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Status of progress on Connected, Cooperative and Automated Mobility in Europe

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INTRODUCTION

This Commission staff working document (SWD) builds on the 2018 Commission Communication ***On the road to automated mobility: An EU strategy for mobility of the future*** ([1]), which provided research, policy and regulatory recommendations at EU level for the development and deployment of **connected, cooperative and automated mobility** (CCAM). This SWD offers a state of play of CCAM in Europe by taking stock of progress made at operational, technological, societal and economic level since 2018. It also describes **10 main European achievements** in this area to date. This document does not present any recommendations for future developments in this area, thus pre-empting the next framework programme for research and innovation and, therefore, does not commit the Commission in relation to potential forthcoming initiatives or decisions on the successor to the current research and innovation framework programme, Horizon Europe.

([1]) COM(2018) 283 final.

Executive summary

Automation in road transport plays a crucial role in advancing top policy priorities set by the European Commission, such as the greening and digitalisation of our societies, industries and economies. **Cooperative, connected and automated mobility** (CCAM) contributes to this dual transition: its integration into the mobility ecosystem will make transport safer and more inclusive, offering sustainable and accessible solutions while boosting the competitiveness of key European industries.

The European automotive industry accounts for more than **one third of private in research and development (R&D) investment** in the EU, employs **12 million people** ([2]), and generates a trade surplus of more than **EUR 100 billion**. However, fast disruptions around electrification and digitalisation are bringing competitive pressures with new entrants from China and big tech-companies from the United States challenging the European leadership position.

Indeed, the digitalisation of transportation not only optimises traffic flows, but also facilitates the introduction of more **inclusive and shared mobility services**, aiming to decrease the total number of vehicles circulating on our roads. This has the potential to **alleviate urban congestion** (a significant contributor to greenhouse gas emissions, air and noise pollution) and **extend the reach of public transportation** at an affordable price. In addition, the integration of clean technologies into CCAM developments, combined with smart mobility, will further advance the **greening of the transport ecosystem**: together with electromobility, charging infrastructure, smart traffic management, smart grid interoperability, as well as energy storage and management, CCAM will increase efficiency, decrease peak usage of road infrastructure, and reduce CO_2 and pollutant emissions in transport.

As such, the introduction of CCAM solutions is driving **significant growth for new business models and services in both passenger and goods transportation**. This already includes automated shuttles in urban environments, last-mile delivery services, and logistics operations in closed environments.

The transition to automation is expected to place the EU at the forefront of **transformative developments, such as the electrification and digitalisation of mobility, that are likely to reshape the automotive industry**. Given that digital technologies are critical and rapidly developing, the ability of the EU to innovate in the emerging field that is CCAM will most probably determine whether European industry remains globally competitive or falls behind. This holds particular significance considering that Artificial Intelligence and advanced semiconductor technologies, serving as a basis for automation, have been identified as **critical technology** areas for the EU's economic security ([3]). In addition to automation, it would be crucial for industry to invest in **key digital enablers**, in particular next-generation automotive electronic hardware and software platforms and artificial intelligence technologies, leveraging EU initiatives.

([2]) Direct and indirect employment.
([3]) C(2023) 6689 final.

International collaboration is already encouraged to support an incremental shift to CCAM and to accelerate progress worldwide: setting global standards, sharing innovative insights, and addressing cross-border challenges are indeed essential.

In the **2016 Amsterdam Declaration**, Member States urged the Commission to support the transition towards automation in road transportation with a comprehensive strategy at EU level to support the twin digital and green transitions. Acting on this request, the Commission published the Communication ***On the road to automated mobility: An EU strategy for mobility of the future*** ([4]) in 2018. It outlines a set of objectives to be accomplished in subsequent years to position Europe as a global leader in the field of CCAM across transport modes. The main recommendation of the Communication revolved around the need to **coordinate EU instruments at research and regulatory level**, together with private sector engagements and funding programmes within Member States, to accelerate the transformation towards a transport sector that is safer, more resilient, more efficient, and capable of meeting the diverse needs of a population. While placing a strong emphasis on addressing societal, ethical and environmental concerns, it also recommended to set up the **Horizon Europe CCAM Partnership** as an instrument to foster research, development and deployment activities with a focus on innovation, standardisation, and collaboration across stakeholders.

This staff working document (SWD) provides the opportunity to conduct a **reality check** on the objectives set out in the 2018 Communication to ensure that these align with current conditions and developing needs. Indeed, in the last few years, there has been a considerable hype around road automation worldwide, driven by a collective aspiration to achieve widespread deployment of automated vehicles and services by 2030.

However, recent developments have demonstrated that the path towards automation is more complex than expected, due to a challenging and interconnected policy and technology landscape. **Automation in road transportation will most likely be achieved gradually, with a focus on relevant use cases, requiring the commitment of various stakeholders** – from industry to research, and from public authorities to users – to innovate and regulate at the nexus of technology, climate and mobility.

Since the publication of the 2018 Communication, many EU initiatives have been implemented and most of the recommendations from this Communication have been achieved or are under way. This SWD highlights **10 achievements that are bringing Europe closer to the deployment of CCAM**. Although the SWD has a **strong research and innovation (R&I) footprint, the scope of the document is broad**: it covers regulatory, financing and policy actions, technical standards, infrastructure adaptation, as well as data and connectivity initiatives.

Specifically, the SWD covers: 1) the **CCAM Partnership** under **Horizon Europe**, aiming to develop CCAM solutions by 2030 with an overall R&I budget of EUR 1 billion, half of which is funded by the EU, 2) the **EU General Safety Regulation and vehicle type-approval framework for CCAM**, the world's first regulation defining the deployment of Level 4

([4]) https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0283&from=EN

automated vehicles (no drivers on board), 3) **Space for CCAM,** emphasising the role of satellite based services such as Galileo as an enabler for accurate and safe CCAM solutions, 4) the **Intelligent Transport Systems** (ITS) **Directive** revision, along with complementary 5) **Cooperative-Intelligent Transport Systems** (C-ITS) activities, aiming to integrate CCAM into a broader transport system through enhanced interoperability, data management and communication, 6) the **Common European data space for mobility,** bringing together data infrastructures and governance frameworks to facilitate data pooling for trustworthy and secure exchanges, 7) the **Data Act,** enhancing data sharing and data innovation across all economic sectors, facilitating data management and improving the connectivity of automated vehicles, 8) the **Chips Act and Chips JU** aiming to increase domestic production capacity and providing European industries with a more stable and reliable supply of semiconductors, reducing their vulnerability to global supply chain disruptions, 9) the **Artificial Intelligence Act**, a landmark regulation that aims to balance innovation and safety while promoting fundamental rights to advance CCAM development responsibly, and 10) **Connectivity**, which enables seamless communication between vehicles, infrastructure, and other elements of the transportation ecosystem through real-time data exchange. In addition, several **R&I success stories** are highlighted throughout the document, demonstrating the impact of EU investment in CCAM.

Continued multi-stakeholder engagement and coordination at local, national, regional and international level, under the umbrella of the Horizon Europe CCAM Partnership, will advance key enabling technologies, assess societal impact, readiness and expectations, and support large-scale demonstrations across Europe. This will boost investments in CCAM, helping to maintain and extend EU leadership in the transport sector. This SWD does not investigate the potential continuation of the Horizon Europe CCAM Partnership beyond the current multi-annual financial framework.

1. STATE OF PLAY

One major trend in the mobility ecosystem is the emergence of clean, connected, cooperative and automated vehicles. The push for **clean** vehicles is driven by the urgent need to reduce greenhouse gas and pollutant emissions to combat climate change and reduce mortality due to poor air quality. This has led to a surge in electric and hybrid vehicles, which have a reduced environmental footprint. Secondly, the concept of **connected** vehicles revolves around integrating advanced communication technologies to increase safety, efficiency and convenience. Vehicles can communicate with their surrounding infrastructure, enabling real-time data exchange. The **cooperative** aspect extends this idea further, promoting direct collaboration between vehicles to create a harmonised traffic flow, reduce congestion, and prevent accidents. Lastly, the aspiration for **automated** vehicles is becoming a reality with the rapid development of self-driving technologies, promising safety and more efficient transportation systems. These four interconnected trends are reshaping the future of mobility, making transportation cleaner, more sustainable and, smarter, while moving from a driver-centred approach to a user-centred approach.

According to the Society of Automotive Engineers (SAE) classification system for automated driving, automated driving technology ranges from level 0 (no automation) to level 5 (full automation). Level 1-2 vehicles are already available: their features include adaptive cruise control, lane-keeping, lane-centering or lane-changing assistance, as well as assisted parking, while the driver remains responsible for all driving tasks ([5]). Level 3-4 vehicles can perform certain driving tasks under specific conditions and environments, also called its operational design domain (ODD) ([6]), with the driver possibly needing to take over in some situations (at least for level 3). Level 3 vehicles have been commercially available in Europe since 2021 with features available for motorway applications (e.g. traffic-jam autopilot). In addition, trucks, robotaxis ([7]), shuttles, automated valet parking systems, tractors, buses, last-mile delivery and mining vehicles, all with different levels of automation, are already being designed, developed and deployed globally. Yet, despite a certain hype that swept the transport community between 2015 and 2019, and while the transition towards automation in road transportation is becoming a reality under certain conditions, the availability of level 5 vehicles, which can operate without any human intervention, anywhere and anytime, remains a distant possibility due to the significant technical and operational challenges that must still be overcome. Nevertheless, there remains clear potential for optimising the entire transport ecosystem through digitalisation, automation and electrification, to the benefit of both people and businesses in the EU.

([5]) In some cases, even without the need to keep their hands on the steering wheel.

([6]) These represent the 'operating conditions under which a given driving automation system or feature thereof, is specifically designed to function, including but not limited to environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics' (SAE 2021).

([7]) Robotaxis (also known as robo-taxis, self-driving taxis, driverless taxis / ride hailing) are automated vehicles (SAE level 4 cars or vans) operated to provide automated-mobility-on-demand services.

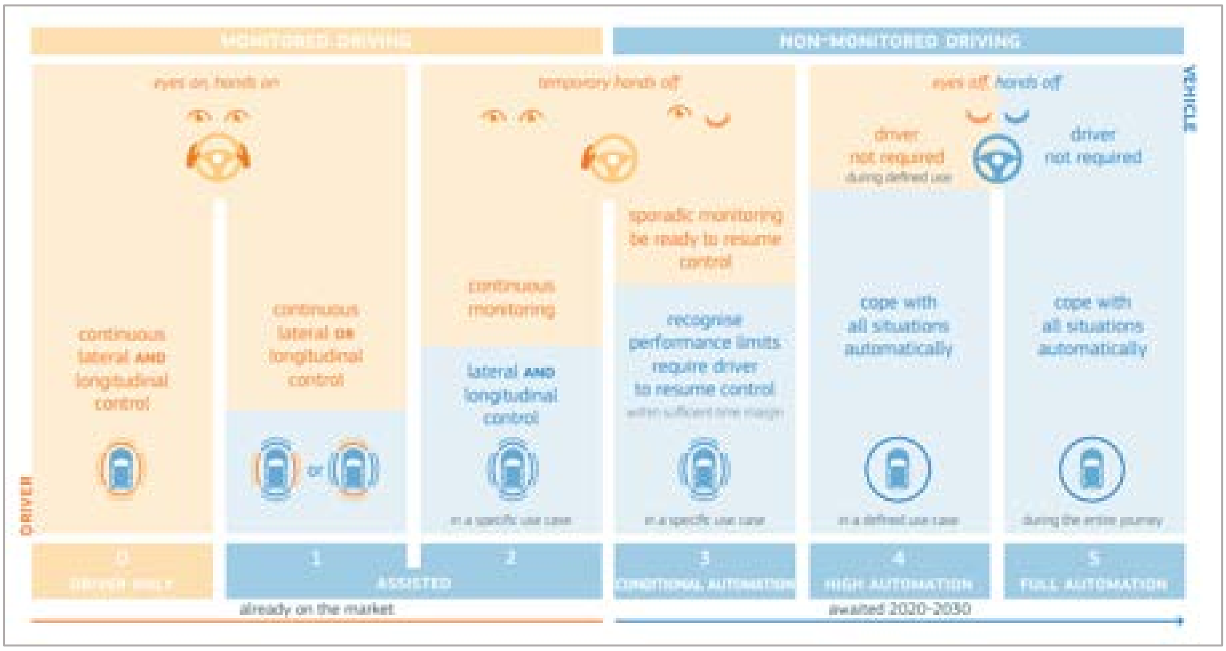

Fig. 1: International levels of driving automation for on-road vehicles set by the SAE (8)

Currently, the EU automobile industry is a leading force in the global market for semi-automated vehicles, specifically level 1-2 vehicles, with plans to steadily advance to levels 3-4 by implementing: (i) large-scale 'highway chauffeurs' on motorways (9); (ii) automated shuttles in urban and peri-urban areas; (iii) automated valet parking services in cities; and (iv) automated logistic and freight transportation in secluded areas. In the transition towards higher levels of automation in mobility, advanced driver assistance systems (ADAS) have played and continue to play a pivotal role as a foundational building block. ADAS refers to a suite of technologies designed to increase vehicle safety and assist drivers in specific tasks, such as collision avoidance, lane-keeping, and adaptive cruise control. It aims to support the driver, who is expected to remain engaged and (legally and operationally) in control of the vehicle. By providing these incremental improvements, ADAS is acting as a precursor to more advanced stages of automation, enabling a seamless transition towards greater autonomy in vehicle operation. Europe has an ADAS-based approach with a systematic progression in its quest to attain higher levels of automation in the field of mobility, with proven safety as a prerequisite to the deployment of any CCAM solution. In Europe, the adoption of the General Safety Regulation (10) accelerated the introduction of advanced driver assistance systems with focus on safety. In 2021, the first level 3 system for highway low-speed driving was made market available. In 2022, the first level 4 automated valet parking application was established in Germany, with plans to expand at European level in the next years.

(8) European Commission, Joint Research Centre, *The future of road transport – Implications of automated, connected, low-carbon and shared mobility*, Publications Office, 2019.

(9) These chauffeurs are level 3 systems that can accommodate a maximum speed of 130 km/h. Type approval of these systems is allowed through UN Regulation 157, applicable in the EU. The GSR provided the legal basis to develop implementing measures to introduce automated vehicles: this was done with the preparation of technical requirements for the approval of L3 systems under UN R157 and of L4 systems under the EU 2022/1426 (ADS Act). For now, vehicles can drive up to 60 km/h on motorways while on traffic jam autopilot.

(10) Regulation (EU) 2019/2144.

At the same time, investment at European level has been focused heavily on moving towards a new mobility ecosystem in which multimodality and shared mobility solutions play a significant role. This has led, among others, to a unique European feature of several start-ups playing a role in the development of vehicles conceived specifically for this new kind of passenger mobility. However, the competition in developing new CCAM solutions is fierce, with tech industries in the US and China investing heavily in scalable solutions, leading, among others, to the massive introduction of robotaxis in urban and peri-urban areas ([11]). The two companies spearheading this effort that are regularly making the headlines are Cruise (a subsidiary of General Motors) and Waymo (owned by Google's parent company, Alphabet), which have been operating their vehicles in specific US states ([12]). In August 2023, the California Public Utilities Commission authorised the two companies to expand their presence, allowing them to operate, charging a fee, on a 24/7 basis ([13]) allowing to gain a better understanding of their possible profitability, which still needs to be demonstrated. Although an incident involving a Cruise vehicle subsequently led to the interruption of all Cruise activities, this decision constitutes a significant milestone in the work to scale up these automated and connected services. Automation in road transportation is also expanding as regards mobility of goods, with the promotion of automated long-haul transportation on motorways, as well as last-mile delivery services in more residential areas. Yet, globally, technical and operational challenges linked to the complexity of urban, peri-urban and rural environments remain, making it challenging to attract significant investment to specific use cases, due to high risk and technical uncertainties.

The green transition, with the electrification of transport, is pulling along the digital transition, redirecting design away from hardware towards software and digital: software content per vehicle almost tripled since 2015([14]). The digitalisation of mobility, supplemented by automation, is thus becoming increasingly important as a strategic pathway to maintain the competitiveness of EU industrial players in the global market. This is true for the development of automated vehicles, smart mobility services as well as electric vehicles. As vehicle capabilities continue to expand, increasingly powerful software, operating systems and electronic hardware will play key roles in enabling these capabilities. On one side, this shift opens the market to highly competitive players, such as new entrants from China and big tech-companies from the United States. On the other side, while EU automotive companies are leading in terms of research and development (R&D) intensity, it is falling behind in information and communication technologies R&D ([15]).

In the future, increasingly connected and automated vehicles will coordinate their manoeuvres by using cooperative systems, but also by using infrastructure support enabling a smart traffic environment for smoother and safer traffic flows, and better consideration of vulnerable road

([11]) Waymo and Cruise, the leading US companies in the field of connected and automated mobility, are deploying robotaxis nationwide.

([12]) Cruise has since been discontinued in San Francisco.

([13])https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-approves-permits-for-cruise-and-waymo-to-charge-fares-for-passenger-service-in-sf-2023

([14]) Cornet A., Heuss R., Schaufuss P., Tschiesner A., A road map for Europe's automotive industry, McKinsey & Company, August 2023.

