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Connected, Cooperative and Automated Mobility Roadmap

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Disclaimer

This document has been prepared by the community of researchers who are members of ERTRAC and it presents a broad consensus from a diversity of stakeholders. It does in no way commit or express the view of the European Commission, nor of any national or local authority, nor single member of ERTRAC.

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1. Scope and Objectives, and Vision 2050

The main objective of the ERTRAC Roadmap is to provide a joint stakeholder view on the long-term development of Connected, Cooperative and Automated Mobility in Europe. In the table below, the structure of this new roadmap is explained with the orientation of the chapters and how they are linked to each other. The Vision for 2050 is what we aim to achieve for society. This long-term Vision calls for the necessary short-term actions, the Agenda 2030, which will then allow an Outlook to 2040.

	Chapter	Key message	Content	Rationale
1	Vision 2050	Automation domains are linked; transport modes are synchronized for the benefit of all citizens	Delivers a long-term picture of road transport and its key challenges	Long-term vision
2	Agenda 2030	Separate domains develop and offer a large variety of use cases	Describes domains, use cases and their specific characteristics	Operational agenda for research, regulation and investments
3	Outlook 2040	Use cases widen up and grow together	How use cases and business models will evolve further in the next decade	Links the operational agenda with the long-term vision
4	Key Enablers	Enablers that are necessary to resolve the 2050 challenges	The key enablers infrastructure, AI and validation will need a permanent development in parallel to market solutions	Technologies, investments and business models need to go hand in hand
5	Projects and initiatives	Overview of EU projects, and national, EU and international activities	Shows the quantity and types of activities taking place for the moment in Europe and worldwide	State of play

In parallel, the new European Partnership under the EU Research Programme Horizon Europe, "Connected, Cooperative and Automated Mobility" (CCAM), has established a Strategic Research and Innovation Agenda (SRIA), which describes the strategy for achieving the expected impacts of CCAM and the corresponding portfolio of activities, resources, and timeline from the start in 2021 till 2030.

The Agenda 2030 of this roadmap should be seen as supplement to the SRIA of the CCAM Partnership, providing some more concrete opportunities for applications within this timeframe, while fully supporting the expected positive impacts for society described in the CCAM SRIA[1]:

- Safety: Reducing the number of road fatalities and accidents caused by human error;
- Environment: Reducing transport emissions and congestion by optimising capacity, smoothening traffic flow and avoiding unnecessary trips;
- Inclusiveness: Ensuring inclusive mobility and goods access for all; and
- Competitiveness: Strengthen competitiveness of European industries by technological leadership, ensuring long-term growth and jobs.

In preparing this roadmap, other roadmaps had been considered. The more policy and regulatory focus of the ACEA roadmap, the visionary US CAR research, and the UK Connected and Automated Mobility Roadmap to 2030, curated by Zenzic, as well as connectivity roadmaps of the C2C Consortium and the C-V2X roadmap from 5GAA. Also, the Ecorys study on autonomous vehicles was considered.

1.1. Vision 2050

In 2050, **users** and usage are in the center of a development where technology needs are derived from societal targets. CCAM plays an important role in meeting the EU "Smart and sustainable mobility strategy". Vehicles and services are to a large extent developed based on requirements expressed by regions, cities and municipalities and their citizens, and are an integrated part of these stakeholders' programmes to meet their objectives. As a result, European industry provides competitive, attractive, safe and affordable services and vehicles, that ensure mobility and access of goods for all persons regardless of their geographic locations, digital experience and individual characteristics like age, income level or gender.

In 2050, **automation domains** (see chapter 2) have linked with each other, costs have decreased, and mature technology allows combining inner city use cases like super-efficient last mile transport of people and goods. Transport modes are synchronized in real-time, as all of them are digitally connected and physically linked and so provide the best solution for any travel and transport needs. Seamless transportation will serve the mobility demand at the right time and place, fulfilling user needs for safe, comfortable and affordable transport with reduced environmental footprint. Thus, CCAM will have found full public acceptance and appreciation based on proven benefits.

In 2050, **transport modes**, be it road, rail, maritime, inland waterways or air have their role. With the "coopetition" of public and private transport suppliers the user needs for individual, privately shared or publicly shared transport can be perfectly supported in a regulatory framework of an integrated transport management system which supports user needs as well as the regional and societal transport targets. With its high flexibility, road transport will cooperate with rail, water and air transport, complementing their high capacity, in order to decrease the overall environmental footprint of transportation. The concepts of "Mobility and Transport as a Service" (MaaS/TaaS) will allow users to fulfill their needs without any complex planning in advance (as today) with a reliable forecast of cost and time for all necessary transport modes.

In 2050, **vehicles** will have 100% real-time connectivity on the relevant road network and the transport management system will have the appropriate quality of service level, also for remote operation. All newly registered vehicles will have automation but in different levels:

- A vast majority of shuttles, buses and delivery vehicles in cities will operate autonomously, supported by a control center to extend the range of public transport and enabling access to

[1] https://www.ccam.eu/our-actions/sria/

previously underserviced areas as well as reducing traffic volume as a whole.

- Nearly all vehicles on highways will be able to operate without immediate driver intervention and so give driving time back to the driver, which he or she may use for various purposes including relaxation and increased productivity.

- All cars and trucks on all roads will have very sophisticated supporting systems installed, including reactions on traffic lights, roundabouts etc. and so contributing significantly to near zero crashes as well as further reducing emissions (e.g. from tires and brakes).

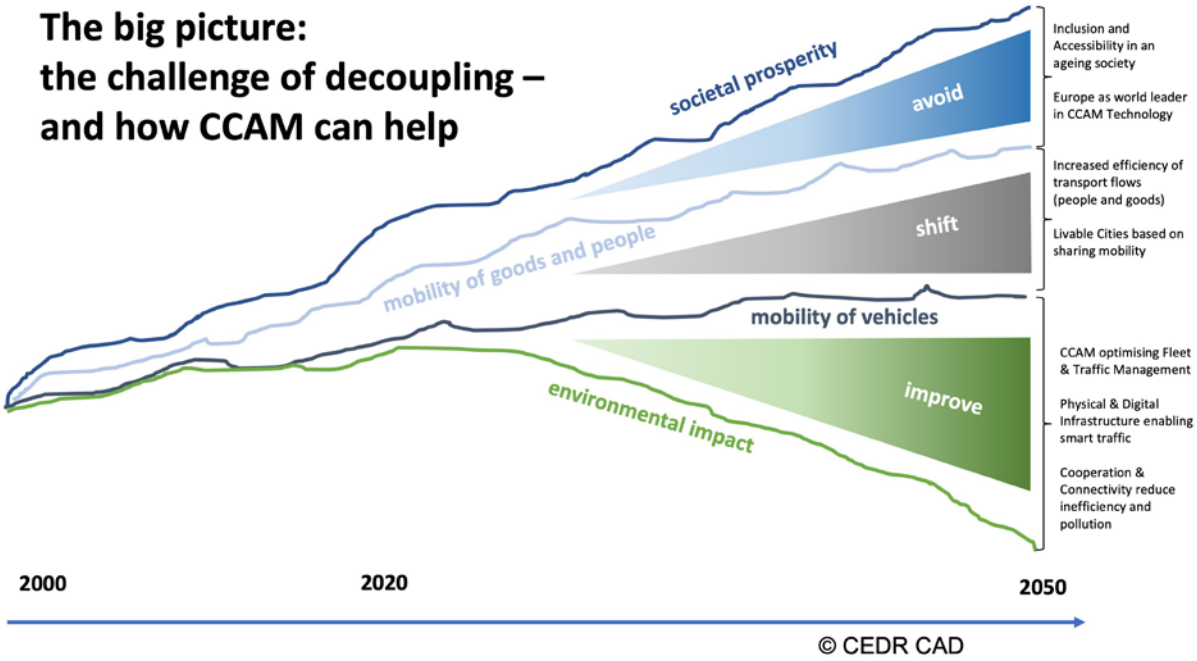
Also in the off-road and construction segment, completely autonomous operations will be common. There could even be an opportunity from an overall perspective: if the autonomous transport system has a very high share in traffic, the whole system could possibly develop itself in an AI based top-down control architecture in selected areas. With such a systemic approach, groundbreaking efficiency and safety could be realized even if still in mixed traffic. Despite the change of mix in traffic towards automation and the share of active transport modes (walking and cycling) is expected to rise until 2050, powered two-wheelers and old-timers will still be there and the interaction with them needs to be handled safely and smoothly. Even automated vehicles may not be able to compensate for all erratic behaviour of road users, and even in 2050, their Operational Design Domains will have limits, beyond which manual control may be necessary. Technical failures can never be excluded completely, either. Therefore, also beyond the deployment of CCAM, clearly intensified efforts for the improvement of road safety will be needed following the Safe System Approach: If one layer of the overall safety concept fails, another one will have to compensate. The ERTRAC Road Safety Research Roadmap[2] provides recommendations for these additional R&I efforts. Another big question is, will autonomous mobility be affordable and available enough to cover all transport needs also in remote rural areas? Already today there is a strong need for alternatives to car driving in these areas, in particular for the young, the old and the disabled to take part in social life and fulfil their daily needs.

1.2. Challenges to the Vision 2050

The next decades confront society with the need for fundamental changes in mobility, with ambitious goals to meet climate objectives. At the same time, improving road safety still remains a priority alongside factors such as improving social equity and societal cohesion. With Physical & Digital Infrastructure enabling smart traffic management, road operators will face new challenges but also new opportunities. Cooperation and Connectivity enables improved management, and reduced inefficiency – thereby contributing to lowering pollution- and supporting the smart and green goals of CCAM. While avoiding and shifting transport needs will have to be exploited as much as possible, a substantial amount of transport on roads will remain and requires new and innovative approaches. Hence, CCAM is not only a prerequisite for moving close to zero fatalities and severe injuries, but also a contributor when addressing the climate impact of mobility, as depicted in the following diagram.

In addition to the technology powered innovations as described below, which will lead to a breakthrough of CCAM services and major changes for the different sectors, achieving innovation through new business models is a significant challenge to reach the 2050 vision. Co-creating the business models with a large number of actors of the CCAM ecosystem must be explored, piloted, validated and applied to market. Then on the longer term the business models will need to be evaluated and refined. Business models must improve and expand in order to sustain. The high expectations on CCAM's contribution to meeting societal and business targets can only be met when offered mobility solutions are used by a sufficiently large population. Operations, services and vehicles need to be perceived as superior to alternatives and, therefore, as desirable. They have to meet criteria derived from societal targets, and deployment needs to take place in cities, regions and nations. It will be particularly challenging to secure attractive and affordable CCAM options for all kinds of citizens, users and customers, and to implement business models that allow sustainable provision of services that foster inclusion of e.g. rural regions or areas experiencing transport poverty.

