platform could be tasked with developing a transition strategy, including an action plan and related funding needs. Placing this responsibility with the platform would contribute to the creation of joint ownership for the transition process. Moreover, it would identify required steps to be taken by different stakeholders, including interaction between those steps, providing the ability to monitor progress of the transition process. First steps towards developing a social roadmap are included in Chapter 7, which aims to provide groundwork in this process.

PO-7: A Framework Agreement on Automation

Another means for enhancing the social dialogue is the development of a joint Framework Agreement on Automation in road transport. Such an agreement, could enshrine a joint understanding between industry and workers on how to address social impacts of the transition towards automated road transport. This would provide certainty to workers and companies. Depending on the ambition of the agreement, it could cover various issues. For example, an agreement on how companies should handle the introduction of automation (e.g. through company level agreements) or an understanding on procedures for retraining workers that might be displaced. For example, in the Port of Rotterdam workers received training by their company in collaboration with the trade union after trucks were replaced by remote-controlled CAVs.

Since industrial relations are organised differently between Member States, such a framework agreement could provide an impetus for collective agreements at national level. These collective agreements could be based on the framework agreement, while providing enough flexibility to consider regional differences as well as the possibility to consider flanking public policies (e.g. medical or unemployment insurances) in Member States. The existing Framework Agreement on Telework could serve as an example for creating such an agreement on automation.

PO-8: Mapping of social legislations affected by CAD

The collaboration platform could also be used to discuss social legislations at EU and national level relevant for road transport workers and how these legislations are impacted by CAD. The legislative framework on driving and rest time as well as the one concerning qualifications for drivers has already been identified as focus areas (more on these two in the following two sections). However, there might be other regulatory areas affected by the deployment of CAD in road transport. For example, one could envision that automation has an impact on regulation on occupational safety and health.[85] In order to identify potential disruptions, one could conduct a mapping exercise on regulatory impacts of CAD either through the proposed observatory or through targeted studies. Once identified, follow-up actions would need to be implemented by European and national institutions to review the relevant regulatory framework and where necessary to update it.

PO-9: Review driving and rest time legislations

With automation in road transport progressing, the question arose what to consider work time and what leisure. For example, is a driver on board of a platooned truck who is not actively driving at the moment resting? Questions regarding driving and rest times are sensitive ones, however they are important to answer as current legislations might not be fit for purpose once automation progresses. Specifically, the following three legislations will need to be reviewed:

- Directive on the organisation of the working time (2002/15/EC);
- Regulation on the harmonisation of certain social legislation relating to road transport ((EU) 561/2006);
- Regulation on Tachographs ((EU) 165/2014).

A proper review should first engage in additional research on stress levels and fatigue in drivers that are not actively driving but have to monitor and be ready to intervene in emergencies. One could make use of the observatory or initiated targeted studies on this subject. In addition, policy makers need to consider future business models and changing responsibilities of drivers. If research shows that drivers could rest in the driving cabin, but new business models would require them to use this time to take up other tasks (e.g. administrative or engaging with customers), then one could hardly claim this as rest time. Here research, but also results from living lab experiences could provide valuable inputs.

Thereafter, social partners and public authorities should engage in discussion (e.g. through the networking platform) on these results and present their views on how to address these changes. Based on that, if change to these legislations is required, the European Commission could launch an impact assessment using the collected evidence on the problem and providing a platform to

[85] The OSH “Framework Directive” (Directive 89/391/EEC).

discuss possible policy options addressing them. This work should be started as soon as possible to ensure that Member States can adapt their legislative frameworks.

PO-10: Review legislations concerning the skill requirements for drivers

Next to the above discussed legislations, it is also important to review the Directive on driving licences (2006/126/EC) as well as the Directive on training of professional drivers (2003/59/EC). The former introduced a harmonised driving licence model across the EU and minimum requirements for obtaining a licence, while the latter regulates the training of professional derivers and outlines among other the previously mentioned periodic training of drivers. Similar to the social legislations, any review should start with additional research using *ad-hoc* studies, the proposed observatory, analysis of sector organisations (e.g. the Academy of German Driving Teachers (DFA)) or inputs coming from experiences in the living labs. It needs to be considered how different levels of automation would change training requirements for drivers and which requirements a mobility operator would have.

One concern is that with advancing automation (up to SAE level 4), driving skills deteriorate while at the same time we would expect human intervention to be necessary in exceptional situation (e.g. extreme weather conditions, roadside constructions). There would still be exceptional situations that would require advanced driving skills. Furthermore, specifically for professional drivers there might arise the need for specialised training on challenges and specificities related to automation including the handling of take-over requests. Other aspects, such a review should take into account are a relaxation of minimum health standards or eligibility criteria for operating a vehicle, (e.g. minimum age requirements, accessibility for disabled persons), need for regular training to maintain driving skills, and harmonisation across Member States to avoid issues with cross-border traffic. Same as above, the work should begin as soon as possible to ensure that Member States can adapt their legislative frameworks.

PO-11: Provide funding for managing the transition, based on a transition strategy

The transition process and the actions therein need to be funded. The development of a transition strategy and an action plan, indicating funding needs, as described above, would provide an ideal basis for securing funding for transition.

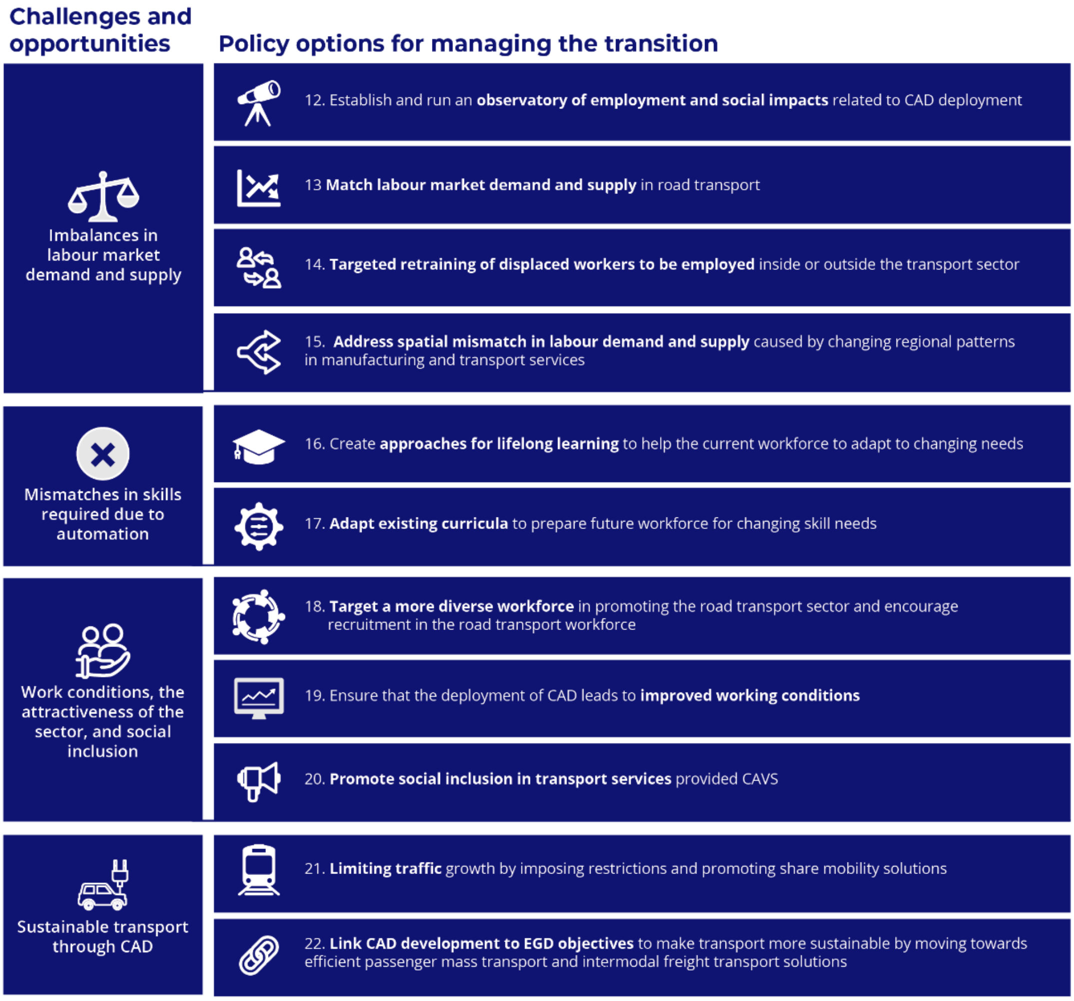
An inventory should be made of potential funding sources at different levels (sector, Member State, EU) to manage the transition. EU funding opportunities could include Horizon Europe; Connecting Europe Facility (CEF); Structural Reform Support Programme (SRSP); European structural and investment funds (ESIF), including amongst others European regional development fund (ERDF), European social fund (ESF), Cohesion fund (CF); funding through the European Investment Bank (EIB) and Special Support and Financial Instruments.