([15]) Brown D., Flickenschild M., Mazzi C., Gasparotti A., Panagiotidou Z., Dingemanse J., Bratzel S., The Future of the EU Automotive Sector, European Parliament's committee on Industry, Research and Energy (ITRE), 2021.

users (VRUs). This will be, among others, enabled by cooperative intelligent transport systems (C-ITS), which guarantee the exchange of secured and trusted driving-related messages between vehicles and their surrounding environment. C-ITS allows vehicles to access valuable sets of transport and traffic information to enhance safe driving, route planning, and other essential functionalities ([16]).

Europe has also taken the lead in deploying C-ITS on a commercial scale. Today, 50 European cities are deploying C-ITS solutions ([17]), with more than 100 000 km of European roads already covered. These smart solutions can, for example, control traffic lights to increase the efficiency of priority vehicles and reduce their response time. Overall, these trends suggest that, in the long term, the cost of a vehicle will increasingly be driven by its software, operating systems, and electronics. Therefore, companies in the mobility and automotive industry will need to focus on cost-effective ways to develop and integrate these technologies into their vehicles to remain competitive on a global scale. In this respect, intelligence and information provided by the road infrastructure (for example, C-ITS units) can supplement on-board hardware and intelligence. The EU industry currently boasts close to 50% of the global car electronics market, with software based on EU standards present in 70% of cars worldwide.

Likewise, EU industries need to stay at the forefront of advancements made in artificial intelligence (AI) to achieve higher levels of automation and cooperation. The rapid development of AI-based technologies and tools – together with Internet of Things, 5G networks and services, edge computing, processing technologies, and data-driven engineering – are essential for developing automated and cooperative vehicles. AI is driving automated vehicles, collecting and processing very large amounts of sensor data from the environment to make decisions. This requires an extensive amount of training to develop robust AI algorithms. The development and operation of automated vehicles thus depends on extremely powerful computing capacities, resulting in a growing demand for high-performance processors and a shift to more centralised vehicle electronic architectures. Electric vehicles also rely heavily on electronic sensing, computing capacities, and advanced software functions. New vehicle architectures must allow electric and automated vehicles to use their resources efficiently to address these various needs. AI is also crucial for vehicle-human interaction with applications such as voice or gesture recognition, improving safety and travel experience. Digital technologies have the capacity to implement advanced prediction and planning systems and optimise traffic, support real-time multimodal travel planning and management, and enable better maintenance of infrastructure. Furthermore, digital technologies play a key role in achieving transport decarbonisation and improving safety by supporting smart grids and digitally connected charging infrastructures.

These complementary technologies provide great potential to accelerate the development of automated vehicles and services. However, their application in the transport sector relies on complex interactions and interdependencies that necessitate timely innovations across various sectors (e.g. digital, energy), including vehicles, infrastructure, logistics, and business models. Synergies with enablers like electronic components, sensing and processing technologies, and

([16]) Today, more than 1.5 million cars providing C-ITS services are in circulation.
([17]) Ongoing work of the C-Roads working group on urban C-ITS deployment. See Urban C-ITS contest: C-Roads.

data-driven engineering would be essential, as these enablers operate on different time scales and innovation paths, as well as various innovative business models like mobility as a service (MaaS) ([18]) and logistics as a service (LaaS) ([19]). Furthermore, the application of AI in transport brings new challenges related to reliability, trust, ethics, security, data protection, privacy, and other human rights. A more harmonised approach at EU level would accelerate transformation, modernise industry and reduce market fragmentation in the long term. In this regard, the European public-private partnerships supported under the European research and innovation (R&I) framework programme, Horizon Europe, are helping to maximise synergies and cross-fertilisation across relevant sectors ([20]).

The need to embrace digital and connected solutions, software development, and advancements in AI poses technical and investment issues to European original equipment manufacturers (OEMs). One challenge is related to the need to maintain in-house expertise to keep up with a rapidly changing technological landscape. In addition to these technical challenges, the cost of entry into the market for automated vehicles is remarkably high and continues to rise ([21]). The race towards clean, connected, cooperative and automated mobility, punctuated by a recurring hype cycle ([22]), is requiring massive private and public investments before profitable, real-world solutions can be deployed. The increasing use of digital tools in combination with advancing technologies has changed the mobility offering for end users, whether these are individual drivers, professional drivers, or mobility and logistics service providers. This brings about aspects such as human factors, user acceptance and human-technology interaction. One of the most critical topics related to advancing levels of automation is handover of control. The input of non-technical expertise from social sciences and humanities is of growing importance to ensure that technological solutions and subsequent service offerings are beneficial and inclusive to all.

To address these challenges, EU car manufacturers are increasingly collaborating with well-known technology companies and suppliers ([23]). Additionally, EU carmakers are currently significantly dependent on non-EU suppliers for critical components such as AI-based technologies, software, cloud services, and semiconductors. Today, the US is leading in vehicle research and chips ([24]), while China leads in public cloud services ([25]). The EU is leading in connectivity services for all vehicles, but it needs to remain competitive and keep pace with the US and China when it comes to digital services. The recent shortage of semiconductors has

([18]) MaaS is a type of service that, through a joint digital channel, enables users to plan, book and pay for multiple types of mobility services. The concept describes a shift away from personally owned modes of transportation and towards mobility provided as a service.

([19]) LaaS represents the main stages of a supply chain, from the factory to the end customer. They include transportation from manufacturer to warehouse, warehousing and order fulfilment, and delivery to the end customer.

([20]) Under Horizon Europe's climate, energy and mobility cluster, transport-oriented European Partnerships are supporting the energy and mobility sectors in becoming climate- and environment-friendly, smarter, safer, more resilient, inclusive, competitive, and efficient. This is supplemented by the programme's digital, industry and space cluster, which aims to shape competitive and trusted technologies for a European industry with global leadership in key areas such as advanced computing and big data, AI, advanced materials, and key enabling technologies.

([21]) Estimated investments for automated vehicles range from EUR 1.5 billion to EUR 15 billion per typical car manufacturer with a tech-oriented approach. Uber sold its autonomous vehicle research unit, Advanced Technologies Group, to the self-driving start-up Aurora for approximatively USD 4 billion in December 2020.

([22]) https://www.sae.org/news/2020/09/2020-hype-cycle-for-connected-vehicles-and-smart-mobility

([23]) For example, Daimler is working with Nvidia, Waymo is partnering with FCA and Volvo, and VW is collaborating with Microsoft.

([24]) Specifically, AI and software technologies (e.g. Waymo).

([25]) Such as Pony.ai operations in Beijing.

highlighted the vulnerabilities in the supply chain of European producers, which are heavily dependent on Asian subcontractors. Closer collaboration between EU car manufacturers and technology companies could help navigate these challenges and stay competitive in the global marketplace. Moreover, AI and advanced semiconductor technologies, serving as a basis for automation (including in transportation) have been identified as critical technology areas for the EU's economic security ([26]). Safeguarding European interests when developing these technologies is paramount, taking into account the potential risks associated with the dissemination of these innovations for malicious purposes.

Against this background, the Chips Joint Undertaking ([27]) (Chips JU, previously Key Digital Technologies Joint Undertaking) stands as a significant European initiative to foster collaboration among key players from the automotive industry, research institutions, and technology companies to position Europe at the forefront of these emerging technologies, mainly pooling resources and expertise ([28]). Additionally, the 2023 Chips Act ([29]) aims to incentivise the set-up and expansion of semiconductor manufacturing facilities in Europe. The Act's primary goal is to increase domestic production capacity, thus providing European industries – including automotive, electronics, aerospace, and telecommunications – with a more stable and reliable supply of semiconductors, helping to reduce their vulnerability to global supply chain disruptions, like in the case of the recent chip shortage. Encouraging innovation and collaboration among academia, research institutions, and private companies will benefit European industries but also drive economic growth and job creation in the region.

EU manufacturers enjoy a competitive advantage in vehicle architectures, having been leaders in this area for some time. With the transition towards clean, cooperative, connected and automated vehicles, they could continue to leverage this strength. An initiative led by European car manufacturers and tier 1 suppliers, AUTOSAR ([30]), has been at the forefront of car system architecture and is now used by over 80% of the global automotive industry. Europe thus would have a significant role to play in shaping the future of the car industry. By building on existing strengths, such as AUTOSAR, and by continuing to lead in areas such as C-ITS, the EU could maintain its competitive edge in the face of rapidly changing technological challenges. Nevertheless, the legacy architecture of traditional vehicles, which has been the norm for decades, could no longer be sufficient in the face of emerging technologies used in CCAM. As the car industry shifts towards these new technologies, a new supportive architecture or 'next-generation operating system' could be required based on collaboration not just among automotive manufacturers and suppliers, but also with large digital platform companies. Until recently, work in this area remained fragmented, and the rise of value creation by digital companies carried a risk for Europe, which could lose its ability to manage the entire value

([26]) C(2023) 6689 final.
([27]) See Chips JU – Starter Portal (europa.eu).
([28]) This requires a highly skilled workforce with expertise in various disciplines such as electrical engineering, materials science, and computer science. Therefore, it is essential to ensure a steady pipeline of talent and to foster collaboration between academia and industry.
([29]) For more information, see Chips Act.
([30]) AUTOSAR is a worldwide development partnership of vehicle manufacturers, suppliers, service providers and companies from the automotive electronics, semiconductor and software industries. It aims to set an open industry standard for automotive software architecture.

chain. The global automotive software and electronics market is expected to grow at 5.5% per year until 2030, ultimately reaching an estimated market value of USD 462 billion ([31]).

To address these challenges and ensure that the Chips JU also considers key industrial sectors such as the European automotive industry, the Vehicle of the Future initiative, driven by industry, was launched to support two closely related initiatives: the development of a RISC-V-based automotive hardware platform ([32]), and the set-up of an open software-defined vehicle ecosystem driven by European automotive companies and suppliers. This vertically integrated approach is expected to increase efficiency by avoiding redundant non-differentiating developments. This would enable Europe to stay competitive and retain a significant role in the value chain for connected and automated mobility. It is expected to also provide new architectures to support the vehicles of the future with functional updates made possible by an independent and consistent development of software and hardware ([33]).

Finally, fostering competitive European value chains must benefit the clean energy transition and the decarbonisation of transport and industry. Indeed, the energy and mobility sectors are closely interlinked: together they cause the largest part of greenhouse gas emissions in the EU – the energy and transport sectors represent 54% and 24% of emissions, respectively ([34]). Decoupling the environmental impacts of these sectors from economic growth and achieving deep decarbonisation would be crucial to create a more sustainable future. In this regard, new mobility solutions like CCAM could play an important role. They optimise traffic flow and reduce the total number of vehicles on roads, especially in urban environments, which helps to decrease congestion and energy consumption. Furthermore, implementing automated mobility solutions is expected to lead to smoother driving patterns and better traffic management, resulting in a decreased collective carbon footprint (e.g. fewer air pollutant emissions including reduced particulate emissions from unnecessary braking and interaction of tires with road surfaces) and less noise pollution. The integration of CCAM into the entire transport ecosystem would support the transition of urban ecosystems to become cleaner and more efficient, thus improving the quality of life, and health, of people in cities and communities.

([31]) https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/mapping-the-automotive-software-and-electronics-landscape-through-2030
([32]) The RISC-V ecosystem is an open standard Instruction Set Architecture and source of technologies and expertise that can support and enable automotive compute development.
([33]) https://digital-strategy.ec.europa.eu/en/library/concept-paper-open-european-software-defined-vehicle-platform
([34]) According to the European Environment Agency.

2. POLICY CONTEXT AND STRATEGIC FRAMEWORK

Since 2018, the EU has embraced the challenge of capturing the potential of CCAM to make transport safer, smarter and more sustainable, to the benefit of society, the environment and the economy. In May 2018, under the umbrella of the wide-ranging '**Europe on the Move**' ([35]) package centred on road, vehicle and pedestrian safety, and answering to the request from Member States put forward in the **Amsterdam Declaration of 2016** to support the transition to automation in transport, the Commission adopted a dedicated Communication ***On the road to automated mobility: An EU strategy for mobility of the future*** ([36]). The strategy outlined a comprehensive and ambitious agenda to position Europe as a global leader in the field of CCAM across transport modes. Through a combination of regulatory, financing and policy measures, the strategy focused on developing critical technologies, services and infrastructure to boost the EU's competitiveness. The aim is to make the overall transportation sector safer and more robust, directly helping to achieve the EU's Vision Zero objective of reducing the number of severe accidents on European roads by 2050 ([37]). Furthermore, the strategy aimed to set a harmonised legal and policy framework at EU level to support Member States and industry in deploying advanced technologies and innovative mobility services. Finally, it placed a strong emphasis on addressing societal, ethical and environmental concerns to ensure a just and equitable transition for all.

The Communication proposed a dedicated EU approach to the development of automated driving technologies and their integration into the transportation system. The Communication addressed the potential benefits and challenges of and strategies for gradually deploying automated vehicles on European roads. It aimed to create a common framework for Member States to work together in ensuring the safe and effective adoption of these technologies. The Communication covered aspects such as regulatory alignment, technical standards, stimuli for R&I, infrastructure adaptation, data and connectivity management, and the involvement of various stakeholders, including industry, research, public authorities, and users. It emphasised the importance of ensuring the safety of automated vehicles, the need for international cooperation, and the potential for automated mobility to help bring about more sustainable and efficient transportation systems across Europe.

The recommendations from the Communication mainly aimed to coordinate EU instruments – both in research ([38]) and at regulatory level ([39]) – with private sector engagement and funding programmes within Member States, to accelerate transformation and maximise impact. Among others, this implied: (i) adapting the existing General Safety Regulation ([40]) to provide additional safety requirements for automated vehicles; (ii) setting up national access points

([35]) Europe on the Move factsheet.
([36]) COM(2018) 283 final.
([37]) The Vision Zero initiative aims to move towards zero fatalities and serious injuries on European roads by 2050. It is supported by a policy framework for 2021-2023 and a strategic action plan on road safety that outlines key measures on governance, funding, roads, vehicles, road use, emergency response, emerging challenges, and the global role of the EU to reach this vision.
([38]) Horizon Europe and the Digital Europe Programmes being prime examples. The Connecting Europe Facility is also a relevant and supplementary funding programme, which focuses on deployment.
([39]) Mainly the General Safety Regulation and the Intelligent Transport Systems Directive.
([40]) Regulation (EU) 2019/2144.

(NAPs) ([41]) to increase transport data accessibility for use in Intelligent Transport Systems (ITS) ([42]); (iii) setting a framework for vehicle data sharing that would enable fair competition in the provision of services in the digital single market, as well as compliance with data protection legislation; and, most importantly, (iv) understanding the societal, ethical and environmental impacts of automated mobility in the medium to long term. This is particularly relevant to the already mentioned user-centric approach to future mobility solutions, fully reflecting people's needs, concerns and expectations.

In 2020, the Commission adopted its **Sustainable and Smart Mobility Strategy (SSMS)** ([43]), together with an action plan of 82 initiatives ([44]) to help the entire EU transport system achieve its green and digital transformation and become more resilient to future crises. As outlined in the European Green Deal, the strategy lays the foundation for moving towards a **90% cut in greenhouse gas emissions by 2050**, delivered by a smart, competitive, safe, accessible and affordable transport system. The below three flagships under the initiative are especially relevant to CCAM development:

- Flagship 6 – Making connected and automated multimodal mobility a reality.
- Flagship 7 – Innovation, data and Artificial Intelligence for smarter mobility.
- Flagship 10 – Enhancing transport safety and security.

The vision behind the strategy is to allow people to enjoy a seamless multimodal experience throughout their journey, through a set of sustainable mobility choices, increasingly driven by digitalisation and automation. Under the **SSMS**, some key interim targets include the large-scale deployment of automated mobility across transport modes and at least 30 million zero-emission cars in operation on European roads by **2030**. The ambition for **2050** builds on these targets: nearly all cars, vans, buses, and new heavy-duty vehicles to become zero-emission, and a fully operational, multimodal trans-European transport network (TEN-T) ([45]) for sustainable and smart transport with high-speed connectivity.

In addition, the **SSMS** identifies the deployment of Intelligent Transport Systems (ITS) as a key action in achieving connected and automated multimodal mobility. ITS combine new developments based on CCAM but also in the field of mobility as a service (MaaS). Indeed, CCAM transforms the driver into a user of a shared fleet of vehicles, fully integrated into a multimodal transport system made seamless by multimodal digital mobility services such as MaaS. ITS deployment improves the functioning of the whole transport system by better informing transport users (e.g. safety-related traffic information services) and enabling a safer, more coordinated and smarter use of transport networks. Building on existing synergies (such as eCall[46]) with the General Safety Regulation, ITS complements and provides support to advanced driver assistance systems that use increasing levels of automation. The Commission

([41]) These are digital interfaces set up by Member States that act as a single point of access to mobility-related data, which are published and made available for use (e.g. in travel information services).
([42]) Action plan and Directive (europa.eu).
([43]) COM(2020) 789 final.
([44]) Annex to COM(2020) 789 final.
([45]) Trans-European Transport Network (TEN-T) (europa.eu).
([46]) The interoperable EU-wide eCall (europa.eu).

Communication ***A European strategy for data*** ([47]) announced the revision of the ITS Directive, including some of its delegated regulations, which was approved in October 2023. This represents a major achievement in increasing data availability and setting up a stronger coordination mechanism for NAPs ([48]) to support the provision of EU-wide interoperable travel and traffic services to end users.