[2] ERTRAC Safe Road Transport Research Roadmap – Towards Vision Zero: Following the Safe System Approach, November 2021; https://www.ertrac.org/uploads/documentsearch/id76/ERTRAC%20Safety%20Roadmap%202021.pdf



CCAM contribution to mobility change

1.3. Challenge Infrastructure

Innovative traffic management options will arise when the conceptual approach evolves from managing road sections to managing vehicle fleets and finally individual vehicles, down to supporting individual manoeuvres. Infrastructure Support for Automated Driving (ISAD) will have to extend the Operational Design Domains (ODD) of automated vehicles by providing a real-time digital twin of the physical and digital infrastructure. This digital twin needs to not only include static data, like precise layout details of lanes in different infrastructure sections e.g. tunnels, bridges, toll stations; loading capacity of bridges, and permanent road signs, but also dynamic data, like temporary road works, road condition and otherwise known safety relevant information. Further, the challenge is that these improvements in accessible and useable data create a cooperative system where functional safety must be assessed for the whole, not separately for its parts. So required standards, specifications and practices must be researched and developed. All this cooperation is based on the evolution of suitable systems for connectivity and the processing and sharing of huge amounts of data. While communication technologies like mobile internet, roadside ITS stations, cloud dataspaces and mobile edge computing will converge, research and development of new public and private business concepts and cooperation patterns must lead to corresponding regulatory frameworks and business models. This is to be seen as an evolutionary perspective in a settled field, not a re-design of transportation. This evolution mandatorily requires strong cooperation of stakeholders from vehicles, infrastructure, and the connectivity sector, not only in research and innovation but further down to the required pre-deployment developments that are the enablers of actual and operational deployment.

1.4. Challenge Validation

By 2050, verification, validation and consumer information schemes and procedures for CCAM systems will be based on realistic and relevant test cases, follow commonly accepted methodologies and make use of validated tools. However, some challenges will remain due to the dynamic nature of the constantly evolving transport system. Therefore, the scenario database from which test cases will be extracted will need to be updated continuously in order to reflect ODDs that will still be expanding in some parts of the road network. Other changes in the transport system will also be considered in corresponding scenarios and test cases, such as a growing number of highly automated vehicles or the emergence of new means of transport, and some relevant trends and disruptions which may occur until 2050 that are still hard to anticipate today. Also, the connectivity context in which CCAM systems will be operating will develop further. Since even safety-critical functions may rely on this connectivity

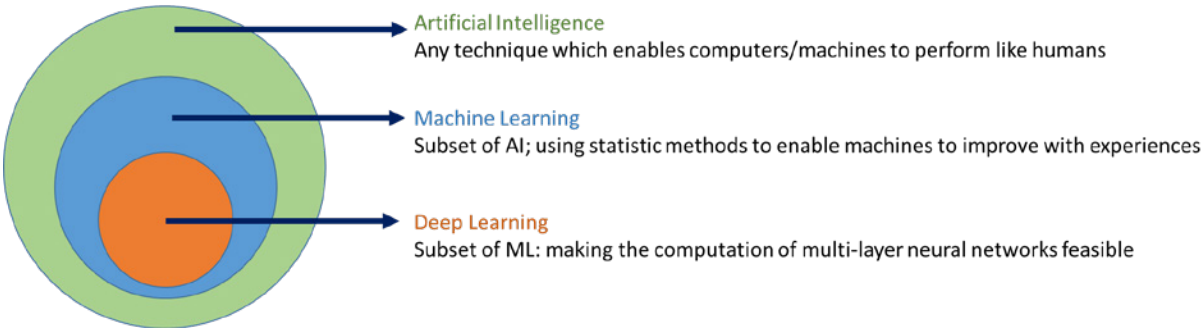
context in the long-term future, its dynamic development will have to be reflected in future validation scenarios, as well. This applies in particular to the remote operation of automated vehicles and to all safety-critical systems with distributed intelligence (on- and off-board) as a particular challenge for validation. While basic issues of the validation of AI-based and self-learning vehicle systems will be solved in 2050, the concept of self-developing systems applied to the transport system level may pose a final significant challenge in this context.

1.5. Challenge AI and Data

Combined data from the host vehicle, other vehicles, infrastructure and back offices can be used in decision making in complex scenarios. This should include safety critical situations, traffic management, emission management, charging of vehicles and provision of many new and emerging mobility services. These combined data, from projects and implementations of CCAM, also offer an important opportunity to improve the evidence-base for CCAM. Proof of the positive impact on societal goals like safety, efficiency and sustainability is crucial for policy making, legislation, investment decisions and accountability. CCAM stakeholders will continue cooperation to make data available for evaluation.

For different CCAM applications, AI can be based at different parts of the overall mobility system: parts of it will eventually be on board at a central unit or at sensor level, or at a central location or service provider back office. With this in mind, it should be clear that setting up a joint and acknowledged data exchange framework will be essential. It needs to be clear how to exchange relevant data, in what format and with whom. An emerging topic in this discussion is the increasing energy use for data exchange, which in light of mobility sustainability needs to be regarded from these early stages of the discussion onwards.

Implementing AI for situational awareness, in CCAM, presents a variety of challenges, e.g. industrialisation, requirement-based development, continuous improvement of trained modules for application in safety critical domains. The ambition is to move from reactive and/or adaptive system support to AI based predictive system state awareness, decision making and actuation. To enable this, contextual information and definition of AI will be needed.



AI and its two major subsets, relevant for Connected and Automated Driving

Furthermore, a major shift is needed from probabilistic modelling to advanced stages of AI, including the incorporation of Machine Learning and Deep Learning. The latter, with neural networks, take into account the fact that it is rarely possible to know everything about a situation. The speed of calculations and learning processes could be increase by the use of e.g. emerging stages of quantum computing. This, however, would impose new and high energy demands, as well as a high level of use of (critical) IT infrastructure. Therefore, focus should be on advancing levels of AI, designed with reduced energy use of the computational efforts.

With these advanced stages of AI, it will be essential to continuously improve the quality of the dataset used to train the AI. It furthermore will remain essential to develop the approaches and tooling for the testing and verification of AI applications, initially for situational awareness, but also for wider application in connected and automated driving. This tooling for verification can include

also scenarios and synthetic datasets. With a software update based on joint learning capabilities, release of such an update should be done after a safety release by engineers. In the years to come, development processes need to be established for systems with self-learning capabilities, such as neural network based CCAM technologies.

Besides this, the recently emerging concepts of trustworthy AI and reliable AI will need to be brought much further: these are seen as key for boosting user acceptance of the technology, as well as for advancing the essential societal benefits like safety, emissions, inclusivity and access to mobility. At the same time, these concepts are needed to build on the ethics fundamentals of AI in road mobility.

2. Agenda 2030

With the Agenda 2030, being the core of this roadmap, separate domains of CCAM products and services are described. They differ in various characteristics, develop in different timeframes and offer a large variety of use cases. These domains in total represent an operational agenda for research, standardisation, regulation and investments. The Agenda 2030 should be seen as supplement to the SRIA of the CCAM Partnership, providing some more concrete opportunities for applications within this timeframe.

Four domains are distinguished in this chapter:

- Highways and corridors – Most likely the first industrialised solutions of temporarily driving without any human driver responsibility
- Confined areas – Various use cases where easier traffic circumstances promote early demonstration and limited industrialisation
- Urban mixed traffic – The most important contributor to societal objectives
- Rural roads – The biggest challenge, combining high vehicle speed with full traffic complexity

All four domains are described in a common structure:

- Description – what characterises this domain specifically?
- Motivation – Why is this domain seen as a focus of development?
- Societal benefits and demonstrations – What is expected to be achieved for Society?
- Use cases – What are the typical expected use cases in this domain in examples?
- Enablers – Which aspects of infrastructure, vehicles technology and validation enablers are specifically important in this domain?
- Standardisation – Which standardisation areas are key for speeding up the industrialisation?
- Regulation – Which regulation gaps are still to be covered?

2.1. Highway and Corridors

2.1.1. Description

The highway automation and assisted corridors domain will enable typical applications for motorway automation, hub-to-hub truck operation and cooperative assistance with infrastructure support. In this domain vehicles with CCAM functionality will be deployed together with infrastructure support. The Trans-European Transport Network[3] (TEN-T) roads network - and in particular the motorways - provides the backbone for road traffic for Europe. Motorways in Europe are generally dual-carriageway highways with a division between traffic in opposing direction and usually more than one lane in each direction.

[3] https://ec.europa.eu/transport/themes/infrastructure/ten-t_en

On motorways vehicles equipped with various levels of Advanced Driver Assistance Systems (ADAS) will be in majority. The share of cooperative driver assistance systems will increase using V2X technologies together with vehicles capable of lower-level automation (L0-L2). Higher level of automation (L3-L4) will be possible depending on regulation as the technology maturity increases.

In 2019 and 2020, the L3Pilot European project piloted the SAE L3 motorway chauffeur and traffic jam chauffeur functions on highways in different European countries. The results of the data analysis of this piloting activities is going to accelerate the deployment of AD functions in motorways scenarios.

The European project ENSEMBLE during 2018 and 2021 paved the way for multi-brand truck platooning as an effective way to improve traffic safety and fuel efficiency in particular for motorway freight transport. This project concerned connectivity, cooperative systems and lower-level automation. Further development will be needed to develop platooning further with automated safe auto-follower and automated hub-to-hub transport use-cases.

Several assisted corridors will be selected, where the road infrastructure and communication system capabilities will meet the requirements for deployment of CCAM vehicles with infrastructure support. Candidate corridors are those implemented with hybrid communication capabilities, consisting of a smart mix of short- and long-range communication technologies, thanks to the European projects on 5G corridors and to the C-ROADS Platform. Assisted corridors will meet specific traffic needs for enhanced safety and efficiency improvements for better network utilization.

2.1.2. Motivation

- Main motivations for CCAM on motorways and assisted corridors.
- Enhanced road safety with automated distance, maneuver and speed management.
- Improved traffic flow on motorways and selected assisted corridors.
- Reduced driver workload and increased convenience.
- Early introduction of higher automation (L3-L4) when feasible to further enhance safety, traffic flow and convenience.

2.1.3. Societal Benefits and Demonstrations

Considering the expected future traffic growth on the motorway network it is important to make use of CCAM as a solution. It is of key importance to demonstrate that CCAM solutions will meet users and society needs and exceed expectations to meet the goal of user's adoption of CCAM.

- Demonstrations of highway automation in different regions, domains, environmental in increasingly complex traffic situations to prove system safety, robustness, interoperability of CCAM as an effective mean to improve road traffic in Europe.
- Demonstrations in selected assisted corridors to provide evidence for societal and users benefits of highly automated solutions with infrastructure support.

2.1.4. Use Cases (examples)

Typical high-level use-cases for highway automation and assisted corridors.

- Traffic Jam Chauffeur: L3 in traffic jam up to 60km/h, following vehicle in front, optionally with lane change. System can bring vehicle to safe stop.

- Highway Chauffeur: L3 on highway up to 130km/h, including lane change. System can bring vehicle to safe stop on emergency lane.
- Safe Auto-follow: L4 on highway up to 130km/h for cars or L4 platooning/auto-follower up to 90km/h for trucks. No driver intervention needed.
- Hub-to-hub transport: L4 transport between terminals/hubs in selected supervised corridors.

2.1.5. Vehicle Enablers

- Affordable vehicles with L2-L4 enabling capabilities.
- Defined parameters for real-time-reaction baseline of CCAM safety functions.

2.1.6. Infrastructure Enablers

- Realtime Traffic control
- Precise positioning
- C-ITS enabled adequate connectivity coverage, quality of service and data trustworthiness
- Infrastructure safe-zones available (e.g. hard-shoulder)

2.1.7. Validation Enablers

- Functional Safety of the whole traffic system
- Efficient validation toolchain complying with certification requirements

2.1.8. Standardisation

- Connectivity Interfaces for V2X e.g. ITS-G5, LTE and 5G technology.

2.1.9. Functional Safety of Infrastructure

- Common evaluation of perception performance for both vehicles and infrastructure.
- Rules and principles for „safe-stop areas“ (e.g. ethic dimensions using hard shoulders and emergency lanes – what if an accident occurs and safely stopped vehicles occupy the lane?)

2.1.10. Regulation

- Safe operation of higher level of automation (L3-L4) in Assisted Corridors
- Harmonized regulation for testing connected vehicle automation in the different European Member States.