For example, it could be considered to see if the Just Transition Mechanism can be used to facilitate the transition as a result of CAD introduction. This EUR 100 billion heavy mechanism, aimed at supporting EU regions most affected by the transition to a low carbon economy, consists of three pillars: a Just Transition Fund, a just transition scheme under InvestEU and a public sector loan facility (European Commission 2020a). This prospective measure will be quite relevant for road transport considering its carbon footprint (see also Section 6.1.2 on contextual challenges). As said, it is worthwhile to consider extending the Just Transition Fund to automation or linking the automation to a low carbon economy. One could establish this link by linking the development of autonomous vehicles to electrification. In addition, the ERDF has the purpose to "contribute to the financing of support which aims to reinforce economic, social and territorial cohesion by redressing the main regional imbalances in the Union".[86] In practice, this may mean improvement of infrastructure, services for enterprises and support for applied research carried out in enterprises. These activities have potential to contribute to the creation of new jobs in regions negatively affected by the transition to CAD.

6.2.3 Managing the transition

The policy options for the identified challenges and opportunities related to managing the transition are presented in Figure 6.4.

Figure 6.4 Policy options for managing the transition



Source: Ecorys.

PO-12: Establish an observatory on the employment and social impacts related to CAD

An observatory of social impacts should be established focused on monitoring the transport labour market. This will be important, since the transition to CAD will encompass large changes to the demand for labour in road transport[87]. Our study showed that currently, there is still a shortage of drivers, which will persist and grow over the coming decade. However, with the expected introduction of CAD this will reverse in the longer term (with the timing depending on the scenario). This development is expected to somewhat coincide with drivers leaving the profession due to retirement, as indicated in Section 5.4.1. An observatory that monitors labour demand and supply

[86] Regulation (EU) No 1301/2013 of the European Parliament and of the Council of 17 December 2013 on the European Regional Development Fund and on specific provisions concerning the Investment for growth and jobs goal and repealing Regulation (EC) No 1080/2006.

[87] The full scope of such an observatory would depend on the outcome of the preparatory study (see section on preparing for transition).

would facilitate the anticipation of oversupply or shortages in labour and would allow policy makers, industry and social partners to react.

Such an observatory could build upon or would need to align with existing observatories, such as the Mobility4EU "European Forum on Transport and Mobility", which intends to become a place for discussion and debate with a focus on user-centred aspects and cross-modality[88]. It remains open if the observatory would focus solely on road transport, overall land transport, or include all transport modes. Disregarding the exact scope, the observatory would conduct studies on relevant socioeconomic issues, provide information to policy makers and benchmark skill demand and supply. Such an observatory on socio-economic (and environmental) impacts has already been proposed in the European Commission's STRIA Roadmap on Connected and Automated Transport (European Commission, 2019d).

PO-13: Match labour market demand and supply road the transport

The impacts presented in Chapters 4 and 5 indicate that the road transport sector will be facing a major challenge in managing the labour market in the coming decades. Notably in freight transport, as illustrated in Section 5.3.1 and 5.4.1, this challenge will be significant, as the current driver shortage is set to increase in the short and medium term with many of the older generation leaving the profession. This with the combined increased demand for jobs in freight transport in the short and medium run results in the need to close the driver shortage gap. As indicated in Section 5.4.1. this can be achieved by (i) improving the image and reputation of the profession; (ii) improving the working conditions of drivers; and (iii) attracting a more diverse workforce, which includes women and youth. Moreover, one could also consider a targeted retraining of displaced workers from other sectors affected by transitions (e.g. mining activities).

Further into the future, funding should be available to facilitate the transition or the phasing out of older workers in road transport that might otherwise be unemployed (see also under facilitating the transition). In the long-run, with the demand for traditional drivers strongly decreasing, as illustrated in Chapter 4, focus needs to be on retraining traditional drivers to become mobility operators (more under the next heading).

In addressing both labour shortage and oversupply, labour market intermediaries (such as public employment services, outplacement offices or temporary agencies) could support the retraining of workers. These intermediaries sit in-between (potential) workers and employers and therefore have a good overview over skill supply and demand. These intermediaries would be in a position to identify and potentially reduce structural skill gaps especially for women in STEM, workers at risk of automation and the low-skilled. There is often an underinvestment in training, because workers and firms are reluctant to make the necessary investments to acquire skills (European Commission 2019a). Third party intermediaries could bridge this gap by sharing in the costs and benefits of training. They could invest in on-the-job training or training of transport workers out of work provided they can recoup the training cost from employers (e.g. through wage premiums) who in their turn will benefit from trained workers. Workers would benefit as they would not have to invest themselves into their own training. National or EU level authorities could support this by offering courses through public employment services or by providing funding to incentivise training of workers.

PO-14: Targeted retraining of displaced employees

Chapter 4 indicates CAD deployment will substantially reduce employment in the road transport sector in all of the scenarios. Especially employees in driver professions are expected to be

[88] Other examples of observatories are the European Road Safety Observatory, the Urban Mobility Observatory, and the European Observatory for Gender Smart Transport.

displaced by CAD in large numbers in both freight and passenger transport. Part of the reduction will be realised through natural outflow of employees due to retirement. However, for others targeted retraining will be needed. In practice, this may involve retraining of displaced employees to new professions and tasks inside or outside the transport sector. Retraining of traditional drivers to tasks required for operation of automated vehicles, such as mobility operators, will be a part of the solution. Depending on the context, different approaches may be needed to organise retraining for employees displaced by CAD. While major freight transport companies or public transport operators may be in a position to provide training and move their employees displaced by automation to new tasks, other approaches will be needed for displaced workers who are self-employed or working for companies with no opportunities for retraining.