In March 2021, as part of its 2030 Digital Compass Communication ([49]), the European Commission identified mobility as one of the five key ecosystems with the greatest digital transformation potential for Europe. This potential relies on digital connectivity solutions for connected and automated mobility. To unleash this potential and achieve the digital targets for connectivity, the **Digital Decade Policy Programme 2030**, adopted in December 2022 ([50]), provides the basis for the initiation of a multi-country project (MCP) for pan-European deployment of 5G corridors. 5G corridors provide an uninterrupted deployment of 5G systems along transport paths – particularly road, rail and waterways – to ensure continuity of quality service that meets the stringent requirements for connected and automated mobility (i.e. low latency, high throughput, high reliability and security) across EU internal borders. The MCP, coordinated by the Smart Networks and Services Joint Undertaking (SNS JU), enables large-scale projects by pooling public and private resources and providing guidance on deployment scenarios and cooperation models. This guidance relies on the adoption of the 5G Strategic Deployment Agendas for road transport, based on input received from stakeholders and endorsed by the main European industry associations (including telecom, automotive, road operators and infrastructure managers).

Since the publication of the **2018 Communication** and the **SSMS**, many EU measures have been implemented and most of the recommendations set out in the Communication have been achieved or are under way. The following chapter will highlight **10 of the main achievements** to date that are bringing Europe closer to the deployment of CCAM.

([47]) COM/2020/66 final.
([48]) NAPCORE | National Access Point Coordination Organisation for Europe.
([49]) COM(2021) 118 final.
([50]) Decision (EU) 2022/2481 of the European Parliament and of the Council of 14 December 2022 establishing the Digital Decade Policy Programme 2030.

3. 10 EUROPEAN ACHIEVEMENTS

The CCAM Partnership and Horizon Europe

The 2018 Communication pushed for a closer alignment between research, regulatory and policy, which led to the set-up of a single EU-wide platform grouping all relevant public and private stakeholders together to coordinate open road testing of CCAM ([51]). The platform, which gathered a total of almost **400** public and private experts, provided advice and support to the Commission in the form of a final report. In line with the 2018 Communication, the main outcome of the platform was the creation of a new European Partnership on CCAM under Horizon Europe, together with the publication of a Strategic Research and Innovation Agenda (SRIA) for CCAM. The SRIA 'provides a flexible background for identifying and defining call topics for research and innovation activities to be included in the Horizon Europe Work Programmes. It also serves as a basis to develop shared activities with national programmes and other Horizon Europe Partnerships' ([52]). This SWD is intended to supplement and not overlap with the Partnership's SRIA. While the SRIA is a forward-looking document within the time frame of Horizon Europe (2021-2027), this SWD is a retrospective description of key accomplishments in the field of CCAM since the adoption of the 2018 Communication.

Overall, the SRIA proposes a comprehensive roadmap that is expected to: (i) allow the Partnership to accelerate the transition towards vehicle automation through R&I; (ii) make it possible to reach deployment readiness by 2030; and (iii) allow CCAM stakeholders to move towards next investment phases (industrialisation, competitive development, and infrastructure deployment) ([53]). As of early 2024, the CCAM Partnership brings together over **200** key stakeholders from across the following areas: automotive industry, mobility and logistics providers, research organisations, public authorities, and representative and regulatory bodies. These stakeholders are members of the CCAM Association, which represents the private side of the CCAM Partnership, while the EU represents the public side ([54]).

The activities, objectives, timeline and resources of the Partnership are structured according to seven key R&I clusters (see Figure 2), which all converge towards the implementation of large-scale demonstrations of CCAM systems and services (Cluster 1). These large-scale demonstrations build on virtual simulations to enable testing of vehicle capabilities under real conditions, putting in practice harmonised driving scenarios and methodologies and exploring wider and long-term impacts.

([51]) With the aim of making the link between testing and pre-deployment activities.
([52]) CCAM SRIA.
([53]) CCAM SRIA.
([54]) Partnerships between the EU and industry intend to bring project results closer to the market uptake and improve the link between research and societal growth. Public-private partnerships take the form of joint undertakings (JUs), European Technology Platforms (ETPs) or contractual public-private partnerships (cPPPs). The CCAM Partnership is a contractual public-private partnership.

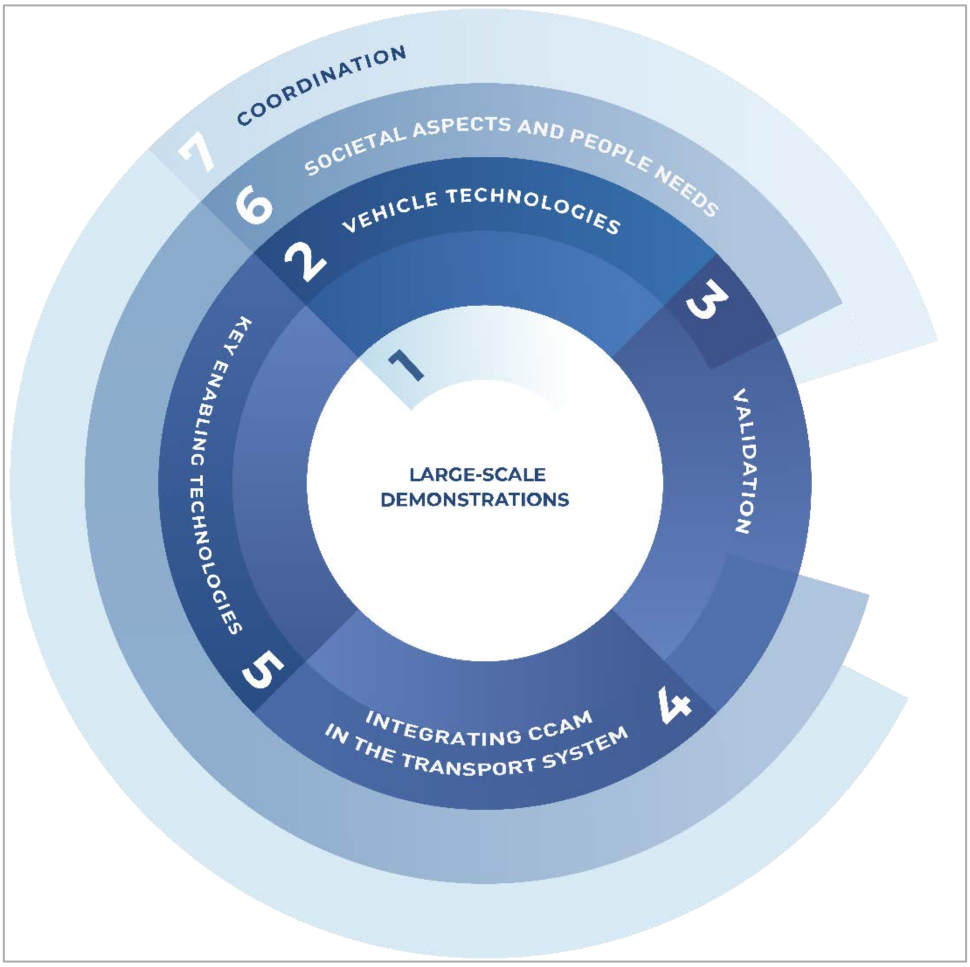

Fig. 2: CCAM Partnership R&I clusters ([55])

a) Scope and activities

The Partnership covers passenger and freight transportation and supports the integration of innovative mobility concepts into the broader transport system, such as public transport, MaaS and LaaS platforms. As such, the Partnership aims to develop inclusive mobility solutions for individuals unable to drive, such as those who are incapacitated, disabled, or without a driving licence, as well as those who choose not to drive. Moreover, through the implementation of automated transport solutions, CCAM has the potential to provide safe and low-health-risk services for vulnerable populations, including viable options for the delivery of goods, especially crucial during public health crises like the COVID-19 pandemic. The shift from a driver-oriented approach to a mobility-user-oriented approach is clear: the Partnership aims to put into practice the **Sustainable and Smart Mobility Strategy** ([56]) For this purpose, a substantial amount of funding is reserved to implement large-scale demonstrations of inclusive and shared mobility services to test combined technologies in complex driving environments, with advanced levels of automation (towards level 4).

([55]) https://www.ccam.eu/our-actions/clusters/
([56]) In particular, the wide deployment of automated driving solutions across Europe by 2030 (Flagship 5).

While recognising that most of the investment in CCAM will come from the private sector, the EU provides significant stimuli for CCAM R&I under its Horizon Europe framework programme, as recommended in the 2018 Communication. Already under the Horizon 2020 framework programme for 2014-2020, a total budget of EUR 300 million was allocated to support automated mobility R&I. Under the Horizon Europe framework programme (2021-2027), and since the set-up of the CCAM Partnership, 19 projects have been launched, with a total value of EUR 159 million. The related calls for proposals take place under the **climate, energy and mobility** cluster of the programme, which aims to accelerate the twin green and digital transitions of the energy and mobility sectors to achieve climate neutrality in Europe by 2050. In total, EUR 1 billion has been allocated to CCAM R&I at EU level until 2027, half of which is funded directly by the EU. Indeed, in addition to the EUR 500 million of EU funding, CCAM Association partners have made a steadfast commitment to providing equal annual investments, notably through in-kind additional activities (IKAAs). These activities are supplementary to projects funded through EU grants. These IKAAs hold strategic significance to EU-funded activities in the pursuit of the overarching objectives of the CCAM Partnership. As of 2023, the total value of IKAAs carried out under the CCAM Partnership amounted to EUR 260 million, surpassing initial projections of EUR 160 million, underlining the leverage effect of the partnership towards private sector funding to supplement EU support.

Since its launch in June 2021, the CCAM Partnership has been cultivating innovation by harnessing the strengths of diverse stakeholders, from private businesses that drive technological advancements, to public authorities, road operators, and public transport providers that will implement the resulting technologies. This collaboration has fostered the exchange of ideas, research findings, and best practice, mostly to accelerate and align development timelines and ensure regulatory compliance, aiming to deliver market-ready solutions. Strengthening the competitiveness of European industries through technological leadership and ensuring long-term growth and jobs are among the key objectives of the Partnership. Simultaneously, the Partnership also ensures a holistic view of and a user-centric approach to the development of CCAM systems, by providing expertise at technical, operational and policy level, while assessing the short- to long-term impact at societal, economic, or environmental level. The Partnership aims to incorporate public-private perspectives, address societal concerns, and to align with market-driven insights and user experiences from the entire stakeholder community. This synergy is expected to yield technologies that are secure, sustainable and attuned to public expectations, providing innovative solutions that further solidify the competitive edge of relevant stakeholders engaged in CCAM.

A European success story: The long journey towards automation in road transportation

Over the past two decades, EU-funded projects have played a critical role in propelling road transportation from driver assistance systems to the cusp of automation. The inception of the EUREKA Prometheus project in the mid-1980s marked the beginning of intensive research into advanced driver assistance systems (ADAS). This early work paved the way for subsequent transformative projects like **PReVENT** and **DRIVE C2X**, which laid the foundation for CCAM development.

Acknowledging the fast-changing nature of the automotive industry, the significance of these European initiatives cannot be underestimated. Global competition, particularly from China and the US, posed a challenge to European carmakers, compelling them to reinvent themselves in the face of shifting paradigms in vehicle power, driving and ownership.

Throughout the 2000s, successive flagship projects shaped the course of vehicle automation, emphasising enabling technologies, human factors, extensive field operational tests (FOTs), and real-life demonstrations. **EuroFOT**, **InteractIVe**, **AdaptIVe**, **L3Pilot** and **Hi-Drive** played instrumental roles in bringing automation closer to market introduction. They validated the safety and feasibility of automated driving functions, spanning from partial to conditional and high automation levels.

The impact of these projects on technology development and safety has been profound. The introduction of ADAS technologies into New Car Assessment Programme tests has demonstrated their potential to reduce accidents and save lives. Studies suggest that the deployment of these systems can prevent or mitigate up to 1.8 million crashes annually worldwide, significantly improved road safety.

However, technical challenges persist, necessitating fool-proof environment perception systems, improved sensor capabilities, and robust AI integration for higher levels of automation. Moreover, understanding user behaviour, fostering public acceptance, and addressing legislative and liability issues remain critical factors in the journey to full automation. As various roadmaps set ambitious targets for vehicle automation, collaboration across multiple stakeholders would be essential. Public-private partnerships have formed a dynamic ecosystem of CCAM development, encompassing OEMs, tier 1 to tier 3 companies, research institutions, legislators, insurance providers, and more.

EU-funded projects have been instrumental in propelling road transportation from driver assistance to automation. Their achievements have shaped the technology landscape, improved road safety, and fostered a collaborative ecosystem that drives CCAM development forward. However, challenges remain to address technical complexities, gain user trust, and create an environment conducive to successful automation implementation.

Cross-fertilisation in the field of R&I with other European partnerships and programmes could accelerate progress in CCAM. But research alone is not sufficient to ensure the deployment and implementation of CCAM solutions to support the green and digital transition of the transport sector. Additional investments, mainly from the private sector, are still needed to build on the outcomes of these research activities and to capitalise on the full potential of automation, electrification and digitalisation in mobility, towards implementation and deployment.

b) Thematic R&I areas for CCAM

As recommended in the 2018 Communication, the CCAM Partnership supports the set-up of European collaborative projects through R&I initiatives under Horizon Europe to advance CCAM technologies and solutions. Since 2018, more than EUR 279 million ([57]) has been dedicated to specific CCAM projects, covering the seven key thematic R&I clusters of the Partnership (see table below), which are reflected in the SRIA and proposed in the 3rd Mobility Package ([58]) of 2018. This includes tools for safety validation, physical and digital infrastructure support, traffic management, developing key enabling technologies, advancing in-vehicle perception, and understanding user needs and socio-economic impacts. These projects act as building blocks to achieve the integration of higher levels of automation into road transportation. The SRIA continues to support these activities by providing intermediary objectives, actionable steps, and key performance indicators that are essential for gauging progress in the field.

Cluster 1: Large-scale demonstrations. The objective of Cluster 1 is to continuously implement results of all other clusters in large-scale demonstrations in pilots, FOTs and living labs. By doing so, it aims to support deployment readiness and a final impact assessment.

Cluster 2: Vehicle technologies. This cluster aims to deliver the most efficient and effective future solutions that have been proven to be safe and reliable. For Europe's future mobility and transport system, significant technical R&I challenges must be overcome. This is because tomorrow's highly automated vehicles will rely on advanced solutions to 'sense-think-act', enabling safe interaction with other road users and providing protection in case of an emergency, while also ensuring the well-being of vehicle occupants.

Cluster 3: Validation. This cluster will provide the procedures, methodologies and tools that are needed to validate, verify and rate CCAM systems, in terms of technology and related to the human factors handling the technology. This will include suitable metrics and references for system behaviour and performance.

Cluster 4: Integrating CCAM into the transport system. R&I projects in this cluster will advance the physical and digital infrastructure support for CCAM vehicles by improving connectivity and cooperation between stakeholders. This will support the integration of CCAM vehicles into the overall transport system to strengthen fleet and traffic management systems.

Cluster 5: Key enabling technologies. AI, big data and cybersecurity will support the whole mobility system consisting of vehicle technologies, which will help integrate CCAM vehicles into the transport system, as well as validate all aspects of the entire system.

([57]) Of which EUR 120.2 million to Horizon 2020 projects under Automated Road Transport and Mobility for Growth calls launched in 2018, 2019 and 2020, and EUR 158 8 million to Horizon Europe projects under calls launched in 2021 and 2022.

([58]) https://ec.europa.eu/newsroom/move/items/631809/en

Cluster 6: Societal aspects and people needs. This cluster provides all other clusters with a framework for understanding and considering the needs of users and the general public, and societal aspects of mobility. Methods and measures for societal impact assessment will be developed and applied to the final societal impact assessment based on the large-scale demonstrations of Cluster 1.

Cluster 7: Coordination. This cluster coordinates all CCAM stakeholders and activities, facilitates knowledge exchange, and promotes lessons learned.

c) Large-scale demonstrations

One of the main objectives of the Partnership is **to implement large-scale demonstrations of user-centric and inclusive automated driving solutions all over Europe by 2030**. These demonstrations play a crucial role in advancing the technology and ensuring its safe and efficient integration into future European transport solutions. Large-scale demonstrations provide a platform to showcase the capabilities and potential of automated driving systems to a wide audience. By presenting the technology in action, these demonstrations create awareness and foster public understanding of its benefits, while also attracting support and investment from relevant stakeholders. These demonstrations also facilitate the collection of user feedback and engagement with various stakeholders, including policymakers, researchers, industry representatives, city authorities, and the public. By involving end users, developers gain insights into user acceptance, usability, and user experience, which are essential for refining the technology and aligning it with societal needs and expectations. In this respect, to maximise the positive impact of the testing activities, it is essential for local stakeholders to take ownership of the testing itself. As such, demonstrations will mainly be taking place in cities, regions, and other specific areas, answering to specific mobility needs and challenges.