2.2. Confined Areas

2.2.1. Description

Confined areas typically have the surrounding under control with perimeter protection and gates to prevent un-authorized entry of vehicles and people. In this domain there could be mixed traffic with manually operated vehicles and other automated vehicles. Vehicles are usually also operated at lower speeds and there could also be specific traffic regulations. Since confined areas are usually under

supervision there is much lower risk for un-authorized vehicle and VRU presence. Typical examples of confined areas are “Closed parking areas and parking houses”, “Logistics terminals and port areas” and “Bus depots and Bus terminals”.

2.2.2. Motivation

Confined areas are well suited for early introduction of highly automated (L4) vehicles due to the reduced risks for unauthorized traffic and opportunities for productivity improvements. Vehicles in confined areas usually operates at lower speeds and local traffic regulation might apply which will reduce ODD complexity considerably. Yet there might be other vehicles and unprotected people moving around the area so the risk for interference is not negligible.

The confined areas will enable early deployment of CCAM functionality due to lower speed and traffic complexity. Deployment will be done to improve safety, convenience and productivity for the confined area operators.

2.2.3. Use Cases

- Typical high-level use-cases for operation in the confined areas.
- L4 Car valet parking to improve convenience and parking facility efficiency
- L4 Shuttles in slower speed in restricted areas without safety driver (remote surveillance) for people and freight.
- L4 Bus self-maneuvering in depot operation to improve safety and productivity
- L4 Unmanned truck/trailer operation in-Terminal/Hub to improve productivity and safety

2.2.4. Societal benefits

There are opportunities to enhance productivity and safety in CCAM operated vehicles confined areas. But due to the nature of autonomous vehicles users need to further develop trust. Hence there is a need to increase user and society acceptance of safety of L4 vehicles. Autonomous vehicles provide considerable opportunities to further enhance productivity and safety in confined areas.

2.2.5. Demonstrations

Demonstration activities should further support deployment to ensure of perceived usefulness and safety. There is also a need to proceed with European harmonization of confined area use-cases to further reduce costs and speed up deployment. It is also an opportunity to replicate solutions for confined areas in Europe and beyond internationally.

2.2.6. Vehicle Enablers

- L4 capable vehicles with parameter setting
- Realtime reaction on connected safety functions

2.2.7. Infrastructure Enablers

- Realtime Traffic control and surveillance in place.

- Possibility to ensure high-bandwidth low-latency connectivity over the domain
- Perimeter safety control using for example gates, fences and geo-fences
- Mechanism to ensure acceptable performance also in non-perfect conditions (e.g. redundancy)

2.2.8. Validation Enablers

- Functional Safety of the whole traffic system
- Efficient validation toolchain complying with certification requirements

2.2.9. Standardisation

- Connectivity and C-ITS Interfaces
- Functional Safety of Infrastructure
- Traffic control and surveillance
- Common evaluation of perception performance (vehicles and infra)
- Interfaces to non-confined domain (e.g. gate procedures)

2.2.10. Regulation

- Safety operation in confined areas.

2.3. Urban mixed traffic

2.3.1. Description

In the short and mid-term improving safety and efficiency in metropolitan areas and cities is one of the most important societal objectives in mobility. Self-driving vehicles bear the potential to crucially contribute to solve the increasing challenges of urban mixed traffic. One key question is how to integrate automation into an intermodal mobility system that includes a wide variety of vehicles with different technical solutions, delivery services and transport of goods, public and private transport, car-sharing and fleet operations as well as pedestrians, bicyclists, powered two-wheelers and micro-mobility solutions.

Therefore, an incremental approach considering the big variety of use cases and linked ODDs appears being the most promising way to deploy road automation in urban applications. It will be feasible to introduce automated driving in cities within this decade at least in restricted applications, such as on dedicated routes where other traffic is limited. But it will be longer before such systems are capable of completely dealing with all complex urban traffic situations independently.

2.3.2. Motivation

Automated driving technologies being implemented and applied in urban environments will contribute to the achievement of different societal goals.

Safety: Automated driving is expected to reduce road crashes caused by human errors, thereby contributing to the so-called Vision Zero, i.e. no road fatalities and serious injuries by 2050.

Efficiency and environment: It will increase the efficiency of the transport system and reduce traffic

congestion. In turn, smoother traffic and less kilometres driven will decrease energy consumption and emissions.

Accessibility and social inclusion: Automated on-demand mobility services complement the range of public transport services and provide access to public transport for people who have not yet had access to public transport. It will be beneficial for people with reduced mobility, providing them with a new source of mobility and increased access to city centers and remote locations.

Clearly defined low-speed use cases enable early deployment based on available technologies especially in cities.

2.3.3. Societal benefits

Safety:

In 2018, 38% of all EU road fatalities occurred in urban areas (Key figures 2020 – Road safety targets, DG MOVE), and the number of non-fatal crashes with personal injuries is disproportionately higher in urban areas compared to non-urban roads. Therefore, safety-enhancing measures in cities will be effective in the reduction of the overall number of road fatalities and, probably even more, in the reduction of injuries. In particular, largely unprotected road users, such as pedestrians and bicyclists, are likely to benefit significantly from improved road safety in urban areas.

Efficiency and the environment:

Automated driving technologies will increase the efficiency of the transport system and reduce traffic congestion regardless of whether they are used in individual transport, in collective mobility services or in goods transport. In turn, smoother traffic will reduce fuel consumption and emissions. This is especially true in urban traffic due to the concentrated demand for mobility. Here, too, however, the prerequisite is a high penetration rate of highly automated vehicles and organized interaction in the traffic environment. Automated driving technologies, for example improved fleet management, have the potential to optimize vehicle usage and future mobility services. In the end, this optimised use of automated mobility modes even shows a potential to reuse space in urban environments and improve the liveability in cities.

Accessibility and social inclusion:

With automated and inclusive on-demand mobility services, people with reduced mobility will have a new source of affordable and easy-to-use mobility providing them with better access to city centres as well as more remote locations. Automated driving allows people to stay mobile for longer and allows for greater participation in social life. Globally, the population in cities will continue to grow in the coming years – and with it the need for transport. With fully automated and driverless vehicles this gap can be closed. This will not remove the existing mobility offers (taxis, public transportation, etc.) in cities, but will complement them in an efficient way.

2.3.4. Demonstrations

Demonstration projects shall support the impact assessment of L4 automation use cases like car valet parking and shuttle services and facilitate the assessment of acceptance and affordability. Moreover, demonstration projects will offer room for the early deployment of L4 automated driving in public transport, goods delivery and municipal services in urban areas.

2.3.5. Use Cases (examples)

The most beneficial applications of automated vehicles in urban area require the ability to drive

autonomously without a driver who must remain alert and ready to take control if the system is unable to execute the task. One example is Automated Valet Parking, where the real added value comes from the driver even leaving the vehicle before parking. So the relevant urban use cases are Level 4 applications. Deployment will happen stepwise and according to very defined ODDs (typically low speed) and infrastructure needs of the specific functionality.

Use cases can be clustered in

- Restricted applications like automated parking, gated areas working with low speed,
- Red carpet use cases on dedicated lanes,
- Residential last mile transport of people and goods,
- Bus(-like) applications on pre-defined routes in mixed traffic and
- Taxi-like operations working on flexible routes in a defined road network.

2.3.6. Vehicle Enablers

Predictive, automated driving requires a situational understanding. The prerequisites for this include, for example, an understanding of topology, traffic guidance, intentions, road rules, patterns of behaviour and the interaction between road users.

- The ability of sensing and perception technologies to cope with more and more complex traffic situations is essential for use urban mixed traffic applications.
- Sensing the environment must also be supplemented using digital map information validated by sensors.
- V2X to fleet management / vehicle control center

2.3.7. Infrastructure Enablers (depending on use-case)

The automated vehicle must identify the way traffic is guided, which in scenarios occurring at crossings and urban intersections, in particular, cannot be resolved using current sensor-based technology – which makes supplementing it with precise digital map and other off-board information necessary.

- Availability of up-to-date HD maps of the urban road network
- PDI connectivity, including real-time traffic information
- Provision of additional infrastructure support (fleet management, vehicle control center)

2.3.8. Validation Enablers

- Efficient validation toolchain complying with certification requirements
- Integration of safety-critical scenarios specific to urban traffic in EU wide scenario database

2.3.9. Standardisation

- Standardisation of test procedures and rankings
- Standardisation on the specific requirements for PDI support for Level 4 automation, following standardisation of PDI concepts and requirements in general and covering the entire lifecycle, in particular maintenance of the PDI support systems

2.3.10. Regulation

- International regulation for type approval and traffic rules almost completely missing for automation level L4.

- Streamlining and harmonization of exemption procedures for L4 FOTs / living labs

2.4. Rural Roads

2.4.1. Description

Mobility for all includes those living and working in rural areas and accounting for almost 30% of the EU population[4]. In many EU Member States, car dependence is high for the rural population, and options to use public transport may be few, with challenging business cases. Driverless vehicles are therefore seen as a great opportunity to improve rural mobility of people and goods.

At the same time, rural roads pose particular challenges to higher levels of automation. They have mixed traffic (incl. wildlife, agricultural machinery etc.), relatively high speeds of up to 110 km/h in some Member States, typically oncoming traffic and therefore extremely high relative vehicle speeds as well as large variations in road infrastructure types and conditions. The latter may even vary daily, e.g. with snow not being cleared. In addition, the quality of digital map data and connectivity is often poor in rural areas.

Therefore, a two-step approach is proposed for road automation in rural areas:

- In the short term, advantage can be taken from existing CAV systems to improve road safety in rural environments without ODD limitations. For mature technology, the focus will be on increasing market up-take and extending functionalities. At the same time, there may be room for the further development of technology and respective regulation in the coming years.

- In the longer term, the development of highly automated mobility solutions can enhance rural living and needs to be accelerated until 2030. This includes services for people and goods, e.g. providing first mile/last mile services to access points as well as shared and/or public transportation. Business cases play an important role here.

2.4.2. Motivation

More than 50% of all EU road fatalities are caused by crashes on rural roads. Therefore, it is these roads where the potential leverage effect of automation with regard to road safety is highest. Even lower levels of automated driving (L1-2) can make substantial contributions to improving road safety on rural roads based on systems that come at relatively low costs. Higher levels of automation, even if not yet in the focus of wide deployment on rural roads until 2030, are very likely to contribute to further safety improvements, as human error as a dominant factor in crash causation will lose importance.

In addition, highly automated driving in rural areas, even if only with limited ODD on pre-defined routes, will enable the more cost-efficient provision of transport services, as labour costs of drivers are a significant cost factor for the operators of such services today. Thus, in the long term, highly automated driving will help ensuring inclusivity of the road transport system, also in sparsely populated areas, where high-quality public transport can only be operated with high deficits today. In particular, those too young or too old to drive themselves, those who cannot afford their own car and those with reduced personal mobility will benefit from such transport services with automated vehicles.

[4] https://ec.europa.eu/eurostat/de/web/products-eurostat-news/-/edn-20200207-1

2.4.3. Societal benefits

The high potential of all levels of automation in improving safety on rural roads and reducing the absolute number of road fatalities and injuries in the EU constitutes a very important societal benefit. This applies to the reduction of physical and psychological human suffering as well as to the reduction of the socio-economic costs related to road crashes in the EU of many billion euros per year.

Moreover, a truly inclusive road transport system will enhance rural quality of life, enable rural living for many of those who cannot drive their own car and thus counteract rural depopulation. In combination with other factors such as digitalisation of all areas of life, a new perception of "attractive rurality" can be a longer-term impact.