PO-15: Address spatial mismatch in labour demand and supply

The rise and fall of Detroit, the “Motor City”, highlights the harrowing effects transitions can have. In the case of Detroit, globalisation (among other factors) led to the sudden disappearance of a once mighty automotive cluster. Turning one of the wealthiest cities in the USA into one of the poorest. A worst-case scenario could see traditional European car manufacturers losing out against global competitors such as American and Chinese due to their better connection to disruptive digital industries. Especially, when considering decarbonisation, European producers seem to be lagging behind in taking up new technologies such as electromobility. However, Section 4.4.2 showcased several European clusters that are well advanced in CAD manufacturing including Île-de-France, Upper Bavaria, Stuttgart, and for automotive suppliers Noord-Brabant, Stockholm, and Dresden. Still, our research has highlighted that regional manufacturing patterns could change with the current conventional automotive industry disappearing in some Member States and concentrating in only a handful clusters. Beyond manufacturing, the results of the modelling part of the study indicate that the impact of CAD on employment in the road transport sector will be different in different regions. This involves the risk that CAD further intensifies geographic mismatch.

In order to address this potential spatial mismatch, EU and Member States policy makers, in collaboration with the sector, should set up dedicated reginal support programmes, as well as to analyse and monitor the extent of spatial mismatch (e.g. through the observatory or dedicated studies). Current examples of the coal industry, showcase how such a transition could be managed. Here, the European Commission implemented various measures to support a just transition in coal regions.[89] For example, the Secretariat Technical Assistance to Regions in Transition (START) was set up to provide needs-oriented expertise and capacity building to help regions take practical steps in economic diversification. In addition, the European Commission provides resources such as toolkits, guidelines and reports on transition-related issues and furthermore it provides a platform for stakeholders to connect and exchange. Similar measures could also support regions that might face a disappearing automotive industry. Further to technical assistance, measures providing funding such as the Just Transition Mechanism or the European Regional Development Fund (more on this under Facilitating Transition) could be beneficial.

Finally, an important aspect will also be labour mobility to ensure that talented individuals across the EU can come and work in these new CAD manufacturing clusters. Mobility of labour force from regions with high unemployment rate to regions with lower levels unemployment is one of the adjustment mechanisms which allocates resources more optimally in the economy. Here recognition of professional qualifications is a precondition for movement of labour force. Professional qualifications are usually recognised on national level, and recognition of professional

[89] European Commission. EU Coal Regions. See: https://ec.europa.eu/energy/topics/oil-gas-and-coal/eu-coal-regions_en.

qualifications between EU member states is covered by Directive 2013/55/EU.[90] However, the requirements of the Directive have not always been implemented in practice and transposed in national legislation (European Commission 2020b). There is a need to continue the process towards wider recognition of professional qualifications between Member States. This can be expected to facilitate the mobility of labour.

PO-16: Create approaches for lifelong learning to help the current workforce to adapt

The inflexible serial logic of first education and then work hardly serves nowadays needs of workers and companies. Rapid technological advancements make lifelong learning approaches and generalist education necessary in order to provide flexibility and keep up with changing work requirements. In this regard, in-company training is a critical pillar in making education systems more flexible. In road transport, this is nothing new as professional drivers are already required to undertake trainings every five years[91] (paid by their companies). However, not only is training required for drivers, but also for workers in packaging, deliveries, and in general for people who will need to intervene or interact with CAVs. A flexible approach to lifelong learning in road transport could include various measures.

First, the already existing periodic trainings could be used to update skills relevant for automation in road transport. The curricula for such trainings should be reviewed and based on the review, national or EU institutions (e.g. European Centre for the Development of Vocational Training) could provide guidelines for driving schools (which could be supported by the German Academy of Driving Teachers (DFA) who have developed concepts for adapting trainings) or training institutes to introduce automation skills into the curricula of the trainings. The uptake of CAD will be gradual, therefore training for workers should be continuously updated too. This needs to be done soon, to create better understanding and acceptance towards automation and build preparedness.

Secondly, one could consider the introduction of certification schemes for mobility operators. A company certification schemes similar to current HAZMAT certification could provide a framework for quality in-company training that provides the worker and their company with a certificate to highlight their skills. Creating a specific certificate for operators of automated vehicles could also lead to a higher professionalisation in road transport, increase salaries, and increase awareness on automation. Finally, a globally accredited system can be useful to inform any stakeholder that the operator was properly trained.

Depending on where responsibilities should lie, one could also provide transport workers with the means to upskill. However, awareness of automation alone would not suffice, but incentives such as personal training budgets and personal time allowances for employees would be required to give workers the means to participate in training courses.

A fourth measure for flexible training approaches would be to introduce reverse mentoring in the transport sector, where older workers are paired with younger ones, thereby enhancing the IT literacy of older workers while transferring other relevant know-how to younger workers.

Finally, national and European schemes should be created to provide sufficient opportunities for workers in threatened occupations to upskill (or reskill). Such schemes could be supported by the European Social Fund.

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90 Directive 2013/55/EU of the European Parliament and of the Council of 20 November 2013 amending Directive 2005/36/EC on the recognition of professional qualifications and Regulation (EU) No 1024/2012 on administrative cooperation through the Internal Market Information System ('the IMI Regulation').

91 For example through the Code 95 training for professional drivers in the Netherlands. For more information, see: https://www.cbr.nl/nl/beroepsexamens/code-95/nl.htm.

Overall, since the transition will be gradual, it is expected that there is sufficient time to train the workforce. Nevertheless, training should start as soon as possible. Today, the focus should be on the right understanding and usage of the most advanced driver assistance systems (e.g. automated cruise control, turning-off assistant), which can be understood as intermediate technology steps towards full CAD deployment. Moreover, considering the current shortage of specifically drivers in the transport workforce, training could be organised in a way to reduce the amount of work time lost, e.g. through the use of innovative methods such as online trainings or virtual simulators. These have also the added benefit of lower costs, wider accessibility, no risk of accidents, and the ability to develop new training modules relatively quickly.

PO-17: Adapt existing curricula to prepare the future workforce

Next to providing flexible training approaches, one needs to also engage in longer-term planning and adapt existing curricula (or create new ones) for a future road transport workforce. Thinking on this should start now, as even if curricula were changed today, one would see the effects only in five years from now. Specifically, social partners and public authorities together with the respective educational institutions need to consider changes to the following occupations:

- Updating curricula for drivers, because with increasing automation levels their responsibilities and required skills will change transitioning more and more to become mobility operators[92];
- Updating curricula for after-sale technical staff, since workers such as mechanics will require additional skills to deal with the electronics and software included in automated vehicles.

Our study provides an approximation, however the exact changes and therefore future skill requirements are still unclear and will depend on the development of CAD technology. Previously, proposed measures such as studies, living labs, and the observatory could provide more clarity. In addition, the involvement of social partners will be crucial in defining and updating skill requirements.