Furthermore, large-scale demonstrations enable rigorous testing and validation of automated driving systems in real-world environments. By subjecting the technology to diverse and challenging scenarios, developers can identify and address potential issues, improve system performance, and improve safety. This iterative process is crucial for building confidence in the technology’s reliability and robustness. Finally, large-scale demonstrations also play a vital role in shaping policy and regulatory development. By observing the performance of automated driving systems in practical settings, policymakers and regulators can make informed decisions to support the development and deployment of automated mobility solutions, based on concrete evidence. This helps in developing appropriate regulations, standards and guidelines that ensure the safe and responsible deployment of automated driving systems across Europe.

In August 2023, a new global standard (ISO 34503) ([59]) was issued, outlining a methodology for specifying operational design domains (ODDs) to support the development of automated vehicles worldwide. The significance of ODDs is underscored in the latest EU act on automated driving systems ([60]), which was adopted in August 2022. This act places the notion of ODD at

([59]) https://www.iso.org/standard/78952.html
([60]) Regulation (EU) 2022/1426.

the core of the safety of automated vehicles. Expanding the ODD will help determine when and where an automated vehicle can operate safely, reducing the risk of accidents and misuse. Well-defined ODD helps to improve monitoring, make handover safer, and ensure compliance with regulations, ultimately making on-road automated driving safer. Collaboration also makes it possible to set up shared testing facilities, which can reduce costs and make testing and evaluation processes more efficient. Similar approaches are under consideration for forthcoming United Nations Economic Commission for Europe (UNECE) regulations. This international standard empowers automated vehicle developers and manufacturers globally to design and test their technology in line with universally accepted safety benchmarks. It enables them to create accurate marketing and communication materials and, ultimately, foster the needed public trust in this technology. Numerous experts from various entities worldwide were involved in shaping the new standard, and key individuals responsible for standardisation under the EU-funded project Hi-Drive played a direct role. This involvement, facilitated by the CCAM Partnership, guarantees synergy and consistency between research and regulatory work.

Organising large-scale demonstrations involves substantial costs and demands significant resources. Addressing the intricate and multifaceted challenges at hand goes beyond the mere development of technologies. The European Partnership on CCAM provides for a systemic approach that engages multiple sectors and a diverse ecosystem of stakeholders, allowing to coordinate R&I across Europe, thereby facilitating the industry's transformation and accelerating the pace of innovation.

Figure 3 presents the development of large-scale EU-funded demonstrations of automated shuttles in urban environments ([61]).

([61]) Also relevant are the Fabulos and Ride2Autonomy EU projects.

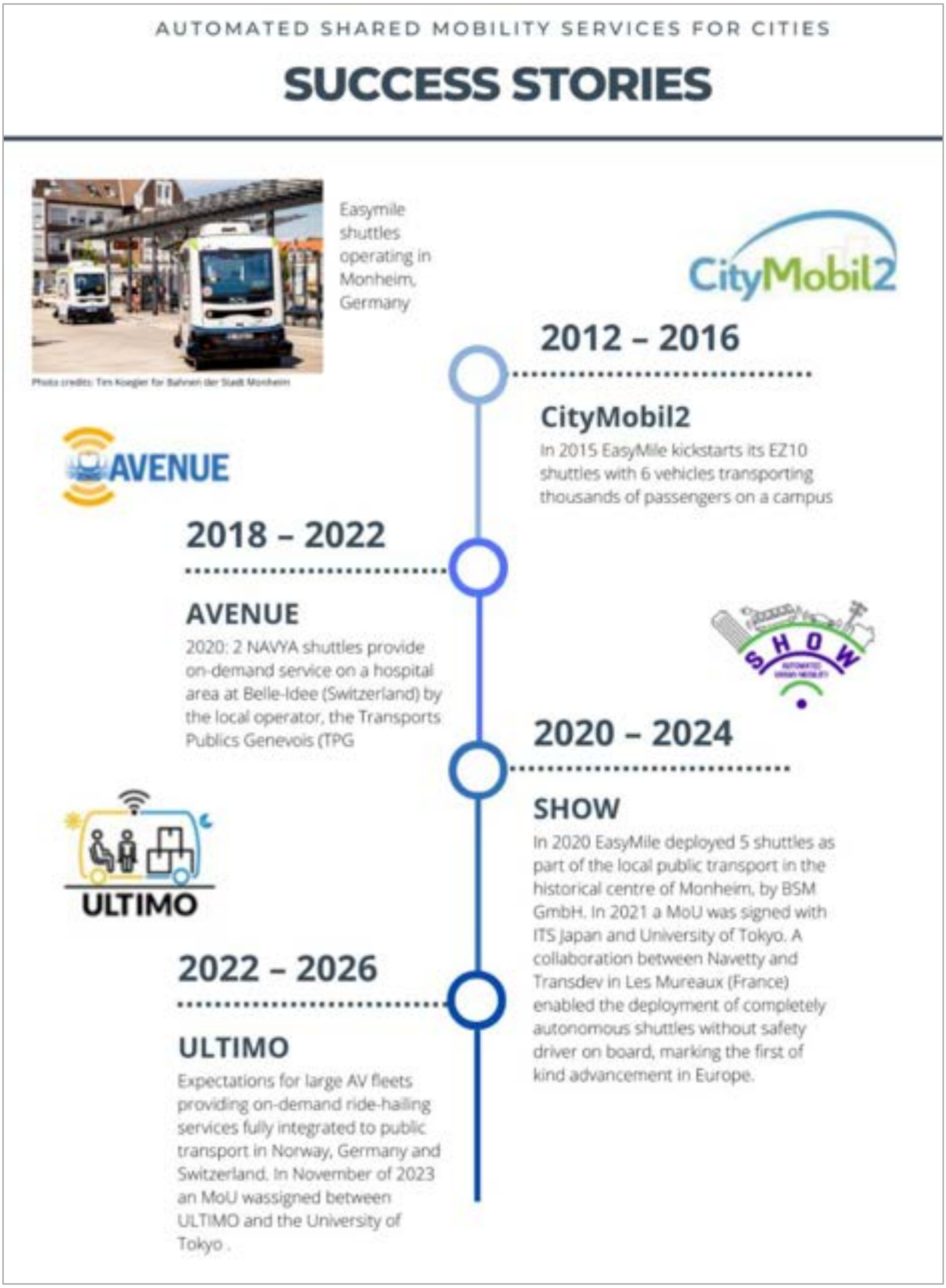

Fig. 3: Demonstrations of shared automated solutions in urban areas

EU General Safety Regulation and vehicle type-approval framework for CCAM

As recommended in the **2018 Communication**, the Commission updated its General Safety Regulation (GSR, Regulation (EU) 2019/2144) in July 2022. This update introduced a set of mandatory ADAS functions to improve road safety and set a legal framework for the approval of automated and connected vehicles in the EU. The GSR is progressively introducing safety features to assist drivers, covering various kinds of road vehicles, until 2029.

In addition to the GSR, the Commission also developed technical rules for connected and automated vehicles: (i) at global level, in UNECE working groups, which focus on automated vehicles that can replace the driver on motorways (level 3); and (ii) at European level, in the Automated and Connected Vehicles subgroup of the Working Group on Motor Vehicles (MVWG-ACV), which focuses on fully automated vehicles, such as urban shuttles or robotaxis (level 4). As a result, the new EU type approval framework now includes the below rules for connected and automated vehicles.

- Regulation UN 157, for the approval of level 3 highway driving. This has covered low-speed lane-keeping applications (highway traffic-jam pilot) since 2020, and lane-changing applications at high speed (up to 130 km/h, also known as highway chauffeurs) since 2022.

- Regulations (EU) 2022/1426 and (EU) 2022/2236, for the approval of level 4 fully automated vehicles – the first international rules of their kind. They set out a comprehensive methodology to assess the safety and maturity of fully automated vehicles before they can be placed on the EU market. These technical rules cover testing procedures, cybersecurity requirements, data recording as well as monitoring of the in-use safety performance and incident reporting requirements by manufacturers. The subsequent type approval of shuttles, robotaxis, automated valet parking (AVP) and hub-to-hub applications can be granted under the small series scheme (i.e. up to 1 500 vehicles per type per year).

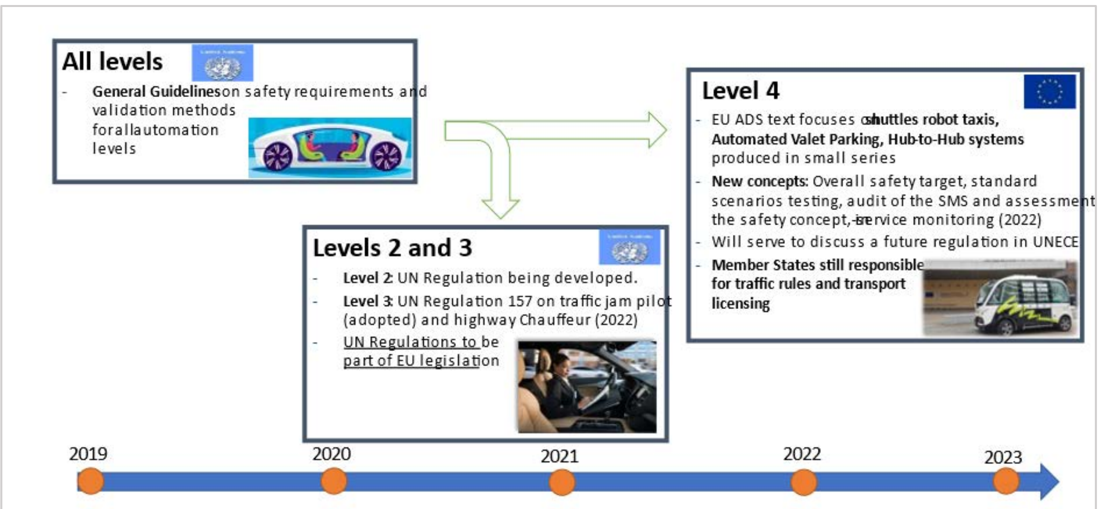

Fig. 4: Timeline of recently adopted EU and UNECE type approval legislation

The EU is also involved in drafting the new UNECE regulation on driver control assistance systems, which addresses the approval of advanced assistance systems (level 2) not yet covered by existing regulations. The regulatory work has been divided into two phases – the first one was to be completed by the end of 2023 and the second one is to be completed by the end of 2024.

Furthermore, the Commission is involved in the development of general high-level safety requirements and validation methods (i.e. not specific to a certain level of automation), which is ongoing at UNECE level. This is part of the regulatory work taking place within the UN, aiming to issue a global regulation for connected and automated vehicles ([62]). The Commission's involvement helps ensure full alignment between the technical rules adopted so far in the EU and the approaches developed at the UN, boosting EU industry's competitiveness at global level.

At EU level, work is currently ongoing on the preparation of an interpretation document for the Automated Driving Systems Regulation ([63]). The innovative open-regulation approach offers the flexibility to address complex and varied automated driving systems, also keeping the pace with future technological developments. However, as a drawback, the high-level description of requirements and assessment methods could lead to different interpretations. Therefore, the interpretation document aims to guide applicants and authorities to ensure consistent application of Regulation (EU) 2022/1426 across Member States. At the same time, the Commission – together with Member States, industry, academia, and other MVWG-ACV stakeholders ([64]) – is working to lift the small series limitation, starting with the automated valet parking (AVP) use case. A new annex with dedicated technical rules for AVP is under development and will be part of the first series of amendments to the type-approval regulation. In parallel, the Commission is also collecting evidence on the safety performance in real environments of the first approved AVP system in Germany. Furthermore, it is changing relevant technical regulations that are not applicable to automated driving systems yet, as described in Regulation (EU) 2022/2236, which will allow manufacturers to move from small to unlimited series approval.

These regulatory developments represent fundamental enablers for the development of CCAM and the deployment of related services. Legal certainty for automated-vehicle requirements and validation methods provide industry with a clear framework to be used when developing their systems and products. An upcoming fundamental step for CCAM will be the update of national rules to enable the deployment of connected and automated vehicles on the roads. Today, in most Member States, connected and automated vehicles can only be deployed as part of demonstrations or research activities, or under exception schemes. This could jeopardise investments in the field, as any new deployment in the real world requires lengthy procedures.

European R&I activities and projects also play a fundamental role in the development of the regulatory framework. The evidence gathered through the activities of the JRC Living Lab for

([62]) This work will start in 2025.
([63]) Regulation (EU) 2022/1426.
([64]) Documents discussed in the MVWG-ACV can be downloaded from the public CIRCABC repository.

Future Mobility Solutions or EU-funded projects such as SHOW, Hi-Drive and L3Pilot ([65]) have been essential for assessing the robustness of the requirements and the validation methods introduced by EU type approval legislation. To some extent, these EU CCAM projects become *de facto* regulatory sandboxes that play a significant role in policymaking and regulatory developments at both European and national level, with their lessons learned being used to develop a comprehensive framework for the deployment of automated vehicles on European roads.

Space for CCAM

The 2018 Communication called for the further development of Galileo services and related vehicle navigation technologies to offer improved accuracy and trust levels for automated mobility. Galileo, the European global navigation satellite system (GNSS), is a major, state-of-the-art asset supporting CCAM, providing absolute positioning of the vehicle, which in combination with other sensors and up-to-date digital maps provides extremely accurate real-world performance and reliability. Galileo is under civilian control and independent from other systems, offering Europe and its people levels of performance beyond those of other satellite constellations. In the last few years, Galileo and its unique services have developed considerably to be able to play a role in the development of new and emerging technologies such as CCAM, in a safe and secure manner.

Indeed, Galileo's High Accuracy Service (**HAS**) ([66]), in operation since January 2023, is a precise point positioning (PPP) service, providing real-time positioning corrections worldwide via the Galileo signal in space and via the internet, for both Galileo and other global navigation systems such as the global positioning system (GPS). Galileo is the only GNSS to provide such service worldwide for free – it is available to anyone with a suitable receiver. For CCAM, the benefit of high accuracy and high-precision positioning is crucial for the safe and reliable operation of its vehicles. The implementation of HAS, in combination with other sensors, constitutes a complete and robust positioning and navigation system that brings the necessary edge to CCAM in terms of increased safety. This relates to the capability of HAS to provide a positioning service with a sub-decimetre accuracy for free, but also its reduced convergence times with respect to other PPP services.

Galileo's Open Service Message Authentication (**OSNMA**) ([67]), which is planned for operation in 2024, will provide data authentication for geolocation information from Galileo. This will increase the capability to detect spoofing attacks, which are intentional malicious broadcasts of false GNSS signals aiming to deceive the receiver, resulting in an incorrect computation of the position or timing. Galileo is currently the only constellation with such a soon-to-be-deployed service, which, once rolled out, will strengthen the overall security of any given application, including cooperative, connected and automated driving. The importance of

([65]) More information is available here: SHOW, Hi-Drive and L3Pilot.
([66]) For a detailed description of HAS, guidance for the optimised use of the service, as well as other relevant and up-to-date documentation, see the programme reference documents, stored in the European GNSS Service Centre repository.
([67]) For a detailed description of OSNMA, guidance for the optimised use of the service, as well as other relevant and up-to-date documentation, see the programme reference documents, stored in the European GNSS Service Centre repository.

this layer of protection in CCAM was recognised in UN Regulation 155 on cyber security and the cyber security management system ([68]), which requires the verification of GNSS message authenticity and integrity to mitigate the threat of spoofing, which will add to the system's overall robustness and resilience.

On future developments, the new EU satellite constellation **IRIS² ([69])** (Infrastructure for Resilience, Interconnectivity and Security by Satellite) will provide a space-based connectivity system offering increased communication capacities via satellite. IRIS² will help provide even more reliable and secure connectivity for connected and automated vehicles.

While GNSS empowers a range of different traffic management services (as mentioned above), Copernicus – the Earth observation component of the European Union's Space programme – supports the planning, design, construction, and monitoring of road infrastructure by drawing from satellite Earth observation and in-situ (non-space) data. Copernicus data are used by service providers to support solutions offering regular monitoring, alert services, as well as decision-making support systems to a range of stakeholders, including road authorities and operators, civil protection agencies and maintenance teams.

The European Geostationary Navigation Overlay Service (EGNOS) is Europe's regional satellite-based augmentation system (SBAS), which is used to improve the performance of GNSS, such as Galileo (in the future). As such, EGNOS ensures safety-of-life navigation services for users of aviation, maritime, and land-based transports. EGNOS is essential for applications where accuracy and integrity are critical, such as civil aviation, for which approximately 1,000 EGNOS-based procedures are available at some 500 airports and helipads in Europe, while allowing for worldwide interoperability.

ITS Directive– public and private data sharing for connectivity and data availability

As automated vehicles, depending on the use case, are still at the beginning of their development, finding the optimal balance between technological advances both within and surrounding the vehicle and the support provided by the physical and digital infrastructure remains an open question. Stringent requirements on the physical infrastructure that require major updates or investments in public infrastructure would face significant budgetary restrictions. However, there are more accessible business cases to be made for investing in digital infrastructure, ensuring a collaborative exchange of data between vehicles and road authorities, and developing ever more advanced intelligence transport systems (ITS) services. Digital information can play an important role in supporting decision-making in automated vehicles (AVs), particularly in handling edge cases or extending the digital horizon beyond the line of sight of on-board sensors. At the same time, data collected by AVs will help infrastructure operators and owners in managing road networks, as well as authorities in achieving policy targets on safety, efficiency and sustainability, by providing better mobility services to users. Building digital infrastructure and exchanging data will increasingly gain

([68]) https://unece.org/transport/documents/2021/03/standards/un-regulation-no-155-cyber-security-and-cyber-security
([69]) Regulation (EU) 2023/588.

importance, supplement the physical infrastructure, and become a strong enabler for road safety and the development of connected, cooperative and automated vehicles.