In view of the rural domain showing the highest potential in improving safety and inclusivity of road transport through automation, also on rural roads, higher levels of automated driving need to be prepared in the decade of co-creation research and technology until 2030.

2.4.4. Demonstrations

Large-scale demonstration projects shall support the impact assessment of lower levels of automation in terms of safety and facilitate the assessment of acceptance and affordability. Moreover, demonstration projects will offer room for the early deployment of highly automated driving in public transport, goods delivery and municipal services extending from urban into rural areas.

2.4.5. Use Cases (examples)

Applications of Automatic Emergency Braking, Lane Departure Warning, Adaptive Cruise Control as well as Steering and Lane Control Assistant Systems constitute typical use cases of lower levels of automation on rural roads.

Driverless shared and/or public shuttle services operating on pre-defined routes as well as automated municipal services, e.g. refuse collection, show a high potential as early use cases of highly automated driving in rural areas. Due to labour costs savings, such services may be attractive from an economic point of view despite high costs of the required technology and even if initially operating in very limited ODDs on precisely defined routes. Moreover, higher quality and availability of shared and/or public transport services would already mean important progress in terms of inclusivity for those who cannot drive themselves. Also first mile/last mile delivery services with very compact, low-speed automated vehicles will probably be a use case with early technological feasibility and economic viability in rural areas.

2.4.6. Usage Enablers (for higher levels of automation)

- (On-demand) scheduling, routing, placement and design of stops and their access points
- Ticketing and business models, also for first mile / last mile services
- Information systems on schedules, destinations, payment etc.
- Support functions ("helpdesk", on vehicles, at stops...)

2.4.7. Vehicle Enablers

- Constantly improving environment perception
- Reducing costs for increased marked up-take of lower levels of automation

- Ability to cope with limited PDI support incl. bad road surface conditions, not perfectly groomed greenery; decreased sensitivity /dependence on perfect infrastructure and maintenance for higher levels of automation

2.4.8. Infrastructure Enablers (primarily for higher levels of automation)

- Availability of up-to-date HD maps of the rural road network (support also for lower levels of automation by digital maps with continuously refreshed contents (roads signs, speed limits etc.))
- Real-time traffic information plus precise information on local weather conditions in rural areas (especially when weather conditions are exceptional, being part of safety related traffic information according to Delegated Regulation 886/2013)
- Reliable connectivity in rural areas
- Provision of non-stationary infrastructure support (e.g. drones, delivering information on short-term road works)

2.4.9. Validation Enablers

- Increased use of virtual validation methods for cost reduction, complying with certification requirements, also for lower levels of automation
- Inclusion of human-machine interaction in validation procedures (mode awareness)
- Integration of safety-critical scenarios specific to rural roads in EU wide scenario database for higher levels of automation (incl. diverse lighting / road conditions + edge cases)

2.4.10. Standardisation

- Standardisation of test procedures and rankings
- Standardisation of interfaces, components and tooling, including minimum information provision by user interfaces
- Standardisation on the specific requirements for PDI support for higher levels of automation in rural areas, following standardisation of PDI concepts and requirements in general (focused in a first phase on other operating environments) and covering the entire lifecycle, in particular maintenance of the PDI support systems

2.4.11. Regulation

- Worldwide alignment of the existing regulatory framework for lower levels of automation
- Increasing market take-up of lower levels of automation by providing (financial) incentives for safety benefits
- International regulation almost completely missing for automation levels L3 and higher
- Streamlining and harmonization of exemption procedures for L4 FOTs / living labs

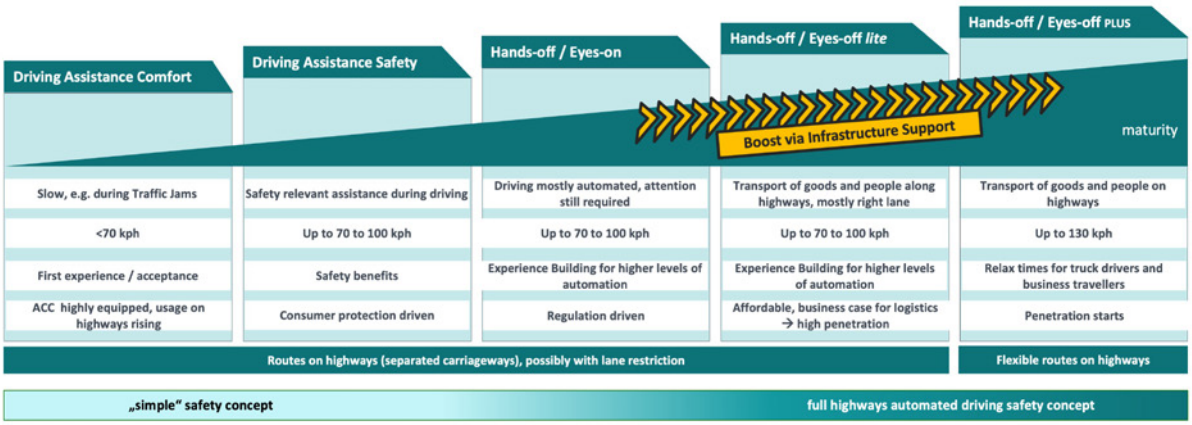
3. Outlook 2040

On the way to meet the Green Deal targets, use cases will widen up and grow together as a result of implementing the Agenda 2030 and the results of Horizon Europe. This will be the decade of technological maturity, bringing benefits to society in larger scale. But there will also be challenges to bring these wide use cases to high market uptake. Public procurement needs to have reached common requirements within Europe across all use cases. The principles of public procurement should be aligned on a worldwide level to make sure that a common worldwide level of robustness and safety will be reached. Also the concepts of Artificial Intelligence, based on huge Data Lakes, which will widely be implemented in perception, need to be established for the driving strategy, which means decision making. With this, the questions around ethical aspects will have a high priority. Increasing attention will have to be given to involvement of and co-creation with a wide range of citizens, regions and cities in the development of mobility solutions, attractive enough to ensure demand. With mature products being available, these products need to find full acceptance, if not enthusiasm, by the mobility users to deliver the effects on safety, efficiency and traffic reduction as demonstrated in the 2030s in daily usage.

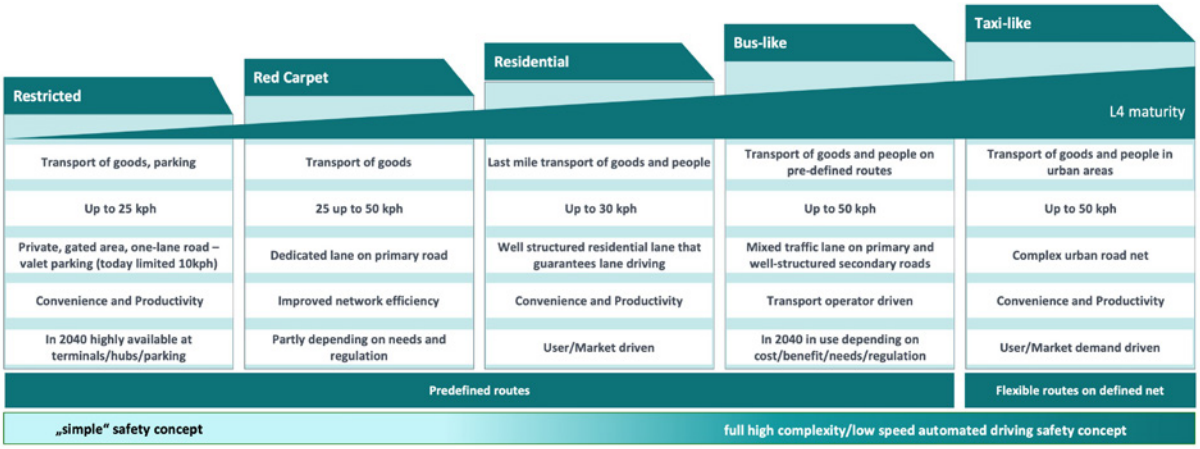
Looking at the domains of the Agenda 2030, corridors will further enable use cases on highways to master speed challenges. After enabled corridors, standards need to be developed for highway ISAD applications including further increasing ODD when it comes to weather conditions or quality of road surface as well as AI-based decision making in traffic interaction. ISAD A Corridors highly equipped with digital infrastructure will be able to handle traffic density including safety benefits on hotspots. Physical Infrastructure, e.g. stop zones need to evolve in parallel to this ISAD increase. Higher service levels e.g. convoys and automated platooning in dedicated lanes in space and/or time and/or corridors for buses and trucks will be established. At the same time, low speed use cases will further evolve and combine to master traffic complexity challenges. Confined areas grow and merge into full urban autonomy shuttles and delivery. Various use cases from confined to urban will receive high market uptake. That is why in the two following graphs, the Agenda 2030 domains of confined areas, urban and rural are combined in the second, low speed automation scheme.

The following graphs represent a logical order of use cases, which will have their fully industrialized rollout for high market uptake with a focus in the 2030´s for the two main approaches of high speed with limited complexity of traffic and lower speeds but covering the full traffic complexity.

Outlook on highway automation:



Outlook on low speed automation:



Beyond the use cases in the schemes above there will be other use cases coming up. Rural autonomy will expand on specific routes reaching out to more remote settlements. These are the most complex scenarios, where the high speed on rural roads including oncoming traffic will find only limited infrastructure support. It is expected that only with a high effort on specific measures to limit the complexity, driverless operation will be available.

Other special use cases will be frontrunners, e.g. robot mower on road shoulders, winter service, road maintenance and construction vehicles as well as highway safety trailers. Depending on the specific circumstances of operations, quick wins, especially when it comes to highway safety will be realized, when the mature basic technology will be validated and affordable.

4. Key enablers

The temporary or even complete hand-over of the driving task from a human to a machine in connected and automated vehicles requires the systems for environment perception, decision making and control to meet highest safety and performance standards that today are still out of reach. Further advancement in enabling technologies thus is essential for making CCAM ready for a wider market deployment, like Sensor components and networks, computing systems and control architectures with high reliability, fail-operation capabilities and efficiency, Embedded software and artificial intelligence at the edge providing agile upgradability and self-learning capabilities and Communication infrastructures and cloud-based services for the gathering, exchange and analysis of critical data at high bandwidth, short latencies and highest levels of data security.

Particularly for autonomous vehicles, a shift from a bottom-up safety logic based on the controls of individual vehicles to merely top-down systemic safety paradigm can be foreseen, requiring data flows, software updates and hardware allocation to be flexibly aligned at vehicle, infrastructure and cloud levels. This will imply the enabling technologies to be widely generic and integrated into a comprehensive and co-designed central architecture, while opening new opportunities for the testing, validation and monitoring of vehicle functions. In this sense, further progress in CCAM will be based on a new enabling technologies path to be jointly explored by the actors of the research and innovation ecosystem.

To describe all these enablers in a structured way – even if they are intensely interlinked – we distinguish for readability:

- Infrastructure including business models, which will end up in new challenges and opportunities for all stakeholders of road transport
- Technology enablers with focus on the vehicle and its development ecosystem, with strong links to
- Validation, far beyond today´s vehicle validation schemes and
- AI and Data Ecosystems which will have strong influence on all of the above.

Note that this roadmap focuses on technical and research topics primarily and thus highlights the technological key enablers required for those. Later, the deployment requires further societal and regulatory enablers, but those are not the focus here.