Besides these two specific educations that will require an update, there are also new emerging occupations due to CAD. While not completely new, the occupation of steward in public transport can become more prevalent in the future. Specifically, early-on on-board personnel with a customer relations but also a safety and security function (similar to stewards on planes) will be needed. Further, mobility operators can carry out their task from on-board of vehicles or from remote steering and super-vising a fully automated vehicle. In addition to stewards and mobility operators working on the unit of a single vehicle, there will be the need for supervisors that monitor traffic, intervene in emergency situations, and redirect traffic where necessary. Such traffic controllers would work in centralised locations similar to air traffic controllers at airports and would be needed specifically for highly connected and automated traffic areas to monitor traffic flows. The exact roles of stewards, mobility operators and traffic controllers will depend on the situation and the type of mobility service, therefore living labs testing CAD technologies might be able to provide additional information required in establishing proper curricula.

PO-18: Target a more diverse workforce in promoting the road transport sector

As discussed in the description of challenges and opportunities, road transport is a male dominated profession that struggles to attract younger workers. This is certainly one contributing factor to the persisting driver shortage. With CAD providing only an opportunity to promote employment in the long-term and prospective workers actually being turned away by the uncertainty that automation causes, policy measures need to be adapted. First, the prospect of transition needs to be acknowledged and addressed by providing effective measures such as funding or re-training opportunities to address these concerns (more on this in Section 6.2.2).

[92] This could go hand-in-hand with the updating of curricula for the periodic trainings as well as the review of the Directive 2003/59/EC related to the training of professional drivers.

Secondly, in the short- to medium-term it will be crucial to increase labour supply by promoting employment targeted towards women and younger people. Therefore, industry but also social partners and public authorities should consider measures (e.g. through communication) to promote the profession as a viable career for these groups as the demand for employment is already there. A recent study prepared for the European Commission (Ecorys, ISI-Fraunhofer, Panteia & PwC, 2018) identified several areas of action to increase female employment in transport, these include:

- Recruitment, training and career development measures;
- Gender awareness measures;
- Work-life balance measures;
- Health and safety measures.

A full list of measures for each of these areas can be found in the report, however to highlight a few rather relevant ones, these include: a targeted recruitment campaign; counter gender bias in recruitment; promote female role models; flexible working hours and adjust shift work; improve maternity leave; and promote a feedback culture.

In addition to increasing female employment, measures should also target promoting the sector among younger people and increase the overall attractiveness of working in road transport. Currently, the transport sector is not seen to be an attractive workplace by young people, partially due to poor communication about career prospects with limited knowledge among younger people on what the sector does and a perception about road transport being noisy or dirty (Deloitte, Coffey & Panteia, 2017). Possible measures to address this include taking a strategic approach to recruitment campaigns with clear targets, going to schools or universities to present career opportunities, providing career advice, providing opportunities such as internships to experience the job, and making use of role models. Besides recruitment campaigns, image campaigns should be considered, shifting the image of working in transport services from being noisy and dirty towards positive aspects, such as working with innovative technology, servicing important needs of the citizens (Schade et al, 2020). Of course, such campaigns need to de developed consistently with the actual improvements of the working conditions in the sector.

Finally, CAD could also provide job opportunities for more disabled people in road transport as the operation and supervision of vehicles might become more accessible with increasing automation.

PO-19: Ensure better working conditions and a more attractive workplace

In order to attract a more diverse workforce, it will also be essential to improve working conditions. CAD provides the opportunity to do so by raising skill levels and thereby salaries, reducing the physical demandingness, broadening the required skillset and facilitating more flexible working hours (e.g. remote working). However, these improvements are neither given nor will they appear in the short- to medium-term. Various stakeholders from our interviews argued that CAD alone will not solve issues, such as salary gaps, but rather that flanking measures in the form of social dialogue and regulatory mechanisms are needed. Therefore, targeted policy measures are needed in ensuring better working conditions and making road transport a more attractive workplace.

The Mobility Package I, which was adopted by the European Parliament in July 2020, already aims to bring social improvements to the road transport sector.[93] The package contains revised rules for posting of drivers, drivers' driving times and rest periods and better enforcement of cabotage rules. These rules will improve rest conditions with the mandatory regular weekly rest cannot be taken in

[93] European Parliament (2020) Better working conditions for truck drivers across the EU. Available at: https://www.europarl.europa.eu/news/en/headlines/society/20200630STO82385/better-working-conditions-for-truck-drivers-across-the-eu.

the truck and companies having to pay accommodation costs. It will also allow drivers to spend more time at home with drivers in international freight transport being able to return home at regular intervals. Moreover, the use of tachographs and the fight against letterbox companies is to be improved in order to tackle fraud and better register cross-border operations. Finally, the package provides a clear legal framework to prevent differing national approaches and ensure fair remuneration for drivers. These rules are expected to improve work conditions in freight transport and make the sector fairer.[94] As a concrete policy measure, it is essential that the application of these rules and their effects are monitored and assessed in order to decide on the possible need for further steps.

In regard to passenger transport, for coach services the driving time and cabotage rules addressed by the Mobility Package I are as well of a concern. However, in regard to shorter distance travel in the form of bus and taxi services, employees face different challenges. Specifically, for the latter the appearance of digital car services such as Uber have raised concern about the erosion of work conditions for drivers. While not directly related to the deployment of CAD, here policy makers need to consider how legislation applies to workers, jobs and activities in road transport that do not conform to the more traditional employer-employee relationship, but makes use of self-employment. Social partners and regulators will need to clarify how digitalised activities will align with the more established labour market models (Eurofund, 2016). Specifically, it needs to be studied more closely how these new services affect work conditions in the road transport sector and social partners should engage in a discussion a collective agreement for workers in the gig economy.

PO-20: Promote social inclusion in transport services provided with automated vehicles

CAVs may be operated as robo-taxis and implemented as automated shuttles providing public transport services. Possible future scenarios of CAD foreseen in our study involve robo-taxis and automated shuttles operating without a driver or any other staff on board. If realised, this will have impacts on travellers belonging to special groups. For example, taxi services provided by a robo-taxi with no driver or other staff on board would not be suitable for a person who needs assistance with boarding or leaving the vehicle. In a market situation in which all or almost all locally available taxis are unmanned robo-taxis, availability of services to special groups may be insufficient and involves a risk of social exclusion. It is therefore preferable to develop accessibility requirements for public transport and taxi services provided with automated vehicles and monitor the impact of connected and automated driving on special groups and their mobility.

PO-21: Limiting traffic growth by imposing restrictions and promoting shared mobility solutions

As CAD has the potential to result in increased traffic, Member State authorities, notably at urban level, need to take measures to limit traffic growth. This can be done by imposing restrictions to the circulation of autonomous vehicles, especially in relation to the circulation of empty cars, as well as by promoting shared mobility solutions, including public transport. In this process, the availability of new individual and shared transport opportunities is to be balanced and the role and organisation of public transport and its supply need to be considered.

PO-22: Link CAD development to EGD objectives to make transport more sustainable

In light of the major challenge posed by climate change and environmental degradation, CAD development and deployment needs to be closely linked to EGD objectives and its added value needs to be assessed in light of the goal to make transport more sustainable. This will require a rethinking of how we organise logistics and mobility, including a move towards efficient mass transport and intermodal freight transport. If EGD policy objectives are mainstreamed at European

[94] ETF-Europe (2020) ETF welcomes MEPs' green light for Mobility Package. See: https://www.etf-europe.org/etf-welcomes-meps-green-light-for-mobility-package/.

and national level, future CAD deployment should be based on shared mobility solutions, as well as freight transport that moves away from road to more efficient modes, such as rail and inland navigation, with only last-mile delivery being done by electric CAVs.