The revision of the ITS Directive ([70]) is a key pillar for building a digital road infrastructure. ITS and cooperative ITS (C-ITS), combined with advances in automated-vehicle technologies, are not just strong enablers but an integral part of CCAM services. Their use in transport data exchange allows vehicles to be connected to the mobility ecosystem in their immediate vicinity (other vehicles, infrastructure) and to the wider mobility ecosystem (central traffic management systems, other modes of transport, etc.). The ITS Directive is a framework that fosters cooperation and sharing of essential digital transport information between industry, infrastructure operators, mobility providers, authorities, and users. This will, in turn, create opportunities for integrating AVs into an inclusive multimodal transport system, as reflected in the **SSMS**.

The ITS Directive has been the EU's main tool for identifying the crucial data that support the provision of EU-wide interoperable travel and traffic services to end users, based on European specifications and standards. It has set up a European framework for providing access to ITS data via the national access point (NAPs) of each Member State, now coordinated by the NAPCORE project ([71]). The revised ITS Directive strengthens this by mandating the collection of crucial datatypes across the entire scope of the Directive, including real-time traffic information, safe and secure parking for heavy goods vehicles and multimodal traffic information, as well as the provision of essential services on road safety-related events.

Improving the interoperability of road and traffic data across the EU is expected to facilitate the seamless interpretation of traffic regulations by AVs as they cross international borders. AVs stand to gain significant advantage when equipped with comprehensive road-related information, right from the initial stages of trip planning. However, for AVs to navigate routes effectively and adapt their actions in real time, a rapid exchange of machine-readable data with various stakeholders in the transportation network would be needed. The availability of extensive ITS data and associated services empowers traffic management systems, making them more intelligent and responsive. In practical terms, this means a heightened capacity to avoid potentially hazardous situations, promote smoother traffic flow, and mitigate congestion.

Hence, the exchange of digital data is a key enabler for advancing CCAM and smart mobility solutions. Yet, its full potential is largely untapped. Harnessing this potential requires finding new business and governance models involving relevant stakeholders – public and private – to foster collaboration and collectively develop the digital infrastructure for our roadways. In the next years, progress is expected on several essential legislative proposals from the Commission to set the enabling conditions for such a collaboration, in line with the EU objectives of safe, sustainable and multimodal mobility for Europeans.

([70]) Directive (EU) 2023/2661 of the European Parliament and of the Council of 22 November 2023 amending Directive 2010/40/EU on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport (OJ L, 2023/2661, 30.11.2023).
([71]) NAPCORE | National Access Point Coordination Organisation for Europe.

C-ITS and integration of CCAM into the broader transport system

Vehicles designed to communicate with the infrastructure will give traffic managers better insight and greater control to manage traffic in their cities. At the same time, infrastructure can support these vehicles, particularly in difficult or non-standard situations such as road works. Vehicles can also exchange messages among themselves, allowing them to give advance warnings of potentially dangerous situations. This type of cooperative communication allows all traffic participants to share information that they would otherwise not have – often in real time – and provides the ability to see around the corner and avoid the line-of-sight limitation of all visual sensors. That is why C-ITS would be a key pillar in making road transport smarter and safer and helping to prepare for higher levels of automation.

The recently revised ITS Directive recognises this importance. Its fourth priority area is entirely dedicated to C-ITS and enabling CCAM. As part of this, the ITS Directive specifies services such as those set out in Table 1. It also defines the essence of C-ITS, which is the ability of any two traffic participants to exchange information without any prior knowledge. Making this possible requires trust between traffic participants through a system that provides this trust. This system is the EU C-ITS security credential management system, which was mandated by the 2018 Communication and first piloted by the JRC ([72]). The ITS Directive ensures that the central roles of that system are executed.

'Day 1' C-ITS services	**'Day 1.5' C-ITS services**
• Slow or stationary vehicles and traffic ahead warning • Road works warning • Weather conditions • Emergency brake light • Emergency vehicle approaching • Other hazard notifications • In-vehicle signage • In-vehicle speed limits • Signal violation / intersection safety • Traffic signal priority request by designated vehicles • Green light optimal speed advisory • Probe vehicle data • Shockwave damping	• Information on fuelling and charging stations for alternative fuel vehicles • Vulnerable road user protection • On-street parking management and information • Off-street parking information • Park & ride information • Connected and cooperative navigation into and out of the city (first and last mile, parking, route advice, coordinated traffic lights) • Traffic information and smart routing

Table 1: C-ITS services (source: A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility[73]*)*

([72]) The JRC has delivered this pilot (2018-2022), through funding by a CEF programme support action, which has covered the design, implementation, operation and evaluation of EU C-ITS security credential management system. The JRC will operate the production of this system in 2024 under the legal basis provided by the revised ITS Directive to support large-scale C-ITS deployments in the EU.

([73]) COM(2016) 766 final.

The main reason why C-ITS is an enabler for CCAM services is its capacity to allow transport infrastructure, vehicles, and other road users to communicate and coordinate their actions. If the vehicle can receive trusted C-ITS messages from the surrounding vehicles and infrastructure, no matter which communication infrastructure is used, it has more information available to make the right decision in ever more complex traffic situations. Examples such as vehicles warning each other of potentially dangerous situations (e.g. emergency braking or a risk of crashing into the end of a traffic jam) and communicating with local road infrastructure (e.g. traffic lights equipped with radars) require C-ITS to move from passive and active safety to cooperative safety. Ultimately, C-ITS will allow vehicles and road operators to increase predictability and orchestrate ever more complex manoeuvres.

C-ITS has been in development for many years and large-scale commercial deployment started in 2019. The C-Roads Platform ([74]) was launched in 2016 to promote Member States' cooperation on standards for cross-border harmonisation and interoperability of C-ITS services (see Table 1).The C-Roads Platform is also developing common requirements for digital representation of physical infrastructure and making digital traffic regulations available via C-ITS. This proves that C-ITS is one of the most technically and organisationally developed digital infrastructures of today, able to welcome both future CCAM services and current achievements in supporting automation.

The updated SRIA of the CCAM Partnership highlights the importance of deploying C-ITS services for the integration of highly automated vehicles into future multimodal mobility services: 'Interaction with infrastructures, road and telecommunication infrastructure as well as automotive backend infrastructure is crucial for the success of the system integration. Both elements of physical and digital infrastructure are important, in particular building a common understanding of what is required, how it can be achieved, and which roads should be prioritised with a view towards implementation'.

Common European data space for mobility

As stated in the **SSMS**, the Commission will propose measures to build a common European mobility data space (EMDS) ([75]) to facilitate access to, as well as pooling and sharing of data from existing and future transport and mobility data sources. On 29 November 2023, a Communication ([76]) announced the objectives, supporting measures, milestones, and a proposed way forward. The creation of a common EMDS will help to better integrate CCAM services into the transport system. For example, linking energy consumption data and data from connected vehicles is expected to accelerate the uptake of AVs and their potential to provide smart mobility services for users. Another example is interlinking vehicles with tourism data to offer on-demand mobility services to newcomers in congested areas of tourist destinations or popular events.

([74]) C-Roads Platform. More than 20 C-Roads projects were funded by the Connecting Europe Facility Transport programme in 18 Member States across Europe to prepare roads for connected vehicles and provide C-ITS services based on a hybrid communication approach set out in the European C-ITS strategy. See COM(2016) 766 final.

([75]) Adopted as part of the Passenger Mobility Package on 29 November 2023.

([76]) COM(2023) 751 final.

Under the Digital Europe programme, a preparatory coordination and support action made an inventory of existing data-sharing initiatives and recommended building blocks for the EMDS, including for CCAM ([77]).

Data Act

On 14 January 2024, the Data Act entered into force ([78]). It aims to boost the EU's data economy by: (i) laying down rules on access and use of data generated by connected products; (ii) fostering a competitive and reliable European cloud market, introducing mechanisms for public sector bodies to access and use data held by the private sector in cases of exceptional need; and (iii) providing measures to promote the development of interoperability standards for data sharing and processing. The combined effect of the Data Act and the Data Governance Act (Regulation (EU) 2022/868), particularly against the background of the anticipated increase in data sharing facilitated by data intermediaries, is expected to play a role in the creation of a EU single market for data ([79]).

Notably, building on the access and portability rights of personal data by individuals under the GDPR, the Data Act is expected to further empower users of connected products, by giving them the right to access and use all the data generated by the products they own or lease. It is expected to also benefit the manufacturers of these products, by ensuring a stable, principle-based framework that increases legal certainty, respects their investment, and protects their trade secrets from being misused. Finally, the Data Act is expected to also increase the supply of data to the market, benefiting companies that need access to data to provide services (e.g. maintenance, insurance, data analytics). Such providers will be able to access data either directly from the users of connected products or from the data holders, who will now be compelled to share data on request of the user. In addition, unfair terms in data-sharing agreements will be eliminated, benefiting companies with less bargaining power, such as SMEs and start-ups.

By laying down horizontal principles on data access and use and by tackling obstacles to data sharing in the EU single market, the Data Act aims to strengthen data sharing and data innovation within and across all economic sectors, including the mobility sector. Vehicles constitute an important category of connected products in scope of the Data Act. Accordingly, vehicle data would become more easily available to service providers, researchers and consumers for innovative use and reuse within the common EMDS, including as part of the deployment of CCAM.

([77]) This coordination and support action is called PrepDSpace4Mobility. A follow-up project, deployEMDS, started in the fourth quarter of 2023.
([78]) Regulation (EU) 2023/2854 on harmonised rules on fair access to and use of data..
([79]) Without compromising cross-border data flows.

Chips Act and Chips Joint Undertaking

As highlighted in the first chapter, semiconductor chips are the essential building blocks of digital products. They determine the performance characteristics of digital systems, including security and energy-efficiency aspects. They are also crucial for essential digital technologies that will become ever more important, such as AI, 5G and edge computing. In 2021, the value of the global chips market was approximatively USD 550 billion. By 2030, it is expected to exceed USD 1 trillion. However, the importance of the semiconductor sector lies in its interdependence on other sectors. The chips shortage of the past 2 years has affected many key European industries and has brought the strategic importance of the semiconductor sector to public attention. In the automotive sector, this was illustrated by a deficiency of 11.3 million cars that were not produced in 2021 due to the shortage of chips, relative to initial global projections. This cost the automotive industry about USD 210 billion in lost revenue in 2021.

These shortages have highlighted Europe's dependence on the supply of chips from a limited number of companies and regions. Semiconductor manufacturing has become increasingly concentrated, and the EU is highly dependent on places such as South Korea and Taiwan, especially to produce the most advanced nodes ([80]). From a geostrategic point of view, the semiconductor sector is very much in the spotlight. Semiconductors increasingly determine the ability of countries to act militarily, economically, and industrially. All major international players are massively investing in this sector, aiming to secure their supply of the most advanced chips. For instance, China, India, Japan, South Korea, Taiwan, and the US all have specific initiatives with public support in place.

The European Chips Act entered into force in September 2023 ([81]). It aims to ensure Europe's resilience and technological sovereignty in semiconductor technologies and applications. It is not a quick fix to ongoing shortages, but a way to secure Europe's green and digital transitions and to better mitigate future crises. The Chips Act brings together three different policy areas: R&I, industrial policy, and crisis management. Specifically, under the Act, the **Chips for Europe Initiative** will support technological capacity building and innovation in the EU. It will set up large-scale infrastructures – such as pilot lines, a design platform and competence centres – to facilitate research into, development and tests of, experimentation with, and validation of new technologies. On pilot lines specifically, through the Chips Act, the Chips Joint Undertaking (Chips JU) will deploy a series of world-leading infrastructures covering topics such as leading-edge nodes, heterogeneous integration and fully depleted silicon on insular (FD-SOI), all vital and relevant technologies for the future of the automotive industry. This addresses the current lack of capacity in the European industry and research communities to support industrial innovation and bring products to the market.

The initiative will be implemented by the Chips JU, the successor to the Key Digital Technologies Joint Undertaking (KDT JU). The Chips JU will support R&I in semiconductor technologies to address the needs of vertical market sectors – mobility, energy, telecommunications, security, defence, and space – that help achieve the EU's green and digital objectives.

([80]) SWD(2021) 352 final, *Strategic dependencies and capacities*.
([81]) Regulation (EU) 2023/1781 for a framework to strengthen Europe's semiconductor ecosystem.

In the area of mobility, vehicles have become increasingly connected and automated, with software playing an ever more important role in overseeing operations and facilitating the introduction of innovative features. The software platform – encompassing operating systems and middleware, positioned between hardware and applications, and its seamless integration into the cloud – is pivotal in the ongoing transformation of vehicle electronic architectures towards more centralised models. This transformation is reshaping the way software is conceived, integrated, and maintained, and is a key enabler for CCAM.

The increased autonomy, electrification and connectivity of vehicles make traditional distributed vehicle electronic architectures untenable to network increasingly interdependent electronic control units together due to overall complexity, latency and scale of the wiring harness, amongst other limitations. Therefore, next-generation vehicles are expected to have a central gateway processor and several domain or zonal processors as seen in Figure 5.

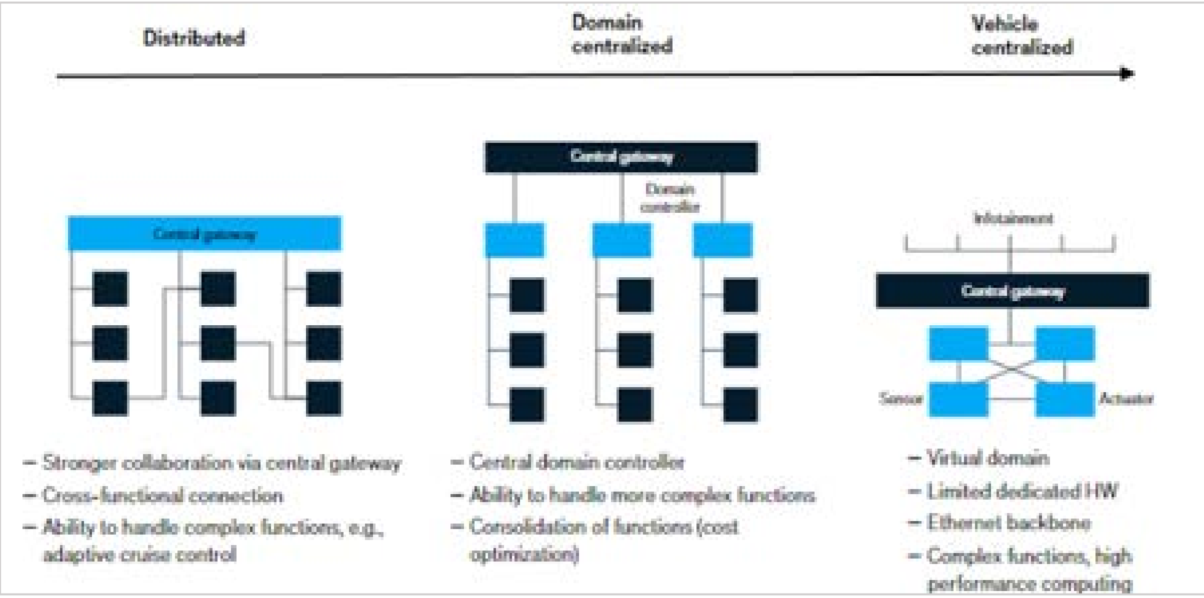

Fig. 5: Centralisation of the electrical/electronic (E/E) architecture (source: McKinsey)

Therefore, the emergence of the software-defined vehicle would demand the incorporation of more advanced node digital chips into vehicles.

The Chips Act and the Important Project of Common European Interest (IPCEI) on microelectronics and communications technology have announced over EUR 100 billion in public and private investments in semiconductor manufacturing capacity in Europe, which will support the automotive industry in sourcing leading-edge node semiconductors in Europe, thus putting an end to some of the dependencies of European industry on other regions. The IPCEI also had several automotive-specific projects ranging from the industrialisation of novel power electronic devices centralised for battery electric vehicles (BEVs), to a high technological readiness level (TRL) development of a centralised E/E architecture for next-generation vehicles. ([82])

([82]) https://ec.europa.eu/commission/presscorner/detail/en/ip_23_3087

Importantly, these transformations are challenging the leadership and competitiveness of the European automotive industry. The upcoming years are expected to be critical for closing the gap between EU automotive players, leading new OEMs, and tech companies from other regions. Software is ever more complex due to the demand for increasingly intricate functionalities and the duplicated work required to adapt to various platforms. In addition, industry is grappling with a shortage of skilled professionals to adapt to these rapid changes.

Until today, European companies have concentrated on developing proprietary technology platforms, leading to inefficiencies as investments are funnelled into areas that do not provide differentiation and visibility to the end consumer ([83]). Nevertheless, there's a growing trend towards fostering partnerships and alliances, indicating a greater willingness to collaborate and combine resources. Against the background of the **European Chips Act** and the **European Data Strategy**, the Commission is supporting the Vehicle of the Future initiative ([84]) to promote pre-competitive collaboration between key European stakeholders (OEMs, suppliers, tech companies, chips providers) and develop both an open software-defined vehicle (SDV) ecosystem and a hardware platform based on RISC-V, an open-source instruction set architecture for microprocessors. This initiative represents a total investment of around EUR 250 million in 2023-2024 by the EU, Member States and industry, ranging across the Chips JU, CCAM and the 2Zero partnership.