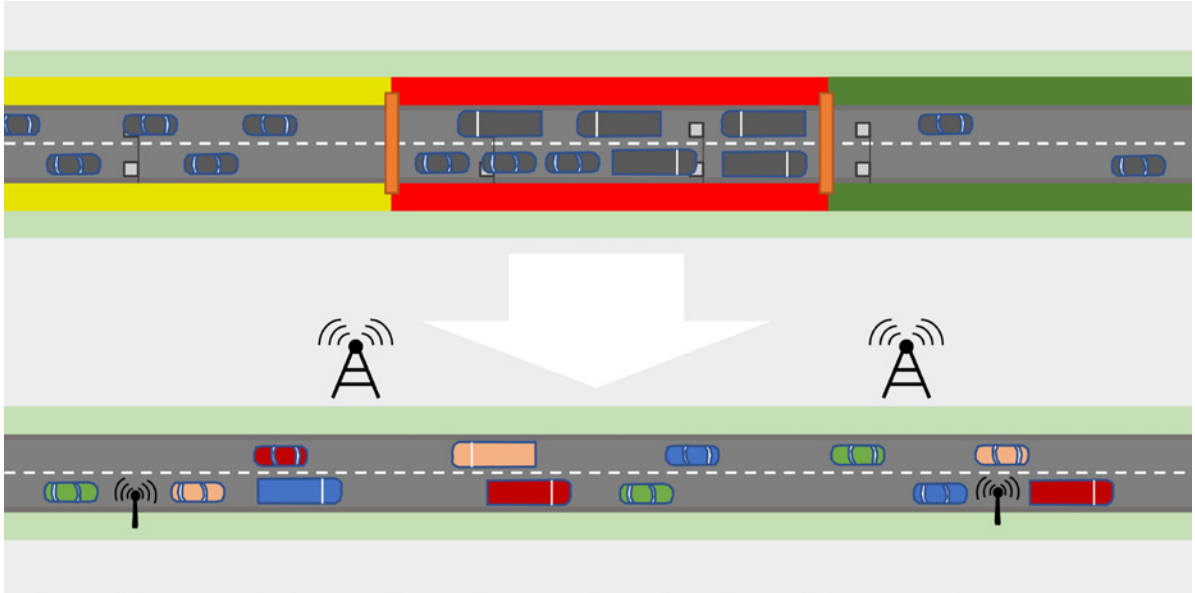
4.1. Infrastructure and business models

4.1.1. Introduction

Optimised traffic and vehicle usage can minimise environmental impact and ensure maximum safety and economic efficiency. Based on connectivity and digitalisation plus cooperation of actors, CCAM enables the benefits of automation for managing traffic. Today, we manage traffic flows and road segments as main objects of concern. Future traffic management will have to make full use of CCAM options in terms of individual vehicle connectivity and data sharing options to address vehicle fleets. CCAM use cases must address this, with huge green and safety potential:

- Individual traffic regulations with fine granularity for vehicles / vehicle groups
- Infrastructure support for vehicle manoeuvres

Future research must enable road networks to become "CCAM-ready" and allow for such fine-grained traffic management, as depicted in the following figure.



From managing traffic to managing vehicle groups

4.1.2. Challenges

The role of the infrastructure is pivotal in addressing carbon-free transport needs as well as increasing traffic efficiency, and it will add a new dimension to road safety, in particular where substantial infrastructure support extends collective perception and the horizon of automated vehicles. Nevertheless, these concepts require a disruptive change in how vehicles and infrastructure interact, that raises challenges that need to be address in Research & Innovation.

- Benefits of autonomous driving occur only where the requirements of the Operational Design Domain (ODD) are met. The physical and digital infrastructure determines the availability of many of the key attributes of the ODD.

- With vehicles and infrastructure forming a single safety-critical system, technical components of their collaboration – such as connectivity – have to be evolved and trade-offs, e.g. between latency and the volume of information that the infrastructure can provide will have to be addressed to ensure functional safety.

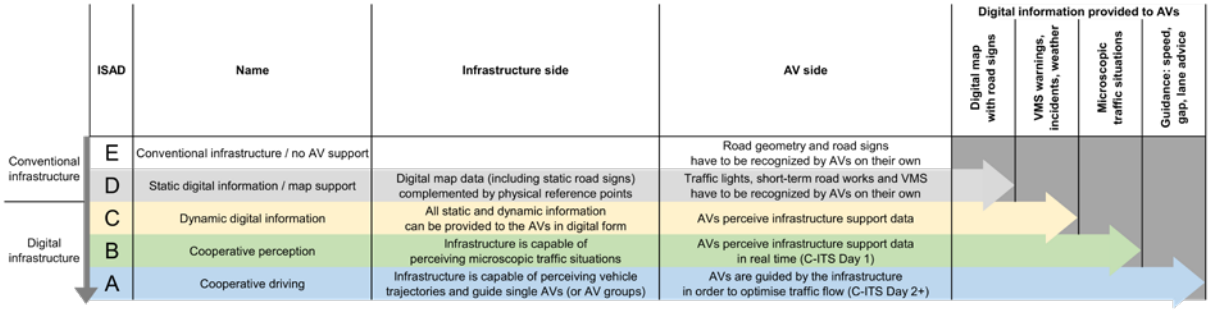
- Data reliability is a major issue for infrastructure and vehicles alike. Already today's emerging data sharing ecosystems show the complementary nature of vehicle and infrastructure data when managing information relevant for the dynamic driving task of the vehicle. Suitable collaboration patterns need suitable data sharing technologies and ecosystems.

- Not only the full automation scenario needs to be addressed, especially the transitional mix traffic situation will pose challenges in having automated vehicles interact and react to non-connected, human driven vehicles and other road users that behave way less predictable. The infrastructure can provide valuable support in this period of co-existence by providing data about the non-connected vehicles to the data network beyond the sensor range of automated vehicles, thus filling possible gaps further increasing safety and viability of automated driving.

4.1.3. Vision

4.1.3.1. ODD and ISAD

The impact of some factors potentially exceeding the ODD can be mitigated and even prevented by infrastructure related actions. The environmental perception of automated vehicles is limited by the range and capability of onboard sensors, which can be extended by roadside information, including roadside sensor data. The ISAD (Infrastructure Support levels for Automated Driving) classification has been proposed, assigning ISAD levels to sections of the network in order to give automated vehicles information about the infrastructure support that can be expected. The ISAD levels depicted in the following diagram may in the future be extended to include further functionality, e.g. related to improved traffic management and co-operative manoeuvres. These roles and responsibilities are to be seen in the context of the evolving traffic eco-system and its business models, both aspects detailed later in this chapter.

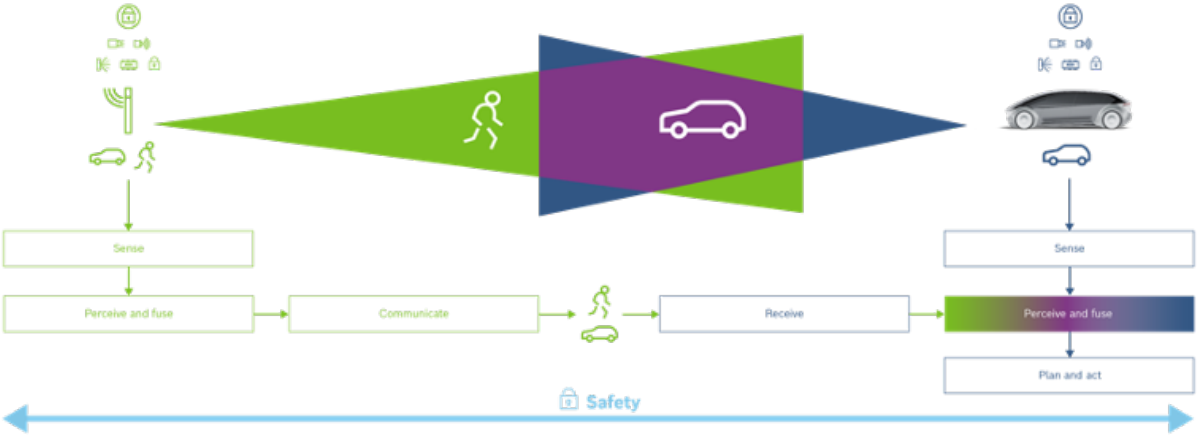


Levels of Infrastructure Support for Automated Driving (ISAD)

The ODD related requirements of the autonomous vehicles will likely evolve along with the evolution of the onboard sensors, software, and AI technologies. The investments in roadside infrastructure are very costly, and the lifetime of physical infrastructure investments is 30-50 years with that of the digital infrastructure being 8-15 years. Hence, the infrastructure support level increases will likely focus on the digital infrastructure aspects, and the physical infrastructure investments in "no-regret" measures benefiting automated vehicles and human-driven vehicles alike. For instance, a backend-based digital HD reference map combining event localization with all relevant infrastructure information in a reference base for automated/autonomous vehicles could be feasible as a central measure for enabling automated driving. This calls for the development of an ODD – ISAD framework in a joint effort of the vehicle industry and road operators.

4.1.3.2. Functional Safety

With sensor fusion on the edge and C-ITS technology, the road infrastructure can provide and disseminate safety-relevant information about perceived objects which will enable vehicles to manage challenging highway scenarios without exceeding their ODDs. This would be of particular importance where adverse weather and lighting conditions apply. Changing environmental condition require technological progress and sensor fusion of infrastructure and vehicle. Interaction and inter-compatibility of the involved systems has to be ensured so that an exchange of the sensed information can happen. The external sensors communicate with the AV, which in turn is able to process this information and fuse it with its own perception, thus gaining a better understanding for how to plan and act accordingly. The concept of functional safety has to be analysed in each single building block as well as in the whole system architecture of the total road transport system combining vehicles and the infrastructure. After the identification of the necessary delta functionalities, these have to be included in the R&D agenda and projects as well as the European standardization process.



Operational principle of sensor fusion in the safety domain

As a next step, key issues need to be addressed such as the trade-off between latency and channel capacity and how to ensure determinism in the collective perception solution. Related technologies must be evolved and standards refined to address the needs of a functional safety system embracing the automotive and the infrastructure domain.