Action is required at the European and national, but also at the local level, as cities will face the challenge of integrating CAVs in their transport system. Policy makers should not be pushed by technology, but should rather ensure that developments, such as CAD, bring added value to the decarbonisation of our transport system, while meeting the expectations of all citizens. Specific measures could be the introduction of (city) tolls or road charging to avoid empty trips, the restriction of the circulation of vehicle types in certain areas to prevent congestion and overall the promotion of electromobility, shared mobility and public transport solutions in connection with CAD development.

7 Towards a social roadmap for CAD deployment

7.1 Preparing, managing and facilitating transition: a social roadmap

In the changing social landscape resulting from the introduction of CAD, transition is introduced as the basis for defining policy options. The implementation of these policy options focusing on employment and fair working conditions would benefit from a coordinated approach resulting in a social roadmap for CAD deployment. The social roadmap intends to operationalise the transition process, mainly by placing policy options in time and allocate tasks and responsibilities in this process.

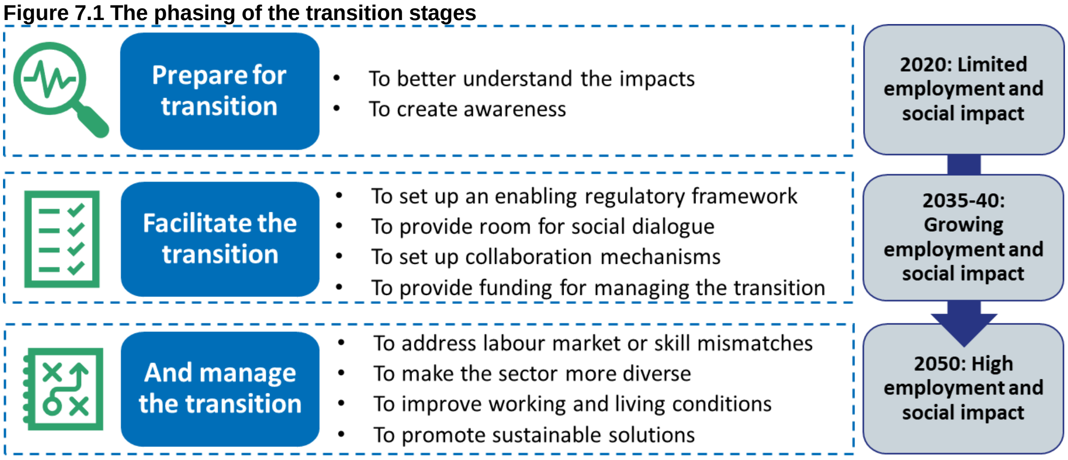
The following guiding principles are applicable in the process towards developing a social roadmap:

- An integrated and holistic approach: the social roadmap covers a variety of challenges and policy options that are interrelated. Understanding of the issues at stake has its effect on awareness, which affects stakeholders to act on the labour market and be involved in training or retraining, etc. In order to deal with the complexity of transition, a holistic approach is needed. This approach goes beyond the employment and social impacts, but also considers other policy areas, such as the European Green Deal, or trends, such as the ageing population and the shared economy;
- A dynamic approach: the social landscape is changing gradually over time and the social roadmap needs to respond to this. Different actions may be needed at different times, as such a dynamic approach is needed. Section 7.2 presents the phased approach;
- Stakeholder commitment: a number of stakeholders are involved, such as workers, companies, authorities at Member State and EU level. CAD introduction affects people employed in road transport services, as well as other sectors, such as car manufacturing and road infrastructure development, as well as the "ordinary" transport user. It is important to mobilise these various stakeholders in developing a social roadmap with broad commitment. It is also important to clearly define ownership, as well as tasks and responsibilities, in developing the social roadmap. The joint responsibility in developing and implementing the social roadmap is presented in Section 7.3;
- Building on existing initiatives and lessons learnt: the social roadmap can build on work carried out, for example in identifying needs, as well as existing initiatives or platforms, already functioning as a means to connect stakeholders, for example the CCAM Single Platform.

7.2 A social roadmap for CAD: a phased approach

There is a natural phasing of the defined transition stages and the policy options included therein. If we consider a short term (2021-2025), a medium term (2025-2035), and a long term (2035-2050) period, preparing the transition would take place in the short term period. Facilitating the transition includes steps to lay the groundwork in the short and medium term. Finally, managing the transition is a continuous process covering the full period up to 2050 (and beyond) and will be especially once the employment and social impacts of CAD unfold, so mainly after 2035. Figure 7.1 illustrates this phased approach.

Figure 7.1 The phasing of the transition stages



Source: Ecorys.

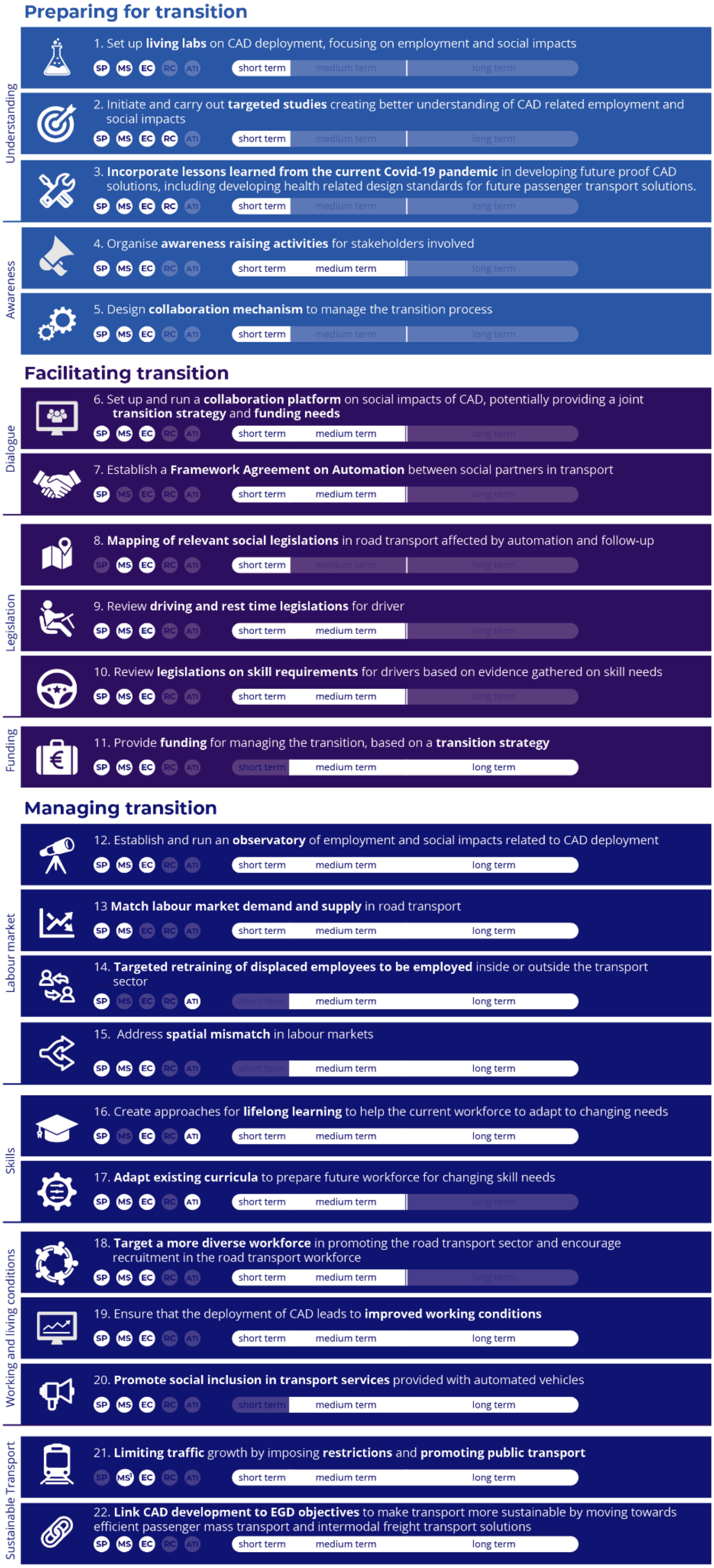
Notwithstanding the full period covered, the policy options could vary substantially though time. For example, in managing the labour market for freight transport workers, the short and medium term focus should be on attracting new workers to close the drivers' shortage gap, while the long term focus should be on (re)training people to be mobility operators or find other jobs in or outside the road transport sector.