While hardware ensures the efficient, safe and reliable implementation of software, the objective of the SDV platform is to foster collaboration on non-differentiating aspects of automotive software through hardware abstraction. The aim is to serve as the foundation for the development of standardised software building blocks, flexible hardware architectures as well as co-designed interfaces, within and outside the vehicle, supplemented by software and hardware development and validation toolsets. The Vehicle of the Future initiative will strengthen open and transparent exchange and coordination along the value chain, among competitors and between existing alliances by coordinating decentralised development ([85]).

Initial steps have been taken ([86]) to create an open European SDV ecosystem and a RISC-V automotive hardware platform, both at governance level and through dedicated R&I initiated under the Chips JU:

- the FEDERATE project, which started in October 2023 and involves major automotive OEMs, tier 1 and 2s, semiconductor companies, industry associations and initiatives, will support the initiative's governance and help coordinate projects across various EU partnerships;
- under the 2023 work programme, one large R&I project focuses on the hardware abstraction layer;
- two RISC-V projects, Isolde and Tristan, which started in 2022 and 2023, respectively, with a budget of around EUR 100 million, incorporate elements targeted towards automotive applications; and

([83]) Concept Paper on an open European software-defined vehicle platform | Shaping Europe's digital future (europa.eu)
([84]) https://digital-strategy.ec.europa.eu/en/library/concept-paper-open-european-software-defined-vehicle-platform
([85]) This is facilitated and supported by the European coordination and support action FEDERATE, which will provide a multiannual roadmap and specific recommendations.
([86]) For more details, see the concept paper on an open European software-defined vehicle platform for the vehicle of the future (link).

- further topics are considered under the 2024 work programme, supporting the SDV ecosystem and the RISC-V automotive hardware platform.

These initiatives are based on the ECS-SRIA 2023 ([87]), which aims to tackle several CCAM challenges, such as:

- affordable automated and connected mobility;
- modular, scalable, reusable, flexible, cloud-based, safe and secure end-to-end software platforms able to manage software-defined mobility of the future;
- necessary tools and methods for validation and certification of safety, security and comfort of embedded intelligence in mobility; and
- real-time data handling for multimodal mobility and related services.

Alignment and coordination between the CCAM Partnership and the Chips JU would ensure that measures are supplementary in terms of system-level integration of all digital components into the vehicles of the future.

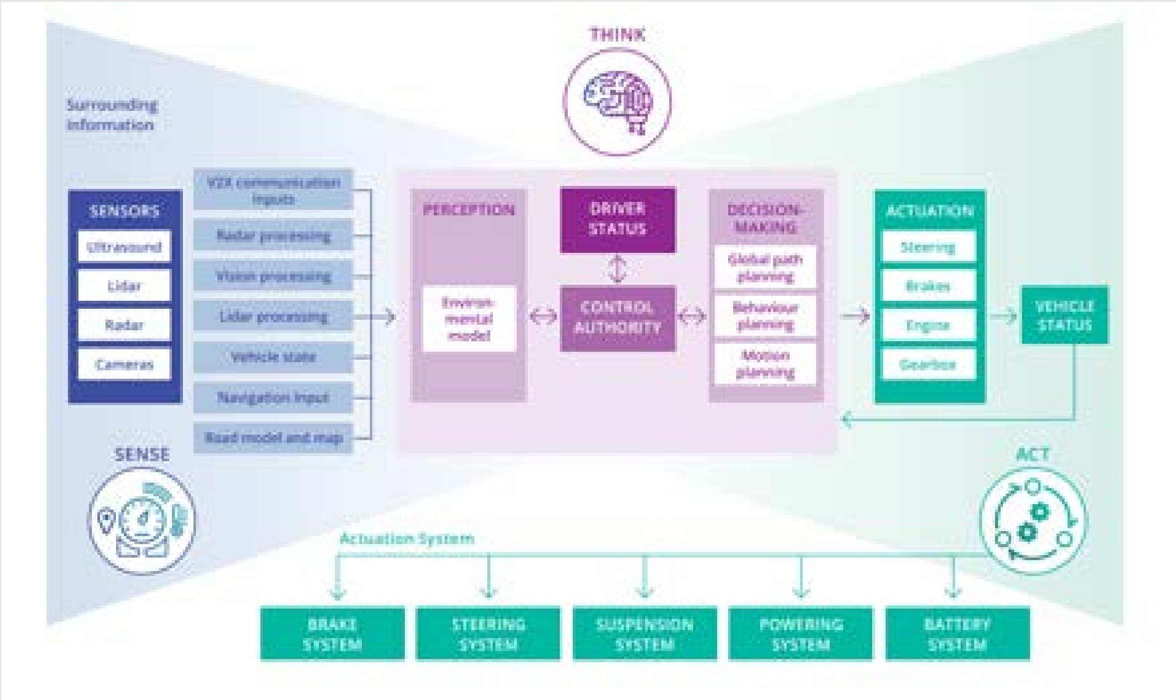

Fig. 6: Overview of hardware and software components for CCAM .

([87]) ECS-SRIA 2023.pdf (europa.eu).

AI Act

In April 2021, the Commission presented the first ever EU legal framework on AI, the Artificial Intelligence Act ([88]). On 13 March 2024, the European Parliament adopted the Act. This Act will make sure that Europeans can trust what AI has to offer by laying down balanced, risk-based and future-proof rules that address the specific risks posed by AI systems, setting the highest standards worldwide.

The AI Act takes a risk-based approach, with four risk categories (minimal risk, high risk, unacceptable risk, and specific transparency risk), where the obligations for a system are proportionate to the level of risk that it poses. In addition, the AI Act considers risks that could arise from general-purpose AI models, including systemic risks. General-purpose models can be used for a variety of tasks and are becoming the basis of many AI systems. Some of these models could carry systemic risks if they are very capable or widely used.

The category of high-risk AI systems (as defined in Article 6 of the AI Act) encompasses two broad categories. Firstly, AI systems that are a safety component of a product and are: (i) already regulated by the existing sectoral product safety legislation; and (ii) subject to third-party conformity assessment. AI systems used in the automotive sector fall under this category. The second category of high-risk AI cases includes products and services that could pose high risks to people's health, safety and fundamental rights. For instance, this covers AI systems intended to be used as safety components in the management and operation of critical digital infrastructure, road traffic and the supply of water, gas, heating and electricity. High-risk AI systems must meet requirements related to data and data governance, documentation and record keeping, transparency and provision of information to users, human oversight, robustness, accuracy and cybersecurity, among other things. Providers of high-risk AI systems must also implement quality and risk-management systems to ensure their compliance with the new requirements and minimise risks for users and affected persons, before and after a product is placed on the market. To facilitate the implementation of the requirements, they will be standardised.

To facilitate compliance with the requirements set out in the AI Act, the AI Act envisages the creation of regulatory sandboxes and real-world testing, which also address the areas of safety and resilience of transport systems and mobility, critical infrastructure and networks. Regulatory sandboxes and real-world testing will provide a controlled environment to test innovative technologies for a limited time, fostering innovation by SMEs, start-ups and other companies in the mobility sector, in compliance with the AI Act.

On AI in automotive industries, the AI Act aims to set a clear regulatory framework including safeguards for passenger safety. This is important, especially as vehicles increasingly have higher levels of autonomy.

The AI Act awaits final endorsement by the European Council. It is planned for adoption in spring 2024. Following its adoption, the AI Act will be fully applicable 24 months after its

([88]) COM/2021/206 final.

entry into force, with a gradual approach. Importantly, obligations for high-risk systems will become applicable after 36 months.

Connectivity

In October 2020, the Commission adopted an Implementing Decision on the 5.9 GHz band for Intelligent Transport Systems ([89]) that significantly expanded the 5.9 GHz spectrum band (from 30 MHz to 50 MHz), which is used for the exchange of safety-related messages between vehicles and their environment. Industry is currently working on standardisation to enable coexistence of incumbent and emerging technologies. Technological developments in the sector have not yet resulted in established industry standards for coexistence, neither at global level nor at EU level. In line with the principle of technological neutrality (as well as long-standing industry discussions on competing communication technologies), the Commission continues to support various market solutions, including Wi-Fi-based and 5G-based communication technologies. However, as technologies mature and enter the market-deployment phase, ensuring policy coherence will increasingly demand strengthened cooperation between the Commission and Member States, especially on digital infrastructure and high-precision positioning systems.

Commercial large-scale deployment of C-ITS services – which are sometimes referred to as cellular vehicle-to-everything (C-V2X) and dedicated short-range communications ITS generation 5 (DSRC/ITS-G5) – started in 2019 and in 2023, respectively, with now over 1 million vehicles driving on European roads delivering ‘Day 1’ services (see Table 1), improving road safety, avoiding accidents, and laying the ground for ‘Day 2’ services and beyond. Current deployment levels already provide valuable insights to road operators as traffic density can reliably be extrapolated from communication between vehicles and road-side C-ITS stations. The deployment of infrastructure-based C-ITS is coordinated by the C-Roads Platform, which brings together 18 Member States and several non-European countries ([90]).

5G technology is also a key enabler for connected and automated mobility, providing ultra-high reliability and security, low latency, and high throughput capabilities. The deployment of uninterrupted 5G connectivity infrastructures and associated edge-computing facilities along road transport paths, or 5G corridors, is expected to enable uninterrupted provision of a broad range of services (including safety and non-safety services). The targeted level of service quality and network performance is driven by the requirements of advanced services for connected and automated driving, such as high-definition maps, multi-vehicle coordination or remote control of vehicles.

Next to ITS, the deployment of 5G corridors across Europe started in 2023 with the support of the Connecting Europe Facility – Digital (see Section 4). This deployment takes advantage of the 5G cross-border trial project co-funded under Horizon 2020 and the 5G public-private partnership (5G PPP). Under phase 3 of the 5G PPP, a total of nine 5G cross-border trial

([89]) C(2020) 6773 final.
([90]) Austria and Germany have already started with a massive upscaling of their deployment and will complete coverage of their major road network in the coming years.

projects were launched. The first wave of these projects, launched in 2018, yielded valuable insights into the capabilities and potential of 5G technology for CCAM. Most notably, trials conducted in cross-border contexts have proven that achieving uninterrupted service continuity in these areas is possible. The solutions presented through these three projects offer significant improvements in terms of minimising service interruption times. What used to take several minutes can now be reduced to just a few hundred milliseconds if the required additional interfaces between operators on both sides of the border are in place. 5G can significantly improve performance compared to previous technologies, mainly 4G, in terms of reduced latency and higher capacity and spectral efficiency ([91]).

Concerning deployment-related lessons learned, the work carried out by the three projects mentioned above concludes that the most suitable way to bring the 5G network into use to provide CCAM services along corridor sections would be to start with the low-band spectrum (e.g. the 700 MHz band) to quickly achieve wide-area coverage, before moving towards the 3.6 GHz band. Six additional projects are still up and running; these are testing and demonstrating advanced 5G-enabled use cases with cross-border service continuity, notably around CCAM.

4. CROSS-CUTTING PRIORITIES

Societal impact, ethics, and skills

The transition to CCAM is first and foremost a societal transition. It represents a profound shift in how people and goods move, with implications for safety, efficiency and accessibility, as well as changes in societal and cultural norms and behaviours. Making sure that CCAM is part of a just and fair transition of the transport system is a EU priority ([92]). In this regard, the 2018 Communication recommended the monitoring and assessment of CCAM impacts at socio-economic and environmental level, as well as support to skills acquisition and transition for a changing workforce faced with increased automation.

In line with the 3rd Mobility Package, the Communication also recommended to explore ethical issues related to the development and deployment of CCAM as a new technology and new form of mobility. Indeed, the fast-changing nature of these emerging technologies can create scenarios and issues that are not fully covered by existing regulations, policies, and social practices. In that sense, technological progress alone will not be sufficient to realise the potential of CCAM. In September 2020, the Commission published an expert group report on ethics of connected and automated vehicles ([93]), providing 20 multi-stakeholder recommendations on road safety, privacy, fairness, and AI explainability and responsibility. These recommendations aim to timely and systematically integrate ethical principles into the

([91]) Already today, 5G based on release 15 (non-stand-alone) can support about 80% of CCAM services including ITS 'Day 1' services, as their requirements are in line with the commercially available performance.

([92]) As mentioned in the Council Recommendation on ensuring a fair transition towards climate neutrality (2022/C 243/04).

([93]) The expert report builds on the AI high-level expert group's guidelines for trustworthy AI, the General Data Protection Regulation, work by the European Data Protection Board, the Commission expert group report on liability and new technologies, work by the Ethics Task Force, and the German Ethics Commission's guidelines for connected and automated driving.

development of CCAM, which is essential for aligning innovation in mobility with societal values and collective needs. This expert report was supplemented by two studies by the Joint Research Centre on emerging complexities, uncertainties, and opportunities in mobility, based on increased digitalisation and technological promises ([94]). In addition, compliance with applicable rules, such as the General Data Protection Regulation plays a crucial role for generating trust and ensuring individual control over the use of personal data.

Broad political and societal discussion would guide the creation, implementation and monitoring of new regulations, policies and practices that would ensure that CCAM is used ethically and has a positive impact. In this respect, promoting ethics as a strategic objective of European R&I policy through responsible research and innovation (RRI) remains a priority within the Horizon Europe research and innovation framework programmes ([95]). The aim would be to keep the emphasis on the sustainability, accessibility and liveability of mobility futures that include CCAM. R&I plays indeed a fundamental role in identifying, mitigating and avoiding negative social, environmental and economic externalities within novel innovation trajectories like CCAM, which must be driven by the needs, values and expectations of diverse social groups to ensure uptake.

One of the specific objectives of the CCAM Partnership is to achieve increased awareness of CCAM benefits among users and society by 2030. The 2020 Special Eurobarometer 496 on Europeans' awareness of and attitudes towards connected and automated driving ([96]) has indeed highlighted that almost 40% of the 27 000 people interviewed had never heard about, read about, or seen any automated vehicles. As a result, more than 70% of them declared that they would not feel comfortable travelling in an automated vehicle, unless a human supervisor was present on board, and 30% of them declared that they would consider buying an automated vehicle only after having seen others use them. Overall, the survey showed that Europeans were not ready to use automated and connected vehicles. It called for public initiatives to inform about their safety and benefits. Additional studies and surveys have shown that public engagement activities are crucial for strengthening the acceptability and relevance of innovative solutions based on CCAM ([97]) ([98]) ([99]) and to tackle uncertainties and opportunities in the field of mobility. These activities would help ensure that technological innovation has ethically and socially desirable outcomes.

Cluster 6 of the CCAM Partnership focuses on societal aspects and people's needs. The aim of the cluster is to explore the needs, expectations, desires and concerns of Europeans, and society in general, when it comes to the introduction of CCAM. This societal understanding at individual and collective level is an absolute prerequisite for ensuring acceptable CCAM solutions that serve social, economic and environmental objectives. Indeed, the effective implementation of CCAM depends significantly on the societal advantages it can yield and on its acceptance among individual users. Delivering the desired benefits requires a comprehensive and authentic understanding of specific needs, encompassing both positive and

([94]) https://publications.jrc.ec.europa.eu/repository/handle/JRC123895
([95]) An example is the EU NewHoRRIzon project, which aimed to bridge gaps between science, R&I communities and society at large by fostering more inclusive, anticipatory, open and responsive R&I systems.
([96]) https://europa.eu/eurobarometer/surveys/detail/2231
([97]) https://www.sciencedirect.com/science/article/pii/S1369847822001358
([98]) https://www.sciencedirect.com/science/article/pii/S0965856422000477
([99]) JRC Publications Repository - Alternative Imaginaries: Citizen Mobility Futures (europa.eu).

negative impacts, along with associated costs. Therefore, the development, deployment and regulation of CCAM would need to be grounded in a well-researched and genuine comprehension of these factors. Activities within Cluster 6 have led to the set-up of two EU projects aiming to analyse socio-economic and environmental impacts of CCAM, as well as assess society-, people- and user-related aspects of needs-based CCAM solutions ([100]).

Following up on the need to increase public knowledge on, and awareness of, CCAM, the Commission launched a stakeholder survey in summer 2023 to take stock of progress made on CCAM at EU level. This survey investigated the potential impact of CCAM in terms of bringing about desired benefits, the required governance within a CCAM transition, the expectations of the stakeholder community, and finally, the overall deployment readiness of these innovative mobility systems and services against the background of EU targets. Trends showed that the introduction of CCAM will have a positive impact on job creation and job growth, across sectors related to road transport (Figure 7). Growth is particularly expected in the fields of IT and data analytics, as well as in the automotive sector. Still job loss and displacement are expected for driving professions, which highlights the importance of skilling, reskilling and upskilling a workforce that is confronted with increased automation. Specific training and education programmes for all professions would play an important role in the transition to CCAM ([101]).

([100]) SINFONICA and MOVE2CCAM.
([101]) The scope of the survey was intentionally broad to better understand the overall impact of CCAM on employment. The sectors listed in Figure 7 are not stricto sensu related to CCAM, as CCAM represents a transport ecosystem in transition that is expected to both create and displace jobs in the future, across sectors. For more information, see a 2021 Commission study on the social dimension of the transition to automation and digitalisation in transport, focusing on the labour force.