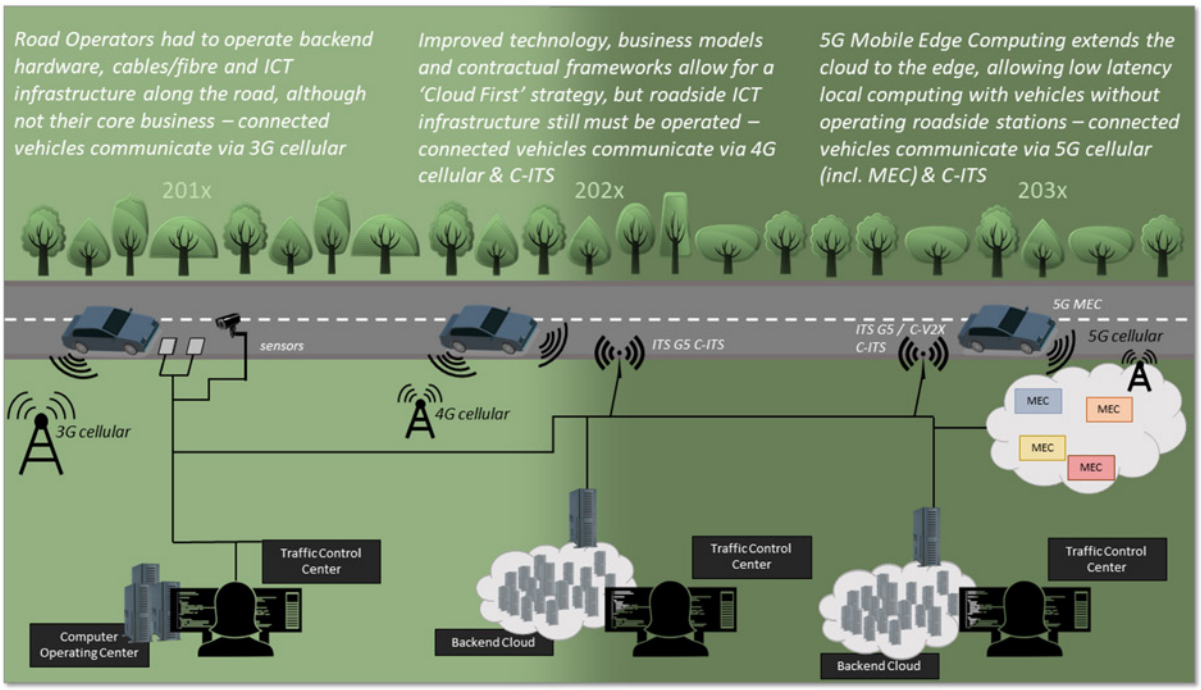
4.1.3.3. IT Trust and Security

Like for functional safety, the machine-to-machine interaction between vehicles and infrastructure in future automated driving scenarios also requires an integrated approach to IT security. Based on the emerging C-ITS infrastructure, a trust domain must be established an operated that allows trustful data exchange between vehicles and infrastructure. The cooperation on system level must also be protected from external interference, providing the interacting systems with data exchange links that allow source authentication, ensure data integrity as well as service availability, and provide non-repudiation. The interaction between these systems creates a potential new attack vector that will require a joined effort of vehicle and infrastructure industry to ensure proper and safe operation.

4.1.3.4. Collaboration and Sharing in Data Ecosystems

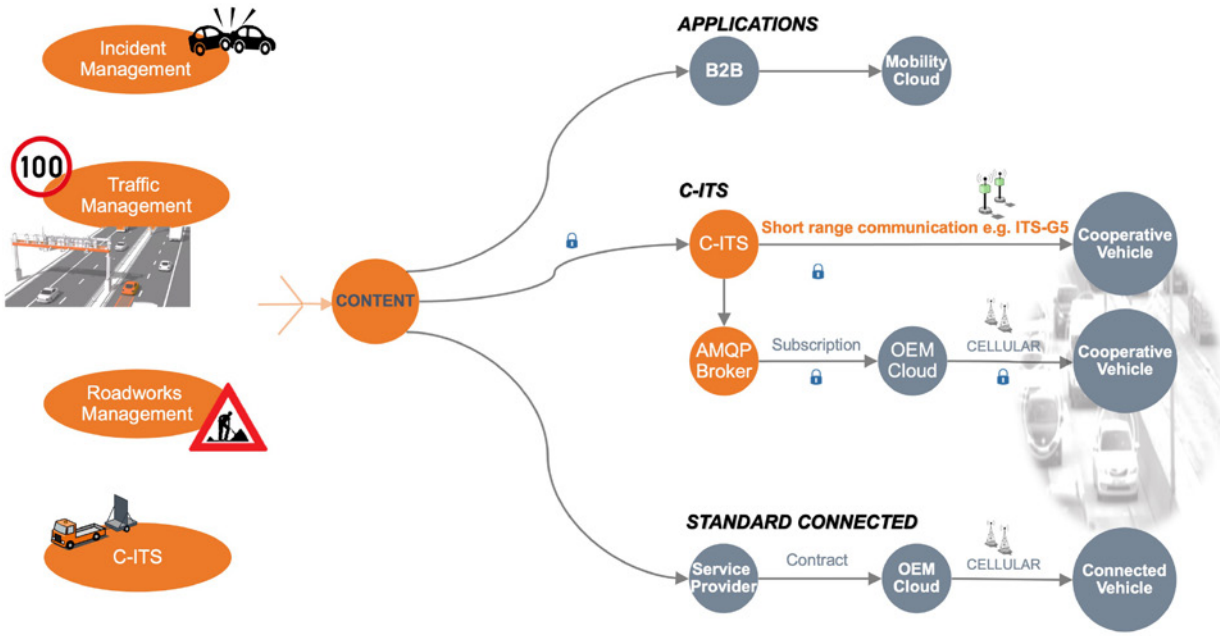
The Data For Road Safety ecosystem (DFRS) – created in 2017 by European Transport Ministers, European Commission and industry representatives – is an example that clearly shows the added value of combining vehicle and infrastructure data. While vehicles detect safety related incidents with the lowest latency, vehicle information only does not allow to manage the lifecycle of the corresponding information created in the ecosystem, which can be better performed within the infrastructure.

This shows a clear need to leverage the cooperation models of different types of data feeds – in particular vehicles and infrastructure – in a suitable environment. There are various approaches to such dataspaces being currently developed and needing thorough analysis, like e.g. GAIA-X. This does not only include backend solutions but should also be extended to cover edge computing architectures, as for example the Mobile Edge Computing (MEC) concept emerging in mobile radio networks. Other Edge Computing concepts are possible for other connectivity options. The following diagram depicts this evolution, using 5G MEC as one option.



CCAM Connectivity evolution

The new and diverse connectivity options allow a variety of collaboration and cooperation as well as managerial patterns. Communication characteristics like reliability, bandwidth and latency have to be chosen based on communication patterns and application / service needs. Data sharing with vehicles requires co-operation of infrastructure operators and OEMs / Service Providers in addressing these research needs. This is in particular challenging at higher TRL levels, where the private sector leaves the domain of pre-competition cooperation. Nevertheless, basic agreements need to be developed in order to allow pre-deployment activities on the infrastructure side. The following diagram depicts the complexity of the landscape of data flows between vehicles and infrastructure already in place today.



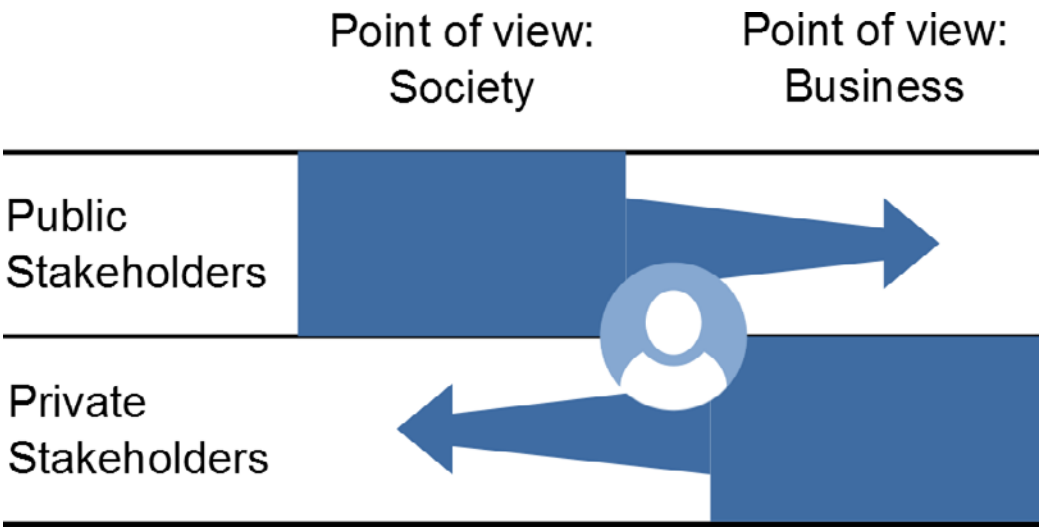
Data sharing patterns between infrastructure and vehicles

4.1.3.5. Business Models

- In a longer-term perspective, the deployment of Connected, Cooperative and Automated Mobility will most likely be transformative and disruptive to existing business processes. Hence, developing a solid fundament for business models forming the CCAM ecosystem adds to the list of enablers feature before. CCAM can be seen as a system enabling the provision of widely accessible yet customizable mobility services, making use of connectivity, cooperation and automation. The CCAM actors contribute to the CCAM ecosystem with different initial motivations (public: serving the common good, private: exploring business potential). These motivations reach out "to the other side", as private actors typically also emphasise their Corporate Social Responsibility and public actors also strive for achieving their responsibilities (often in face of budget constraints) in a more efficient way. This motivation cocktail forms the glue for exploring the co-creation of the CCAM ecosystem and the collaboration on the underlying value network through which CCAM services are delivered to users, citizen, customers etc.

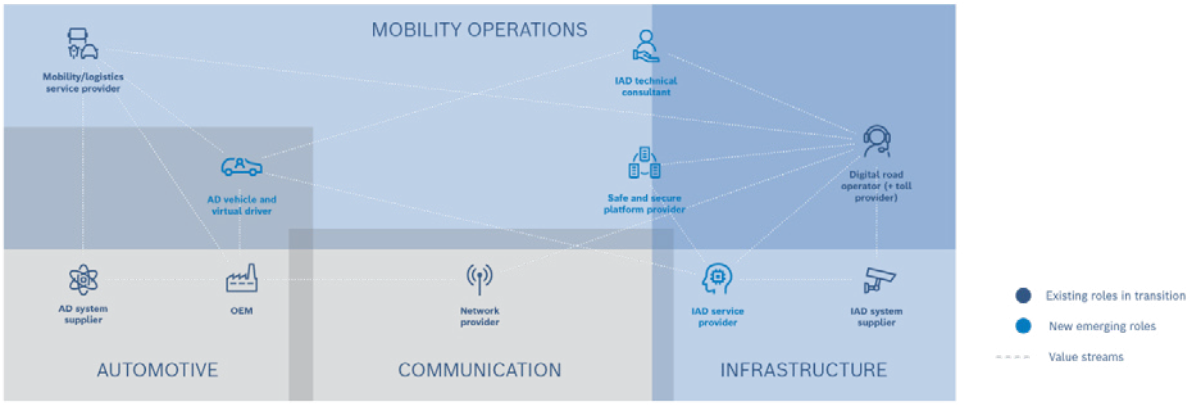
- The overall behavior of the actors in the CCAM ecosystem can be labelled as coopetition. They collaborate on the essential parts of the system whereas they compete in other elements of the value network. This brings along a duality in responsibilities. Individual actors fill a role in the value network by performing their own responsibility (this can be both directions, e.g. serving brand customers in different industries as well as providing cross-cutting essential facilities such as a Security Credential Management System). On a system level, all actors contribute to functioning CCAM services which represents a joint responsibility for the system.

- The enabling character of applicable business models for CCAM deployment implies a significant innovation challenge since today business models forming and sustaining ecosystems - such as the CCAM one - are not available off the shelf. Apart from dedicated research and innovation actions it requires a deeper mutual understanding of business processes (e.g. innovation cycles, planning routines) in different industries. This becomes necessary for forming a relevant market for CCAM services in the future: to synchronise investment directions in terms of services, locations and time. On top of this there is a wide field for applied research and innovation, a.o. in forming and nudging collaborative behavior in value networks as well as studying perceived equilibrium conditions of what actors bring in and get out of the collaboration. The sustainability of the ecosystem is directly linked to the principle of fairness when sharing costs and benefits.



Stylised motivation of actors in the CCAM ecosystem

- Nonetheless, these disruptive changes will also create new roles and potentially new stakeholders in the ecosystem of mobility. Especially where different business sectors overlap, new roles will emerge. These roles and future stakeholders need to be addressed early in the process to ensure best cooperability and to start generating a value stream for all stakeholders, especially for the end user and society as a whole. Especially the roles and responsibilities between all players in this field will provide new opportunities e.g. between automotive industry, national road agencies, and new mobility services providers.