The phasing of policy options is presented in Figure 7.2 on the next page. For each of the 22 policy options we present the stakeholders involved distinguishing between the following categories:

- Social partners, i.e. companies and workers (SP);
- Member States, i.e. the national governments and their regional and local authorities (MS);
- European Commission, i.e. decision-makers at the EU level (EC);
- Research community; i.e. scientific researchers on CAD and social aspects (RC);
- And academia and training institutes, i.e. educational institutions (ATI).

It should be noted that close collaboration between all the stakeholders is foreseen, each with their specific roles in the identified policy options. The specific roles are described in the tables further below in Section 7.3.

Figure 7.2 Phasing of policy options, with stakeholder involvement



Source: Ecorys. Note: [1]Includes the involvement of municipalities (For PO-21).

7.3 A social roadmap for CAD: a joint responsibility

Preparing and implementing the social roadmap is a joint responsibility in which different stakeholders play a role. Figure 7.2 indicates the stakeholder involvement in each policy option. In the next sections, the role of each of the defined stakeholder groups is summarised.

7.3.1 Contribution of the European Commission

The contribution of the European Commission in the social roadmap is presented in Table 7.1.

Table 7.1 Social roadmap contribution of the European Commission

Policy option	Description of contribution
Preparing transition	
PO-1: Set up living labs on CAD deployment, focusing on employment and social impacts	• Initiate and support the development of living labs. • Provide technical knowledge, based on setting up living labs in other fields, and provide funding.
PO-2: Initiate and carry out targeted studies creating better understanding of CAD related employment and social impacts	• Develop a R&I agenda (in consultation with Member States and the sector). • Provide funding through available instruments, such as Horizon Europe.
PO-3: Incorporate lessons learnt from the current Covid-19 pandemic in developing future proof CAD solutions, including developing health related design standards for future passenger transport solutions.	• Initiate a dialogue on how to develop future proof CAD solutions, making use of Covid-19 lessons learnt, by bringing together stakeholders. • Support the development of design standards to deal with Covid-19 or other pandemic related health risks.
PO-4: Organise awareness raising activities for stakeholders involved	• Facilitate the communication process by providing access to EC communication channels (website, social media) and funding awareness raising activities
PO-5: Design collaboration mechanism to manage the transition process	• Engage with stakeholders in designing a collaboration mechanism. • Provide support in how to design the collaboration mechanism or platform, based on similar mechanisms and platforms.
Facilitating transition	
PO-6: Set up of a collaboration platform on social impacts of CAD, potentially providing a joint transition strategy and funding needs	• Together with relevant stakeholders, establish a collaboration platform, either new or linked to an existing initiative[95]; • Participate in the development of the transition strategy and establish a link to relevant EU policy initiatives, such as European Green Deal. • Closely monitor progress of the implementation of the transition agenda. Within the platform, specific Expert Working Groups on social aspects can be facilitated.
PO-8: Mapping of relevant social legislations in road transport affected by automation and follow-up	• Review whether social aspects in EU legislation is fit for purpose, as a result of CAD introduction and identify areas where adjustment is needed. • Manage the revision process of EU legislation, where needed.
PO-9: Review driving and rest time legislations for drivers	• Linked to the mapping exercise mentioned above, already prepare for the revision process of this are of EU legislation.

[95] For example the CCAM Single Platform.

Policy option	Description of contribution
PO-10: Review legislations on skill requirements for drivers based on evidence gathered on skill needs	• Linked to the mapping exercise mentioned above, already prepare for the revision process of this are of EU legislation.
PO-11: Provide funding for managing the transition, based on a transition strategy	• Mobilise funding for managing the transition process, based on the inventory of funding needs (see above) and in collaboration with other funding sources (the sector and Member States authorities).
Managing transition	
PO-12: Manage an observatory of employment and social impacts related to CAD deployment	• Provide technical support, based on experiences with similar observatories in which the Commission is involved, and provide funding for setting up and running the observatory. • Develop KPIs and data needs.
PO-15: Address spatial mismatch in labour markets	• Develop programmes to deal with the spatial mismatch, in collaboration with Member States policy makers and the sector.
PO-16: Create approaches for lifelong learning to help the current workforce to adapt to changing needs	• Provide guidance to the sector in ways to provide lifelong learning to the road transport sector workers, based on experiences with similar programmes in other sectors. • Establish platforms for exchange of good practices, and provide funding for developing and implementing lifelong learning programmes.
PO-17: Adapt existing curricula to prepare future workforce for changing skill needs	• Facilitate, where relevant, the development of EU wide standards for curricula, facilitating labour mobility throughout the EU.
PO-18: Target a more diverse workforce in promoting the road transport sector and encourage recruitment in the road transport workforce	• Communicate the merits of working in the sector for younger people, as well as women. • Continue to create platforms in which best practices are shared and can be disseminated to a wider audience.
PO-19: Ensure that the deployment of CAD leads to improved working conditions	• Mobilise knowledge and experience related to linking the introduction of CAD and the change in type of work and skills required to improve working conditions. • Try to mainstream this topic into the living labs.
PO-20: Promote social inclusion in transport services provided with automated vehicles	• Develop accessibility requirements for public transport and taxi services provided with automated vehicles. • Monitor the impact of CAD on special groups and their mobility.
PO-21: Limiting traffic growth by imposing restrictions and promoting public transport	• Establish mechanisms to collect and compare experiences on restrictions and approaches to promote public transport. • Disseminate information on successful application on restrictions and approaches to promote public transport. • Support the process of harmonisation of such approaches.
PO-22: Link CAD development to EGD objectives to make transport more sustainable by moving towards efficient passenger mass transport and intermodal freight transport solutions	• Continue to challenge the transport sector community to making the sector more sustainable and linking CAD to EGD objectives. • Provide continued funding for research and innovations in attractive mass passenger transport services and intermodal freight transport solutions that contribute to EGD objectives.