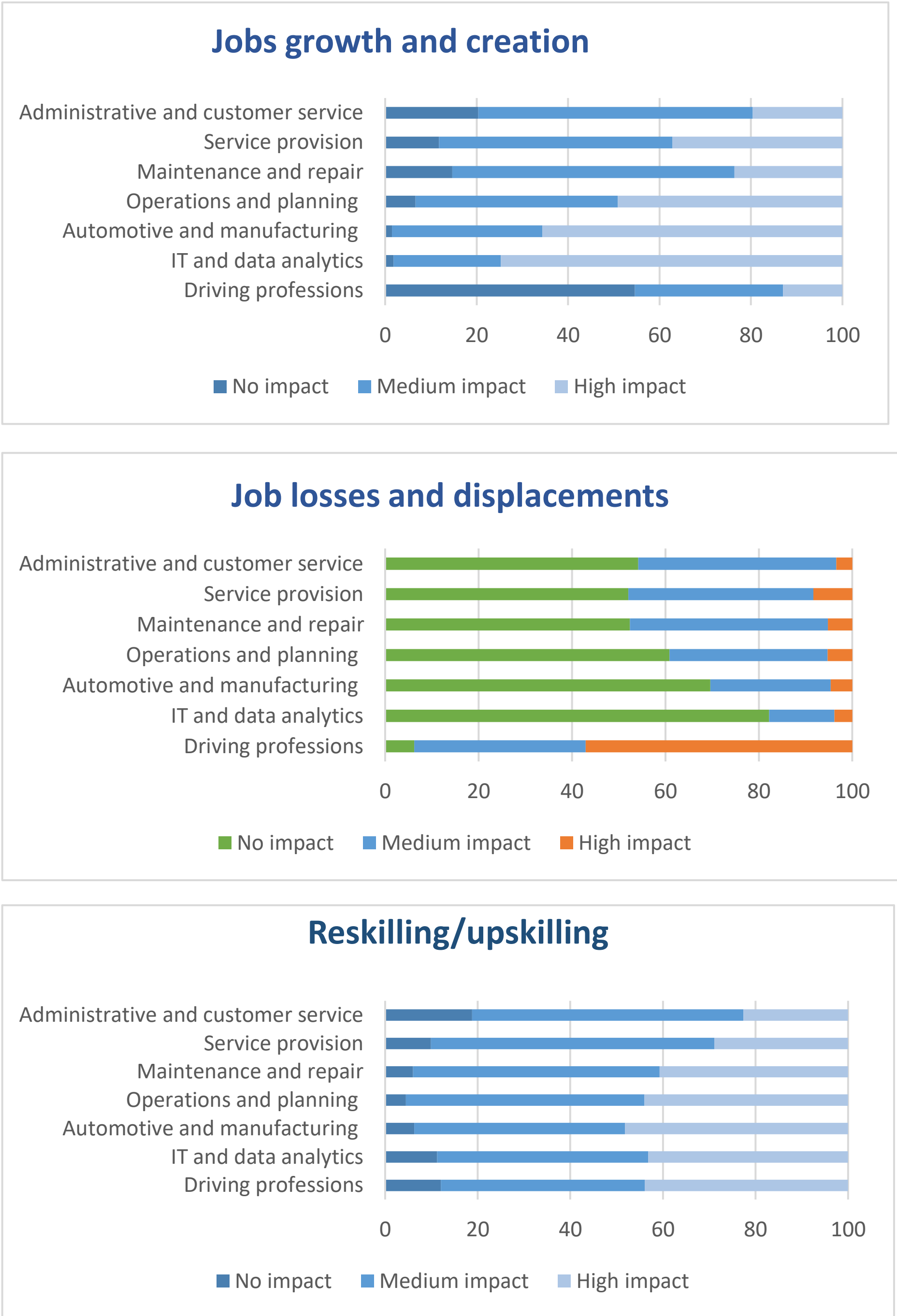

Fig. 7: CCAM stakeholder survey results on jobs and skills (2023)

The main challenge for the mobility ecosystem is the scale of adaptation affecting current jobs and the need for labour reskilling created by the green and digital transition, as well as by international competition. The ecosystem is also marked by an ageing workforce; in automotive, 25% of the workforce is over 50 years old. Fierce competition in the industry has resulted in declining market shares in global production, exports, and employment. At the same time, the mobility ecosystem is facing substantial shortages of workers with the required skills. The CCAM survey's results are in line with EU policies aiming to reprioritise lifelong upskilling and training. The 2023 European Year of Skills has shown that the twin transition can only succeed if the EU has the skilled workforce it needs to stay competitive. Training, upskilling and reskilling would be central to raising awareness and boosting skills for developing all mobility-related technologies and services. These priorities are reflected in Action 95 of the **SSMS**, which sets the objective of issuing a recommendation for the transition to automation and digitalisation and on means to address the impact of automation and digitalisation on the transport workforce, which was adopted as part of the Passenger Mobility Package in November 2023 ([102]).

Another direct result of the activities of the CCAM Partnership's Cluster 6 and the 2023-2024 calls under Horizon Europe is the CCAM-ERAS project ([103]) that is investigating the effects of CCAM on jobs and education, with the aim of developing plans for skills that match CCAM development, as well as CCAM prerequisites for employment growth ([104]).

The issue of accessibility was also addressed in the CCAM survey. According to most respondents, the primary expectation of CCAM systems and services is for them to improve road safety, but another significant majority expressed the belief that CCAM has the potential to broaden mobility options for non-drivers. Additionally, respondents envisioned CCAM to increase the accessibility of mobility services in rural areas, and to support commuting journeys to and from peri-urban areas.

While the upcoming large-scale demonstrations of CCAM solutions under Horizon Europe are expected to show how innovation can improve mobility overall, further awareness raising remains critical, whether among members of the general public, experts, users, or decision-makers. To boost awareness of progress made in CCAM in Europe, the Commission collaborates closely with the CCAM Partnership to organise the **European Conference on Connected and Automated Driving** (EUCAD) biennially. This event brings together a diverse array of stakeholders, including policymakers, industry leaders, researchers, and innovators, fostering collaboration and exchange of innovative ideas. EUCAD features panel discussions, technical workshops, exclusive exhibitions, and demonstrations of latest research and technologies. Amid transformative changes in the automotive landscape, EUCAD serves as a catalyst for positioning the EU as a global leader in the field.

Green transition and clean technologies

CCAM plays a role in the digitalisation of our societies, with the potential of placing the EU at the forefront of transformative developments in the automotive industry, but it also aims to actively promote and support a sustainable transition. Indeed, environmental benefits are seen as one of the most important factors for encouraging the introduction and adoption of CCAM ([105]). Reducing pollution and the environmental cost of transportation is a priority, not

([102]) Passenger Mobility Package (europa.eu).
([103]) More details here.
([104]) Two projects are currently under evaluation and are planned to start by summer 2024. Another project, WE-TRANSFORM, has also investigated the effects of automation on the transport labour force, future working conditions, and skills requirements.
([105]) *Destination CCAM*, 2023 stakeholder survey, available here.

only for relevant stakeholders in the field but also for Europeans, as shown in the latest CCAM EU survey ([106]).

In this regard, CCAM provides an opportunity to advance sustainability targets using a multifaceted approach based on smart mobility: optimising traffic efficiency, integrating electrification and alternative fuels, developing shared urban mobility solutions, and greening the digitalisation of mobility services.

Optimising traffic through dynamic traffic management, using real-time data, enables adaptive measures to avoid congestion, consequently reducing greenhouse gas and pollutant emissions associated with stop-and-go traffic. Combined with the integration of electric and alternative fuel vehicles, CCAM has the potential to foster a greener transport ecosystem overall. Indeed, CCAM systems can assist in maximising the deployment of electric vehicle (EV) charging infrastructure, ensuring efficient placement and usage to support a growing fleet of electric vehicles. Integration with smart grids would enable optimised charging schedules, taking advantage of periods with lower electricity demand, reducing the environmental impact of charging EVs. CCAM technologies can also support the integration of alternative fuels, such as hydrogen, by optimising refuelling infrastructure and routes for vehicles powered by these fuels. In terms of advancing sustainable urban mobility, connected and automated systems can facilitate the development of shared services, such as shuttles or ride hailing, reducing the overall number of vehicles on the road and promoting a shift towards more sustainable modes of transportation. This is made possible by improving last-mile connectivity, as well as by integrating various transport modes into a seamless system. This would enable users to easily switch between different modes, reducing reliance on individual car ownership and promoting a more sustainable and diverse transportation mix.

Overall, investments in smart mobility and clean technologies – such as electromobility, charging infrastructures, alternative fuels, internal combustion engine improvement, smart grid interoperability, energy storage and management – and integrating them into the development and deployment of CCAM, are expected to further leverage CCAM's greening potential, in line with the European Green Deal and specifically the 'Fit for 55' package ([107]), which aims to reduce EU greenhouse gas emissions by at least 55% by 2030 and 90% by 2040 ([108]).

Indeed, the mission of CCAM is to supplement and optimise the existing transport system through evidence-based and targeted innovation. CCAM could provide this greater innovation in zero-emission technologies in answering to the strengthened CO_2 emission performance standards for new passenger cars and new light commercial vehicles under the 'Fit for 55' package ([109]). By 2035, all new cars and vans placed on the market in the EU should be zero-emission vehicles. In combination with the Automated Driving Systems Regulation (see achievement 2), automation and electrification are expected to both act as boosters to bring the transport sector closer to Europe's climate-neutrality ambitions. The Joint Research Centre is currently working on better understanding the energy demand of automated vehicles, exploring

([106]) Ibid.
([107]) https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/
([108]) According to the 2040 Climate Target.
([109]) Cars and vans are responsible for around 15% of the EU's total CO_2 emissions.

the energy consumption of increased computer performance and software use in connected and automated vehicles.([110])

Innovation in the energy and mobility sectors is crucial for the green transition towards zero emissions climate neutrality and clean air. Embracing innovation, against the backdrop of a data-driven service economy, is expected to not only facilitate the integration of renewable energy sources and clean technologies, but also to foster resilient and adaptive systems that are pivotal in steering society towards a carbon-neutral future.

Synergies between EU partnerships and other EU initiatives

The Commission is committed to fostering synergies between various EU funding instruments that are crucial for advancing CCAM systems in Europe. These include funding sources such as Horizon Europe, the Digital Europe programme, and the Connecting Europe Facility (Digital and Transport programmes), all of which support different facets of technology and infrastructure development and deployment. By harnessing these synergies, stakeholders and projects' holders can access essential financial support at various developmental stages. This ranges from the inception phase, encompassing early research and feasibility studies, to the later stages, involving large-scale demonstrations and infrastructure deployment. This strategic alignment of funding programmes aims to not only ensure the availability of necessary resources but also to facilitate the exchange of knowledge, research insights, and best practice among multiple projects and stakeholders. This, in turn, is expected to mitigate the risk of redundant work, which helps to encourage innovation, improve overall efficiency in the R&I process, and reach EU targets ([111]). Furthermore, encouraging synergies between EU funding instruments promotes cross-sector collaboration, bringing together stakeholders from diverse thematic domains such as automotive, telecommunications, information technology, infrastructure, and policymaking. This interdisciplinary collaboration is instrumental for the development of comprehensive automated driving solutions that are both robust and future-proof.

The CCAM Partnership has mapped the below synergies within the European research, innovation and deployment landscape.

([110]) Results will be presented at EUCAD25.
([111]) Such as reducing road fatalities and serious injuries on European roads by 2030 (Vision Zero), deploying CCAM by 2030 (SSMS), reducing greenhouse gas emissions from the transport sector by 2050, and more.

Fig. 8: Synergies between CCAM Partnership and other European partnerships and EU funding instruments

Most notable is the collaboration with the 2Zero partnership, the Key Digital Technologies Joint Undertaking (KDT JU) and the Climate-Neutral and Smart Cities mission. The 2Zero partnership ([112]), succeeding the European Green Vehicles Initiative under Horizon 2020, aims to accelerate the adoption of zero-emission vehicles using a comprehensive system framework. The coordination between 2Zero and the CCAM Partnership is expected to enable innovative climate-neutral mobility services and logistics operations, addressing both decarbonisation and digitalisation challenges and unlocking opportunities to improve efficiency at both vehicle and mobility system level.

The Chips Joint Undertaking (Chips JU) succeeded the KDT JU ([113]) under Horizon Europe and the Electronic Components and Systems for European Leadership Joint Undertaking under Horizon 2020. It aims to strengthen the EU's open strategic autonomy in the electronic components and systems sector to make Europe a competitive leader in the world's digital economy. The CCAM Partnership and the Chips JU appear interconnected through a dynamic push-pull relationship. CCAM would delineate requirements for functions and services, while

([112]) https://www.2zeroemission.eu/
([113]) https://portal.chips-ju.europa.eu/

the Chips JU would facilitate the realisation of these requirements by providing enabling technologies.
Finally, the CCAM Partnership aims to supplement the activities of the Climate-Neutral and Smart Cities mission ([114]). This mission, launched in 2020 under the EU missions initiative, aims to reach at least 100 climate-neutral and smart European cities by 2030 ([115]), making sure they act as experimentation and innovation hubs to help Europe become climate-neutral by 2050. Urban mobility plays a crucial role in this transformation, which is why a call was published in 2022 for the design of smart systems and services for user-centred, shared and zero-emission mobility of people and freight in urban areas. This joint work was co-led by 2Zero and the CCAM Partnership, pooling a budget of EUR 50 million, reflecting the overall ambition to develop mobility solutions that respond to people and cities' needs, harnessing the combined potential of electrification, automation and connectivity ([116]).

In addition to the Horizon Europe framework programme, and as part of broader work by the EU to create a digital single market, the Connecting Europe Facility (CEF) Digital programme (2021-2027) aims to support the development of digital infrastructure and services in Europe. Mainly, CEF Digital will provide funding to: (i) improve digital interoperability across Member States; (ii) support the development of secure digital public services; (iii) strengthen cybersecurity infrastructure; and (iv) encourage the sharing and reuse of public sector data to drive innovation and economic growth. For CCAM, CEF Digital supports the pan-European deployment of 5G corridors, which ensure proper solutions for service continuity when crossing borders, with a planned budget of EUR 780 million (2021-2027). The goal is to catalyse investment and speed up the deployment process of CCAM systems and services. Since 2023, a total of 18 projects, studies and works, have been supported by CEF Digital for a grant total investment of EUR 106 million and a corresponding overall grant of EUR 42 million. This supports the deployment of 5G corridors, notably over cross-border corridor sections, to connect different regions ([117]). Additional and supplementary projects are expected to be launched in 2024 on the basis of proposals submitted under Call 3 ([118]).

In addition to CEF Digital is the CEF Transport programme (2021-2027), which provides a budget of EUR 25.8 billion to support innovation in the transport system to improve the use of infrastructure, reduce the environmental impact of transport, improve energy efficiency, and increase safety. Specifically, CEF Transport includes an average yearly funding of EUR 100 million for projects that aim to implement ITS and C-ITS services and infrastructure in the road sector. This includes projects that develop technologies based on automation, integrated infrastructure capacity, traffic management, improved transport services, modal integration and MaaS. All these innovations and developments would feed into the long-term deployment of CCAM.

([114]) https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/climate-neutral-and-smart-cities_en
([115]) The list of selected cities can be found here.
([116]) Two projects have started, Mobilities for EU and metaCCAZE.
([117]) Seven of these projects started deploying the supporting connectivity infrastructure by early 2023 and eight inception studies are paving the way for future large-scale 5G infrastructure deployment projects. A new wave of projects, under the second CEF Digital call for proposals, have started in the fourth quarter of 2023.
([118]) These projects will be based on the inception studies carried out under the 2021 call. Call 3 was open from 17 October 2023 to 20 February 2024.

International and national collaboration

a) Alignment with nationally funded activities

As mentioned in the section on large-scale demonstrations, the role of local players is key to ensuring ownership of and investment in CCAM solutions. In this regard, in July 2021, the Commission set up a state representative group (SRG) to serve as a strategic advisory body to the CCAM Partnership. It aims to advise on and actively support the achievement of the Partnership's objectives, and ensure complementarity with national policies, priorities and programmes. The SRG is composed of representatives from national authorities of Member States and associated countries ([119]). It acts as a bridge to activities taking place at national level. This connection is key to the future of CCAM due to the integral role national authorities play in facilitating real-world (and cross-border) testing of CCAM solutions. Additionally, the SRG is intricately linked to the national initiatives responsible for deploying CCAM solutions, which necessitate infrastructure support and a harmonised regulatory framework for CCAM testing.

Therefore, the SRG holds a strategic advantage in identifying domains essential for facilitating the implementation of the Partnership's outcomes and in fostering a comprehensive development of the CCAM ecosystem. By emphasising the harmonisation of legislation on CCAM testing, as well as by developing physical and digital infrastructure and robust data connectivity, the SRG is expected to help achieve common goals in CCAM testing and deployment.

A continuous exchange of information regarding specific measures taken at national or regional level should support the exploitation, deployment and scaling-up of the results achieved by the CCAM Partnership, and help align innovation, development and deployment plans for the long term. To facilitate this alignment, the Partnership has created a centralised Knowledge Base ([120]) that catalogues all projects in the field of CCAM, considering international, national and regional work ([121]).