CCAM ecosystem with established and potential new roles

4.2. Technology enablers

Technology challenges of automated driving include: reliable detection of the vehicle environment using sensors based on radar, video, lidar and ultrasound technology, localization solutions so that the self-driving car knows exactly where it is, derivation of a suitable driving strategy, resilient, robust and safe system architecture, data safety and security including safe and resilient approaches for over the air updates, validation and verification of the systems.

The key technologies base upon three domains of similar central importance:

- In-vehicle-technologies
- automated driving toolchain (technologies and processes for development, testing and validation)
- Cloud and back-end technologies

In summary, all - strongly intertwined – technology enablers must meet the challenge of designing, validating, and continuously improving data-driven complex software-dominated systems with high functional safety requirements.

4.2.1. In-vehicle-technologies

An in-vehicle system needs to cover the complete functional chain from environment perception and vehicle localization over decision making to actuation to perform the driving task.

Efficient and robust perception systems based on video, radar, lidar and ultrasonic sensors acquire environment data needed for real-time driving decision-making. New hardware concepts for sensors and for computing units are key enablers to provide the sufficient computing power considering affordable energy consumption and integration costs.

Vehicle localization is another essential enabler for highly automated vehicles. There is a need for an on-board high definition, accurate, precise, digital map integrating several input data like video and radar road signature information. The digital map also needs to cover detailed dynamic road infrastructure information and real-time traffic information.

Another issue is the available on-board computing power, which must be coherent with the overall vehicle energy use. To ensure efficient use of the limited on-board power resources, dedicated actions and new software development approaches will be needed. Towards a Low energy - high computation approach. In addition to on-board power, real-time computation in the cloud could allow more computationally intensive methods to be used (larger networks, Bayesian neural networks, large ensembles, etc.). This can enable a further increase in performance.

HMI design: The introduction of CCAM reshapes the interaction between humans and vehicles, both inside the vehicle (e.g., mode awareness, switching between different levels of automation) and outside the vehicle (e.g., communication with other motorized traffic as well as vulnerable road users). Human interaction with the automated driving system inside the vehicle is mediated by the Human Machine Interface (HMI). A safe interaction can be realized if the HMI provides an understanding of the capabilities and status of the technology (e.g., minimize mode errors), facilitates correct calibration of trust, stimulates an appropriate level of attention (e.g., when a takeover is imminent), provides comfort (e.g., reducing stress), and is usable in an intuitive way (e.g., by providing consistent feedback). A safe interaction outside the vehicle can be supported by an external Human Machine Interface (eHMI). Similar to the HMI, eHMIs must communicate important information, such as state, in a comprehensible way. Many of these challenges can be addressed by taking a human-centred design approach in the development of CCAM technologies. With this approach both the automated driving system and the internal and external HMIs are designed with the human capabilities and limitations in mind, supporting safe interaction.

4.2.2. Automated driving toolchain

Automated driving systems must be designed, tested and validated in such a way that they are

- Scalable and transferable to cover the wide variety of ODDs, use cases, vehicle platforms, models and markets,
- Resilient to meet very high safety requirements and system availabilities,
- Secure against cyber-attacks to ensure system integrity.

Thus the applied toolchains are key enabling building blocks to make highly automated driving happen. These must cope with the large complexity of the technical solutions to be realized. Facing that the development will be spread more and more over several companies it will be crucial to agree on a seamless set of tool chain in order support engineers to master this challenging complexity efficiently.

4.2.3. Cloud and back-end technologies

Specific back-end structures like control centres and data cloud support are prerequisite for safe operation of highly automated vehicle fleets. Control centres will provide services and functions for remote control of vehicles that become necessary in emergencies, maintenance or authorities intervention. Cloud functionalities will provide additional information for automated driving functions, cooperative environment and traffic data.

Additionally, there is need for data aggregation in a back-end in order to realize field observation and to enable over-the-air (OTA) updates. Regular updates are required to continuously optimize the algorithms with new high information content data acquired in the field. A necessity for this is to be expected, since on the one hand there is the long-tail problem for the Open Context (i.e. there

is a large amount of potentially critical situations that have only a low probability of occurrence so that they cannot be completely covered during development with a high degree of probability), on the other hand there is the problem of the distributional shift (i.e. the distribution of the data in the ODD changes over time e.g. due to new fashion trends, new vehicle models).

OTA-updates allow new features to be brought into existing fleets. Updates are to be secured and reliable through end-to-end encryption and complex security architectures. If new functions are played out via OTA, this may affect the authorization granted and cause them to expire. A concept is also needed here.

4.3. Validation

4.3.1. Introduction

The homologation of Automated Driving Systems as proposed by the JRC is based on the Multi-Pillar Approach[5] which combines virtual validation, physical validation on test tracks, and physical validation on open roads or operational sites. The need for virtual validation is mainly linked to the safety goals required for a wide public adoption of Automated Driving functions. Physical validation over several millions of kilometers with prototype vehicles is not sustainable. But recent progress in the fields of software development, High Performance Computing and digital technologies opens the possibilities for extensive virtual validations, with the involvement of the whole Automated Driving eco-system.

4.3.2. Challenges

Several challenges are still being addressed in several European Research programs in the fields of Automated Driving and virtual validation, such as:

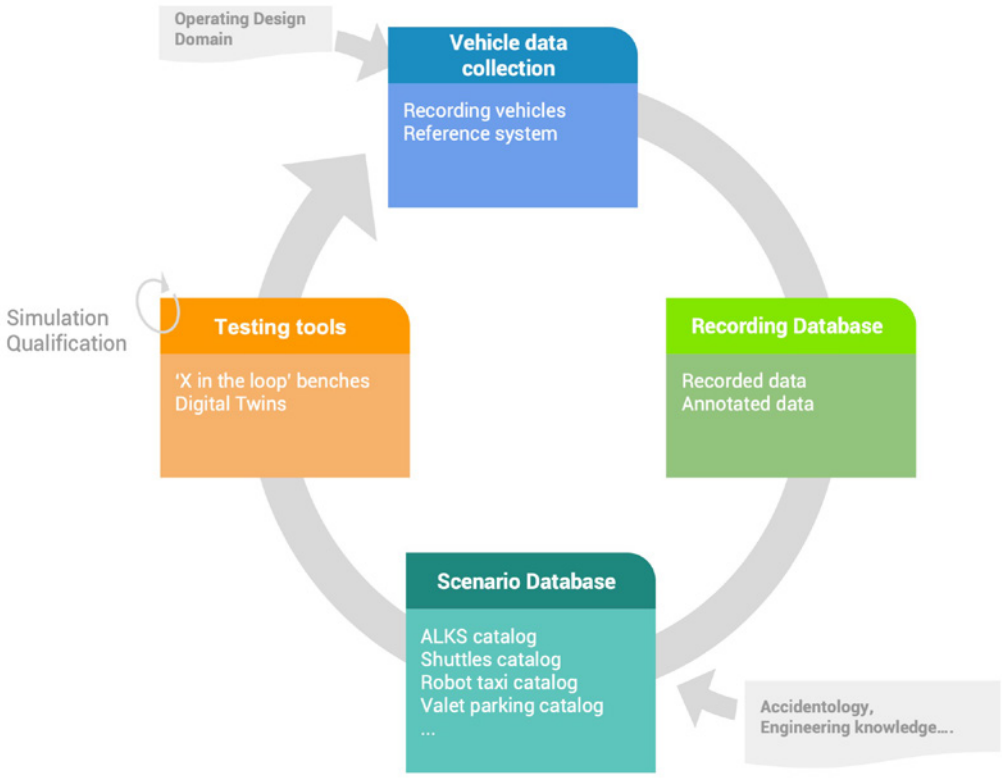
- How can we define, create and validate the models of vehicles equipped with their sensors, and human behavior models of drivers and other road users?
- How to validate the accuracy of a driving simulator and virtual test platforms?
- How can we build, share and validate recorded databases of safety critical situations acquired with different vehicles, in different countries, recorded in different formats and how can we leverage these data to build and maintain the scenario databases in a scalable manner? How can databases be merged to form a pan-European scenario database?
- How can we deal with new paradigms like the introduction of major software updates during the life of a vehicle, self-learning and self-developing systems, distributed intelligence (on- and off-board) and remote operation?
- How can we deal with other changes in the road transport system, such as the introduction of new means of transport?
- Road user behaviour and accidentology will change with the uptake of automated driving: how can the virtual validation process integrate these changes?
- New State of the Art will be acquired in the fields of Artificial Intelligence, Robotics, Digital Infrastructure, Telecommunications: how can virtual simulation cope with the introduction of these new technologies?
- How shall human-machine interfaces be included in the validation process?

[5] JRC proposal for Safety Assessment of Automated Vehicles, 3rd VMAD meeting, July 1st, 2019

- How can we leverage the progress made in AI & Machine learning for virtual data generation & qualification?
- How to deal with massive simulation needs using optimal resources sharing and at an industrial level of maturity?
- Constraints related to CO2 neutrality, cybersecurity, privacy and ethics will be integrated 'by design' in the Automated Driving functions: should virtual validation also integrate these societal expectations?
- How to select specific test cases, from an infinite number of possible customer situations? How to proof that the safety targets have been met, based on the results of a limited test case catalogue?
- How to decompose the test activities on sub-system level?
- How to consolidate the test results of these different sub-systems?
- How to fund the data acquisition and processing that the need to continuously update the pan-European scenario database entails?
- How to manage the ownership of this big data?

4.3.3. Vision

Our vision for the implementation of virtual validation in the homologation process of automated driving systems is illustrated below[6]:



The Operating Design Domain is one of the cornerstones supporting the virtual validation process. The validation process for a specific ODD will be extended to include human factors related to the behaviour

[6] S. Ahiad, CCAM vehicle technologies workshop, June 16th 2021

of other road users, and drivers and passengers in the automated vehicles. Human behavioural models will depict the full performance spectrum of human drivers in all relevant situations.

A common industry-wide test methodology will be created, with a special consideration to critical scenarios and edge cases.

When the automated driving function involves support from the road infrastructure in the ISAD framework or from C2X connectivity or from digital maps, then these supporting means shall be integrated in the virtual validation process.

The catalogues of basic automated driving scenarios are made publicly available, and are updated continuously, amongst others with new accidentology knowledge. Recording databases and virtual validation tools are built according to industry standards to be interoperable across the eco-system, and their accuracy is monitored.

Digital Twins are assembled so that mid-life updates, or the effects of new regulatory constraints can be validated over the whole Automated Driving System.