Source: Ecorys

7.3.2 Contribution of the social partners/the sector

The social partners represent the companies and workers affected by the introduction of CAD. More broadly, this group can be referred to as "the sector", including representatives from companies, business associations, trade unions, professionals' organisations and NGOs. The contribution of the social partners in the social roadmap is presented in Table 7.2.

Table 7.2 Social roadmap contribution of social partners (sector)

Policy option	Description of contribution
	Preparing transition
PO-1: Set up living labs on CAD deployment, focusing on employment and social impacts	• Participate in the process of setting up living labs; mobilise companies, workers and authorities involved; share experiences and good practices in a network of living labs; contribute to funding (also in kind).
PO-2: Initiate and carry out targeted studies creating better understanding of CAD related employment and social impacts	• Provide input in the form of needs and areas in which better understanding is needed.
PO-3: Incorporate lessons learnt from the current Covid-19 pandemic in developing future proof CAD solutions, including developing health related design standards for future passenger transport solutions.	• Contribute to a dialogue on how to develop future proof CAD solutions, making use of Covid-19 lessons learnt at company and individual workers level. • Develop design standards to deal with Covid-19 or other pandemic related health risks.
PO-4: Organise awareness raising activities for stakeholders involved	• Develop an awareness raising agenda, actively participate in awareness raising activities, including making information available through the existing communication channels and hosting events.
PO-5: Design collaboration mechanism to manage the transition process	• Collaborate with relevant stakeholders (Commission, Member States) on designing the collaboration mechanism in the sector.
	Facilitating transition
PO-6: Set up of a collaboration platform on social impacts of CAD, potentially providing a joint transition strategy and funding needs	• Together with relevant stakeholders, jointly establish a collaboration platform. • Based on common needs, participate in the development of transition strategy and action plan and related funding needs • Use the platform to manage the transition and monitor progress of the transition agenda.
PO-7: Establish a Framework Agreement on Automation between social partners in transport.	• Initiate a discussion between social partners on how to address social impacts of the transition towards automated road transport and upon reaching an agreement on a mutually beneficial approach, formalise this in a framework agreement.
PO-9: Review driving and rest time legislations for driver	• Provide input to the Commission and Member States in the revision process of relevant legislation.
PO-10: Review legislations on skill requirements for drivers based on evidence gathered on skill needs	• Provide input to the Commission and Member States in the revision process of relevant legislation.
PO-11: Provide funding for managing the transition, based on a transition strategy	• Mobilise funding for managing the transition process, for example in funding of retraining programmes, taking into account the availability of existing funds (for example sectoral social funds) or creating new funds.

Policy option	Description of contribution
	• Match these funds with other funding sources (Commission and Member States authorities) to come up with a funding mechanism for the defined transition strategy.
	Managing transition
PO-12: Establish and run an observatory of employment and social impacts related to CAD deployment	• Agree with other stakeholders (Commission, Member States) on the role and mandate of the observatory. • Contribute inputs to the observatory, in line with the agreed KPIs and data needs.
PO-13: Match labour market demand and supply in road transport	• Take actions to respond to labour market developments, notably in matching supply to demand, including attracting new workers and/or retrain the existing workforce. • Closely collaborate with labour market intermediaries, notably in reducing structural skill gaps and providing a means towards mobilising a more diverse workforce.
PO-14: Targeted retraining of displaced employees to be employed inside or outside the transport sector	• Companies and the sector to take responsibility in developing retraining programmes for displaced workers. • Displaced workers to actively participate in training opportunities that are provided.
PO-15: Address spatial mismatch in labour markets	• Provide information on the extent of spatial mismatch, as input for developing programmes to deal with the spatial mismatch (by EU and Member States policy makers).
PO-16: Create approaches for lifelong learning to help the current workforce to adapt to changing needs	• Develop a view on the scope of life-long learning programmes, based on changing needs. • Mainstream the concept of life-long learning in road transport companies and organisations.
PO-17: Adapt existing curricula to prepare future workforce for changing skill needs	• Provide input in required (changing) needs in the road transport sector as a basis for adapting the curricula for students, preparing for a career in the sector.
PO-18: Target a more diverse workforce in promoting the road transport sector and encourage recruitment in the road transport workforce	• In order to attract new people to the road transport sector, work on making the road transport sector attractive for more diverse workforce. • Communicate the merits of working in the sector and target younger people, as well as women. Take specific measures to make the work more attractive for women.
PO-19: Ensure that the deployment of CAD leads to improved working conditions	• Use the introduction of CAD and the change in type of work and skills required to improve working conditions, both on the road or in office. • Link this to attracting a more diverse workforce (see PO-18).
PO-20: Promote social inclusion in transport services provided with automated vehicles	• Incorporate accessibility requirements for public transport and taxi services provided with automated vehicles.
PO-22: Link CAD development to EGD objectives to make transport more sustainable by moving towards efficient passenger mass transport and intermodal freight transport solutions	• Develop and invest in attractive mass passenger transport services, taking full advantage of technological innovations. • Develop and invest in innovative intermodal freight transport solutions that contribute to EGD objectives.

Source: Ecorys.

7.3.3 Contribution of the Member State authorities

The contribution of the Member States in the social roadmap is presented in Table 7.3.

Table 7.3 Social roadmap contribution of Member State authorities

Policy option	Description of contribution
	Preparing transition
PO-1: Set up living labs on CAD deployment, focusing on employment and social impacts	• Support the development of living labs by identifying living labs areas (cities or regions); creating an enabling environment for such living labs and provide funding.
PO-2: Initiate and carry out targeted studies creating better understanding of CAD related employment and social impacts	• Develop a R&I agenda at national level and coordinate with the Commission and the sector. • Provide funding through available national instruments.
PO-3: Incorporate lessons learnt from the current Covid-19 pandemic in developing future proof CAD solutions, including developing health related design standards for future passenger transport solutions.	• Participate in a dialogue on how to develop future proof CAD solutions, making use of Covid-19 lessons learnt, Share experiences at national level.
PO-4: Organise awareness raising activities for stakeholders involved	• Support the awareness raising process, by utilising communication channels at Member State level, including campaigns through traditional and social media. Provide funding for awareness raising activities.
PO-5: Design collaboration mechanism to manage the transition process	• Collaborate with relevant stakeholders (Commission, sector) on designing the collaboration mechanism in the sector.
	Facilitating transition
PO-6: Set up of a collaboration platform on social impacts of CAD, potentially providing a joint transition strategy and funding needs	• Contribute to the collaboration platform as representatives from Member State authorities; actively participate in the development of the transition strategy and establish a link to relevant national policy initiatives. • Monitor progress of the implementation of the transition agenda.
PO-8: Mapping of relevant social legislations in road transport affected by automation and follow-up	• Review whether social aspects in Member State legislation is fit for purpose, as a result of CAD introduction and identify areas where adjustment is needed. • Manage the revision process of Member State legislation, where needed.
PO-9: Review legislations on skill requirements for drivers based on evidence gathered on skill needs	• Linked to the mapping exercise mentioned above, already prepare for the revision process of this are of Member State legislation.
PO-10: Review legislations on skill requirements for drivers based on evidence gathered on skill needs	• Linked to the mapping exercise mentioned above, already prepare for the revision process of this are of Member State legislation.
PO-11: Provide funding for managing the transition, based on a transition strategy	• Mobilise funding for managing the transition process, based on the inventory of funding needs (see above) and in collaboration with other funding sources (Commission and Member States authorities).
	Managing transition
PO-12: Establish and run an observatory of employment and	• Agree with other stakeholders (Commission, sector) on the role and mandate of the observatory.