Fig. 9: Mapping of CCAM testing sites in Europe ([122])

([119]) These representatives are designated by the delegates to the Horizon Europe Cluster 5 programme.
([120]) Together with the EU Arcade project. See the CCAM Knowledge Base for more information.
([121]) Available at Connected Automated Driving | R&I Projects.
([122]) See the CCAM Knowledge Base for more information.

b) International collaboration

The European work on CCAM development cannot be separated from a broader global setting. From an industrial perspective, harmonisation in the regulations would enable the deployment of automated road transportation solutions across different markets, to avoid unnecessary fragmentation and unsustainable production costs. For example, different technical requirements in the EU, the UK and Japan would imply the need for manufacturers that aim at markets outside the EU to comply with three different regulatory frameworks at the same time.

Automated driving is a complex and multidisciplinary field that requires expertise in various domains, including AI, sensor technology, vehicle dynamics, cybersecurity, legal frameworks, and human factors. International collaboration supports the exchange of knowledge, research findings, and best practice. This exchange of information helps to accelerate technological advancements, promote innovation, and avoid duplication of work. It enables stakeholders to learn from each other's experiences and leverage collective expertise for the development of safer, more robust, and efficient automated driving systems.

Moreover, developing and validating automated driving systems requires access to diverse datasets, as well as suitable testing infrastructure. International collaboration enables the pooling of data from different regions, encompassing variations in traffic patterns, road infrastructure, and driving behaviours. By sharing data([123]), researchers and developers could access a more comprehensive and diverse set of scenarios – including edge cases – leading to improved system performance and safety. This rings especially true when it comes to expanding the operational design domain (ODD): extreme weather conditions, complex urban environments, or uncommon scenarios might be outside of the capabilities of current technology. Expanding the ODD could help determine when and where an automated vehicle can operate safely, reducing the risk of accidents and misuse. Well-defined ODD would help improve monitoring, make handover safer, and ensure compliance with regulations, ultimately making on-road automated driving safer. Beyond their use in the development process and in expanding the ODD, shared data and scenarios could have a valuable contribution to validation, verification and certification work. Collaboration also makes it possible to set up shared testing facilities, which can reduce costs and make testing and evaluation processes more efficient.

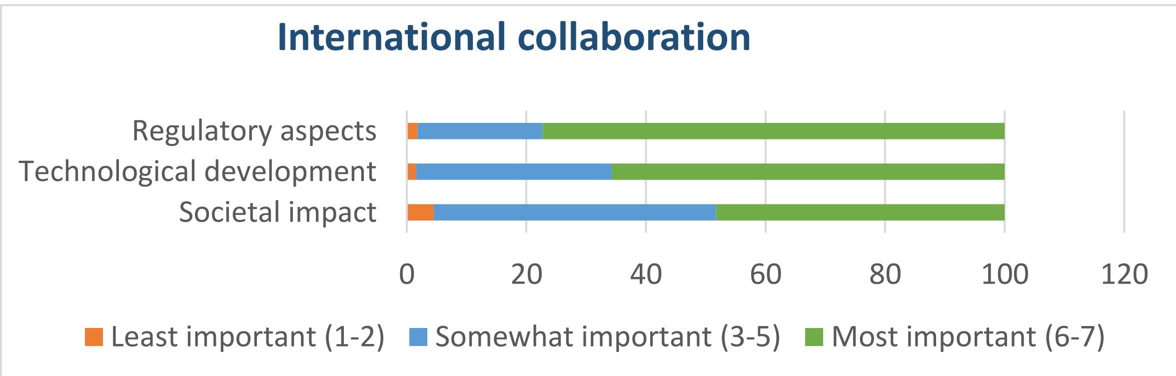

Fig. 10: Results from the CCAM survey on the importance of international collaboration ([124])

([123]) In line with the rules set out in the GDPR.
([124]) *Destination CCAM,* 2023 stakeholder survey, available here.

In addition, as automated driving systems continue to evolve, consistent international standards and regulations would be needed to ensure interoperability, safety, and legal compliance. International collaboration facilitates the harmonisation of these standards and regulations by bringing together experts, policymakers, and regulatory bodies from different countries. By working collaboratively, stakeholders can align their approaches, share insights into regulatory frameworks, and develop common guidelines. This harmonisation would simplify the global deployment of automated driving systems, facilitate international trade, and help avoid fragmented regulatory landscapes that could impede technological progress. As previously highlighted, the EU attributes strategic value to the work of the UNECE World Forum for Harmonization of Vehicle Regulations (WP.29) as well as its Working Party on Automated and Connected Vehicles (GRVA; see Section 3 for more information).

In the frame of international collaboration, and in line with the Commission Communication on the Global Approach to Research and Innovation Strategy, the Commission explicitly encourages the participation of entities from non-EU countries in projects funded under the CCAM topics of Horizon Europe and, at the same time, directly supports the set-up of structured cooperation between EU-funded initiatives and projects under the umbrella of non-European research programmes.

Moreover, while dependencies on non-EU countries in relation to critical technology areas such as AI and advanced semiconductor technologies need to be considered, there is also a concrete opportunity in maintaining a structured dialogue with non-European countries that are developing CCAM solutions, to benefit from respective experiences and knowledge (reduce development costs and paths) and to avoid unwanted (and costly) fragmentation of the automated vehicles market on global scale.

The need to ensure a certain level of collaboration at international level (also guaranteed through the activities of the UNECE Working Party on Automated/Autonomous and Connected Vehicles), does not preclude each region from having its own specificities in the overall development picture: China's approach relies on investments in infrastructure to plug in automated vehicles, the US has been fostering a tech- and vehicle-centred approach([125]), while Europe, and Japan, promote a hybrid strategy that is vehicle- and infrastructure-oriented.

Against this background, without excluding possible structured ties to other strategic non-EU countries, the US and Japan are historically two countries with which the EU has entered into a structured dialogue on the development of CCAM solutions and, as such, are explicitly mentioned in the CCAM research topics. More specifically, in addition to exchanges held at policy and technical level on a bilateral basis, the EU, Japan and the US regularly organise an International Workshop back-to-back with their regional automated mobility events (EUCAD in the EU, the Automated Road Transportation Symposium (ARTS) in the US, and the Japanese Mobility Innovation Week, respectively).

The main impacts of such structured dialogue are, on the one hand, a certain degree of alignment in research programming and, on the other, collaboration that is then set up between projects funded by the different regions. Positive examples of this type of collaboration include the memorandum of understanding recently signed between the ULTIMO project and the

([125]) Although this appears to be shifting towards a more hybrid approach, similar to Europe and Japan.

Japanese project Cool4 on the development of shared automated mobility services in urban environments, building on previous collaboration between the Cool4 project and the EU project SHOW, or the participation of the University of California in the EU Move2CCAM project, which deals with the societal impact of CCAM solutions.

While international collaboration represents an added value, collaboration opportunities must also be assessed against possible risks to research security. This is also in line with the previously mentioned EU economic security strategy ([126]), which identifies AI and advanced semiconductor technologies, serving as a basis for automation (including in transportation) as critical technology areas for the EU and subject to a risk assessment given their potential risks and possible misuse.

5. OPEN ISSUES

CCAM holds the potential to play a significant role in achieving crucial societal goals, including road safety, sustainable and efficient transportation, as well as climate neutrality. Nevertheless, stakeholders contributing to this Staff Working Document pointed out that numerous challenges persist. Therefore, a comprehensive reality check is imperative to evaluate the feasibility of the ambitious targets set for the upcoming years and decades.

A first challenge is to ensure the safety and reliability of CCAM systems. This necessitates the development of robust technologies, including human-technology interaction, and their rigorous testing and validation across a spectrum of real-world scenarios. Moreover, the adoption of appropriate safety regulations and standards must precede any real-world deployment. Simultaneously, addressing potential risks, vulnerabilities, data protection and cybersecurity threats associated with CCAM systems is essential to instil trust and confidence into users, stakeholders and the general public.

Creating the right enabling conditions for a much swifter deployment of CCAM services include technical guidance and implementation and monitoring of important policies in areas such as vehicle type approval, standardisation, interoperability, safety, digitalisation and data, or intelligent transport systems and having an up-to-date legal framework.

Distinct from non-automated driving, CCAM systems heavily rely on advanced communication networks and intelligent infrastructure. Deploying essential infrastructure components, such as road sensors, intelligent traffic management systems, and high-speed communication networks, necessitates substantial investments, in addition to those already being made, and harmonised coordination among a multitude of stakeholders ([127]). Work on achieving and maintaining adequate infrastructure readiness and interoperability across regions and countries is ongoing. Today, automated vehicles already benefit from ITS and improved data availability, facilitated by public-private cooperation such as for national access points. Nevertheless, there is significant untapped potential for digitalising and sharing data to further

([126]) JOIN(2023) 20 final.
([127]) A great example is the cooperation set up by the Data for Road Safety Consortium.

improve mobility services. This is particularly relevant when automated vehicles communicate not only with each other but also with infrastructure. The challenge lies in building a digital road infrastructure, which hinges on investments from various stakeholders in the transport community, including the automotive industry, road operators, infrastructure managers, service providers, and traffic managers. Progress in this domain needs to continue to harness the benefits of CCAM services and their positive impact on society.

Furthermore, the successful adoption of CCAM solutions very much depends on its public acceptability and on fostering public trust. Users must have confidence in the safety, reliability, and benefits of these technologies. Ongoing developments already address issues such as data protection and privacy, cybersecurity, ethical considerations, explainability of technology and socio-economic impact. Europe also has a wealth of regulations that cover these issues, providing a stable and innovation-friendly business environment for the further development of technological solutions in the sector. Public awareness campaigns, user-centric design, inclusion of social sciences and humanities in R&I activities, and effective communication about the advantages of CCAM systems, can be used to further support ongoing work ([128]). The introduction of CCAM solutions may have socio-economic implications, including potential job displacement and changes in mobility patterns. Ensuring a just transition and minimising negative distributional impacts require monitoring, anticipation and proactive measures such as reskilling and upskilling programmes, supporting affected workers, and addressing social and economic inequalities. In addition, increasing automation in vehicles and infrastructure could fundamentally shift the relationship between them and require new expertise. Hence, there is a strong need to strengthen the institutional capacity of policymakers in unfamiliar skills.

With these ongoing developments, the activities and role of the end users, whether these are individual drivers, professional drivers or mobility and logistics service providers will change. For example, new rules will be needed on handover of control while the driver is partially engaged in other tasks. Moreover, the development of generative AI-based solutions and several other ongoing developments described in this SWD would make it possible to move towards higher levels of automated driving. Human-technology interaction is rapidly evolving as well, and harmonised approaches will ensure safe use and broad acceptance, enabling CCAM to benefit all Europeans. This is particularly essential in the transition phase to CCAM, during which there will be mixed traffic of automated and non-automated vehicles on European roads.

On a more technical level, achieving interoperability among diverse CCAM systems and ensuring harmonised standards represents a substantial challenge. CCAM technologies are developed by various manufacturers and service providers, making it crucial for them to seamlessly communicate and cooperate. Developing common communication protocols, data formats, and interoperability standards is pivotal to the seamless integration and deployment of CCAM systems across Europe. CCAM systems also rely on vast amounts of data, demanding effective management, analysis and protection. Building on the framework created by EU legislation, ongoing work to set up robust data governance mechanisms – addressing

([128]) Missions Publiques initiatives, PAVE Europe, specific deliverables of EU projects such as SINFONICA, MOVE2CCAM and LEVITATE.

issues pertaining to data access, privacy and security, and enabling secure and trusted data sharing – is of critical importance. This will also include the combination of CCAM with zero-emission vehicles, where technologies are optimised towards decreasing energy use and improving safety, comfort, service offering and traffic flow. The extensive use of data also calls for innovation to decrease the use of energy in on-board calculation and for data centres, as well as for limiting data exchange to a useful selection of information. Deepening and structuring collaboration between stakeholders, including public authorities, industry, and research organisations, is indispensable to tackle these data-related challenges. Another technical challenge – and opportunity – lies in the ongoing development and growing use of digital twins of vehicles and infrastructure to improve mobility operations in terms of safety, security and reliability through over-the-air updates. Further benefit lies in predictive maintenance, proactive planning and routing, circularity, and end-of-life approaches.

Additionally, the adoption of automation and digitalisation may usher in new mobility opportunities and heightened comfort. However, this may also lead to an increase in transport demand and a transition from transit and softer modes, such as walking and cycling, to the use of privately owned or shared automated vehicles ([129]). A recent study underscored this point by revealing that a significant portion of users who embrace shared automated vehicles for daily mobility previously relied on sustainable modes, further increasing the need to address these behavioural changes. Moreover, the study posits that the behavioural shifts introduced by automation could potentially undermine the environmental benefits of electric, efficient and shared automated vehicles. Research on their environmental rebound effect suggests that these behavioural changes may offset the benefits and even result in an increase in CO_2 emissions (of between 2 and 5%). To mitigate the emergence of such scenarios, driven by the intricate interplay between mobility and other societal systems, CCAM must promote an improved governance of the multimodal transport system, reinforcing low carbon mobility alternatives. This governance should facilitate a balance between various modes and ensure the efficient use of all available transport opportunities ([130]). Finally, advanced knowledge and tools are needed for road authorities to ensure efficient traffic management and to enforce this governance.

In light of the identified challenges, research and innovation continues to play an important role, in particular:

- on key enabling technologies, also facilitating cross-fertilisation with other fields.
- on societal impact: societal readiness, exploring needs, expectations, mobility behaviours, desires, and concerns.
- on testing: towards large-scale demonstrations of mature CCAM solutions across Europe, leading to their commercial deployment and market uptake, based on EU research; and
- to feed into standardisation and regulatory activities at both European and national level.

([129]) https://journals.sagepub.com/eprint/RRSJQJPC29MYPXXCJHMD/full

([130])https://publications.jrc.ec.europa.eu/repository/handle/JRC116644#:~:text=The%20JRC%20report%20%E2%80%9CThe%20future,technologies%20and%20cybersecurity%2C%20and%20legislation

Most importantly, CCAM requires the European industry to embrace and invest in key technologies, especially considering non-European competitors' major investments. This applies to the electronic hardware and software platforms, where there is a risk of dependence on large non-EU companies if European automotive OEMs and suppliers do not invest and increase collaboration.

6. CONCLUSION

There is a progressive introduction of automated solutions in road transportation at global scale. Automated functions in passenger cars on highways, automated shuttles in urban environments, automated valet parking and automated logistic operations in ports and airports are already commercially available. The transition towards full automation (level 5 vehicles) is longer than initially expected. The technological landscape that enables CCAM is extremely complex and closely interconnected with societal and regulatory dimensions.

The EU has been at the forefront of this transition from the beginning, supporting the development and deployment of CCAM solutions through both funding and regulatory initiatives. Work started with the roadmap to connected and automated mobility under the 2018 Communication and continued with the set-up of the CCAM Partnership and the adoption of its Strategic Research and Innovation Agenda in 2021. More recently, this was supplemented by the adoption of the Automated Driving Systems Regulation in 2022 and the ITS Directive in November 2023. Moreover, CCAM developments are influenced by other regulatory initiatives, such as the Chips Act (adopted in summer 2023), and by recent policy developments, such as the AI Act (adopted by EU Parliament) and the Data Act, which entered into force in January 2024.

As illustrated throughout this SWD, support at EU level to the CCAM transition is playing a role in achieving key policy priorities, including to contribute to Europe's green and digital ambitions by:

- improving the efficiency and inclusivity of the road transport system, to facilitate more comfortable and affordable mobility solutions for society;
- making a substantial contribution to the reduction of severe road accidents, to promote safer transportation practices;
- boosting EU competitiveness and growth in strategic and critical industrial sectors, such as transportation and energy, where complementary advancements in automation and electrification play a pivotal role; and

tackling workforce shortages and creating opportunities for reskilling and upskilling, to maximise the benefits of digitalisation for our societies.

As depicted in this SWD, the EU has demonstrated its capacity to be at the forefront of CCAM development. Considering major investments by non-European players in the electronic hardware and software platforms, there is however a risk of dependence on large non-EU companies if European automotive OEMs and suppliers do not invest and increase collaboration. The CCAM Partnership represents a unique instrument capable of bringing together all relevant entities involved in CCAM development and deployment, including industry, academia, research and technology organisations, public authorities (strengthened by the set-up of the SRG), road operators, public transport authorities and operators, telecommunication operators and more. Furthermore, the Automated Driving Systems Regulation serves as a first regulatory example, worldwide, for enabling the type-approval of level 4 automated vehicles. It ensures that these vehicles can only be placed on the market if they fulfil the Regulation's strict safety conditions.

This SWD provided an updated overview of the current state of play of CCAM in Europe, highlighting the measures that have been taken since 2018, and presented a unified European vision that will enable a progressive and seamless transition to CCAM, from research to widespread deployment. It also shed a light on a collective understanding of what CCAM represents and what it can bring to our societies, economy and environment. The future mobility ecosystem could be multimodal, shared, sustainable, inclusive, affordable and safe. As envisaged in the 2018 Communication, Europe has emerged as a pivotal player in shaping the trajectory of mobility over the coming decades.