Policy option	Description of contribution
social impacts related to CAD deployment	• Contribute inputs to the observatory, in line with the agreed KPIs and data needs.
PO-13: Match labour market demand and supply in road transport	• Support programmes in making the sector more attractive in order to attract workers (including a more diverse workforce) in case of shortage of workers. • Facilitate the process of downsizing the workforces in line with reduced demand for (certain type of) workers by supporting the natural outflow of workers (retirement) or retraining workers.
PO-15: Address spatial mismatch in labour markets	• Develop programmes to deal with the spatial mismatch, in collaboration with the Commission and the sector.
PO-17: Adapt existing curricula to prepare future workforce for changing skill needs	• Support the process of maintaining curricula in line whit the needs of the sector by participating in educational and academic committees responsible for developing the curricula.
PO-18: Target a more diverse workforce in promoting the road transport sector and encourage recruitment in the road transport workforce	• Develop programmes to attract a more diverse workforce to the road transport sector. • Communicate the merits of working in the sector for younger people, as well as women.
PO-19: Ensure that the deployment of CAD leads to improved working conditions	• Develop programmes linking the introduction of CAD and the change in type of work and skills required to improve working conditions.
PO-20: Promote social inclusion in transport services provided with automated vehicles	• Develop accessibility requirements for public transport and taxi services provided with automated vehicles. • Monitor the impact of CAD on special groups and their mobility.
PO-21: Limiting traffic growth by imposing restrictions and promoting public transport	• Transport authorities, notably at local level, as urban congestion could be negatively affected, need to impose measures to reduce traffic growth, for example by imposing restrictions and promoting public transport.
PO-22: Link CAD development to EGD objectives to make transport more sustainable by moving towards efficient passenger mass transport and intermodal freight transport solutions	• Align national policies, including in CAD deployment, to EGD objectives and invest in attractive mass passenger transport services and innovative intermodal freight transport solutions.

Source: Ecorys.

7.3.4 *Contribution of other stakeholders*

The contribution of other stakeholders such as the research community, academia and training institutes in the social roadmap is presented in Table 7.4.

Table 7.4 Social roadmap contribution of other stakeholders

Policy option	Description of contribution
	Preparing transition
PO-2: Initiate and carry out targeted studies creating better understanding of CAD related employment and social impacts	Research community • Provide high quality research results, based on an established R&I agenda and make results available to create a better understanding of the social impacts of introduction of CAD, helping to prepare for and manage transition.

Policy option	Description of contribution
PO-3: Incorporate lessons learnt from the current Covid-19 pandemic in developing future proof CAD solutions, including developing health related design standards for future passenger transport solutions.	Research community • Carry out research related to future proof CAD solutions, making use of Covid-19 lessons learnt at company and individual workers level, and providing input in developing future policies.
Managing transition	
PO-14: Targeted retraining of displaced employees to be employed inside or outside the transport sector	Academia and training institutes • Develop training and retraining programmes, based on changing needs in the sector and changing skills required. • Provide (re)training programmes to displaced employees.
PO-16: Create approaches for lifelong learning to help the current workforce to adapt to changing needs	Academia and training institutes • Develop an approach for lifelong learning that responds to the need of the sector, for example, in transferring from traditional drivers to mobility operators. Implement programmes and evaluate results, facilitating a continuous improvement process of the lifelong learning process.
PO-17: Adapt existing curricula to prepare future workforce for changing skill needs	Academia and training institutes • Continuously develop and update the curricula based on changing needs as a result of the introduction of CAD.

Source: Ecorys.

8 Synthesis

The deployment of CAD in road transport is an ongoing process, which will take us from current SAE level 2, with drivers support features, to fully connected and automated vehicles, i.e. SAE level 5, in the coming decades. The progress (technical, legal, general acceptance, etc) that will enable CAVs to drive widespread on our roads is expected to take place at the earliest after 2035. Consequently, major impacts on the mobility systems and on employment seem to appear only after 2035. This can be concluded from our consultation with the stakeholders in the sector and the scenario analysis framed by this consultation, as well as through our model-based analysis.

CAD deployment at aggregate EU level is stimulating growth and jobs in scenarios with fast deployment and high penetration of CAVs for private use. Results are mixed for scenarios with slower deployment of CAD and when fostering sharing modes. Looking closer at the details of structural change and employment, our analysis reveals that demand for employment in freight transport could strongly decline after 2035 as a result of fast deployment of CAD SAE level 4 and 5 trucks. In particular, the number of traditional driver jobs is expected to sharply decline, while new demand for mobility operators will emerge, resulting as net effect in less jobs. In passenger transport services, the level of jobs is expected to be maintained, but a conversion from driver jobs to supervision jobs can be expected. For both, freight and passenger services, the number of jobs operating the systems is increasing and the level of IT skills required is also growing. On the one hand, this structural change of jobs in transport services can make the sector more attractive, including an average increase in salaries. On the other hand, it will require re- and up-skilling of the workforce in the mobility sector.

Earlier than for the transport services starts the structural change for manufacturing jobs in the automotive industry, though these changes are by far less drastic. Employment in electronics, computers and IT sectors is increasing from today on for developing the new CAD technology, both for vehicles and for the infrastructure. The increase becomes stronger after 2030 when the manufacturing of SAE level 4 and level 5 vehicles is covering larger shares of the new purchased vehicle fleet. There seem to be a tendency that manufacturing of CAD vehicle technology is regionally much more concentrated than traditional or current vehicle manufacturing in Europe.

The analysis reveals that the transport service sector over the next two decades is expected to face two rather distinct transition periods. In the first decade, a growing shortage of drivers will have to be addressed. Afterwards, with SAE levels 4 and 5 vehicles deployed, a reduction of traditional driver jobs, combined with requirements for re- and up-skilling towards other jobs, including mobility operators, will be the central topic. This against the background of an ageing driver population, with a workforces that is reducing in size due to retirement and a remaining workforce, which needs to be subject to lifelong learning in order to adapt to changing job requirements.

This complex situation needs to be addressed through a holistic transition pathway, to be developed and implemented by the key stakeholders in the process. Our study presents the basis for developing a social roadmap for CAD, including a set of policy options that should be taken in the short-, medium- and long-term. The policies will prepare the transition, for example by enabling knowledge generation in living labs, adapting the legislation where required, etc.; and facilitate and manage the transition towards SAE level 4 and 5, for example by re- and up-skilling of the workforce, monitoring the transition process, etc. In doing so, CAD development needs to be linked to European Green Deal objectives to make transport more sustainable and by moving towards efficient passenger mass transport and intermodal freight transport solutions. Moreover, lessons learnt from the current Covid-19 pandemic needs to be incorporated in developing future proof CAD solutions, including developing health related design standards for future passenger transport solutions.

A core element of a successful transition will be the co-operation and dialogue between industry, and transport workers, as well as authorities and the transport users, which needs to be supported by policy makers at the level of the EU and the Member States.

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