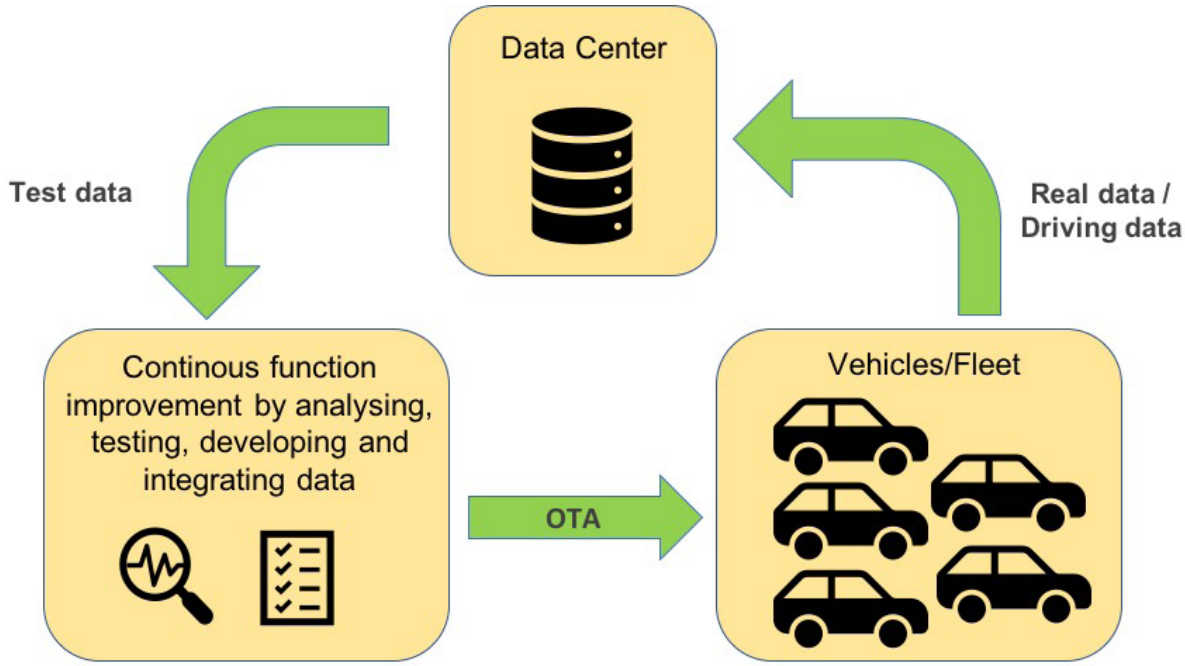
Digital Twin instances find new value propositions beyond virtual validation, and contribute to other global business objectives such as Manufacturing 4.0, Driving License Training, Road Traffic and Vehicle Fleet Management, Smart EV charging, Monitoring of CO2 emissions, De-commissioning, etc.

4.4. Artificial Intelligence and Data analytics

The ability to generate new knowledge from large amounts of data is a key competence of the future. Vehicle and traffic data bases will increasingly create multiple benefits for users and society. The collected data shall support evidence to prove these user and societal benefits.

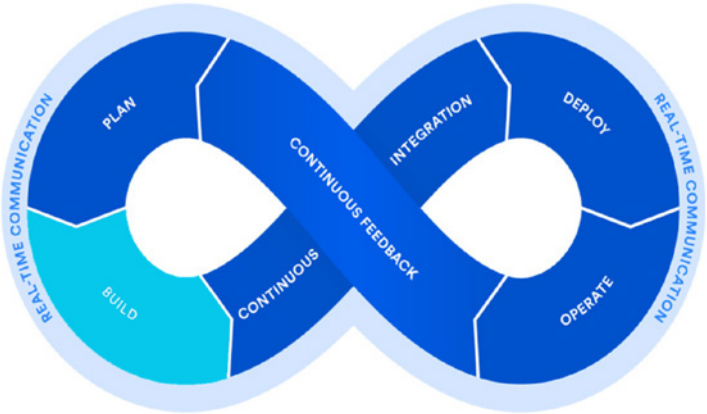
Data sovereignty and data access are major factors determining success and are fundamental for developments. This is valid in particular in the field of automated driving. A sovereign, open data infrastructure that observes security standards will thus become a key prerequisite for successful development and deployment of CCAM.

A central approach of developing automated driving systems is to collect data for development, during (fleet) operation and to update software after deployment, as well.



Examples for the required data are untypical or critical driving scenarios (corner cases), information about current traffic situations like a temporarily closed lanes or ends complex information about driving behavior during operation to e.g. improve on-board trajectory planning. This requires several types of information like sensor data and HD map data. Improvements in one of these domains (e.g. improved camera-based object detection) can be used to software improvements and updates.

Especially the last topic – learning during fleet operations - is important in order to gather statistically representative driving data (field data) to validate, verify and improve driving behavior. Just in the field - means learning during driving – it is possible to gather data about real driving behavior of other traffic participants, information about typical and especially corner cases.



According to the DevOps cycle items plan and built on basis of the monitoring data an off-board analysis and software improvement process starts. This process leads to a unique and validated knowledge and behavior of driving functions. But new knowledge and behavior is not part of single improvement of individual vehicles furthermore the process ensures that all vehicles derive at the same time the same state of functions. Means that the "continuous integration" part of the DevOps cycle is in fact a defined single point where OTA improves the vehicles performance. Safety and process standards ensure that earning new features for a vehicle is a controlled, defined and certified process that ensures that all affected vehicles are at all time on the same state of performance.

The continuous learning process for CCAM as described above needs requirements to guarantee save and reliable software in the vehicles on the roads. Core processes hereby are

- Basic standards and rules for the access for stakeholders to collected driving data where it regards to safety critical driving behavior. This ensures that safety critical driving data are exchanged within the automotive developers with the aim to improve safety on uniform data base.

- Basic standards on the minimal implementation and updating of safety relevant driving behavior for all vehicles.

- Standard for the data exchange format to ensure that collected driving data and data basis are exchangeable within the stakeholders.

The fundamental importance of data in many areas in the technology map of automated driving is reinforced by the fact that Artificial Intelligence (AI) technologies are essential in a variety of applications as well. One important application field is in supporting to take over human driver tasks.

Technically, automated driving stands or falls on robust, reliable recognition of the vehicle's environment using sensors. Only if we correctly detect and assess a situation, the correct driving behavior can be derived. Artificial Intelligence algorithms are used to significantly increase performance in the recognition of objects, to refine scene understanding for action intention and pedestrian gestures. The aim is therefore to interpret complex and unpredictable traffic situations - including rare special cases - develop the right driving strategy for them and then implement it.

Due to its extraordinary performance, machine learning (ML) - a subfield of AI- is a key technology for automated driving. Especially for challenges which are difficult to specify in detail (e.g. pedestrian detection), it has a clear advantage overrule-based algorithms. Due to its ability to automatically recognize basic patterns and correlations in large amounts of data and to learn from them, ML is already indispensable in the area of environment recognition in driving assistance systems that exist today.

However, it is also true that highly and fully automated vehicles must be able to cope with all potential traffic situations in their area of use and function reliably. The validation of these vehicles must therefore also include the validation of the AI-based algorithms used. Appropriate methods must be developed and applied.

A key step will be for deep learning methods (as a subfield of machine learning) to reliably indicate how trustworthy information provided by them is. This will enable the vehicle to make confident decisions even in difficult situations.

The fully trained and secured network will be embedded in the vehicle and will process incoming sensor signals. It will not continue to learn on its own, as it is not possible to monitor for each vehicle whether it is learning meaningful things; learning will be shared learning. In the case of necessary software updates, these will be developed and secured centrally. Only then will new versions be made available to existing vehicles through various channels.

The requirements for a proof of safety of AI-based function modules for highly automated driving should be made in the sense of a consensus within the framework of a generally accepted safeguarding strategy, which should also be taken into account in vehicle approval but also corresponding standards.

Accordingly, accepted metrics for the evaluation of AI algorithms are required. The use of AI means that algorithms must be taught with many different data sets of traffic events and scenarios until a function (e.g., person detection) reaches a level of robustness. Relevant sets of real and synthetic scenarios are needed to serve the metrics for a safety proof.

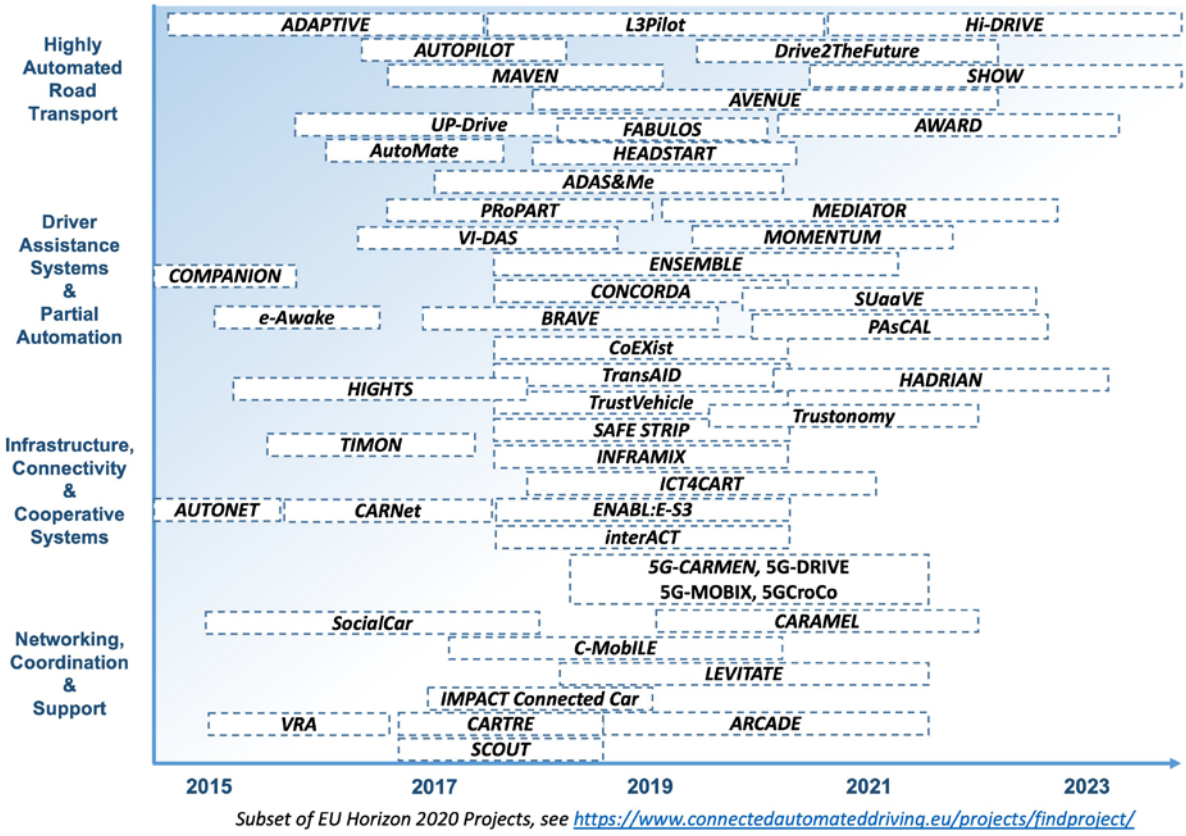
The importance of AI training data specification, collection, processing and labeling cannot be overstressed: the quality of the training data set determines the robustness and thus operational reliability of the AI-function.

5. Projects and Initiatives

5.1. European research projects

The European Union has a strong experience in funding collaborative research in the field of CCAM, as shown by the picture below, which provides an overview of the major recent and current European funded projects. EU funding for the domain started in the 6th Framework Programme and intensified in the 7th Framework Programme. In the Horizon 2020 Programme, a specific call on "Automated Road Transport"[7] was launched from 2016, and provides over 300 Mn € of funding in the successive calls up to 2020. The previous editions of this Roadmap contributed to the identification of the topics addressed by this "ART" call. The European research funding will now continue in the framework of the Horizon Europe programme for 2021-2027, with a specific Partnership for CCAM (see below).

Note that only the most prominent projects are included in the picture below: the reader should consult the online **CAD Knowledge Base** for a complete and up-to-date list of all projects funded by the EU. The picture gathers the projects, using their acronyms, into four research fields: Networking, Coordination & Support, Infrastructure, Connectivity and Cooperative Systems, Driver Assistance Systems and Partial Automation and Highly Automated Road Transport.



Subset of EU Horizon 2020 Projects, see https://www.connectedautomateddriving.eu/projects/findproject/

Overview of a subset of EU funded projects that support development of CCAM.

Get details on these projects and consult the CAD Knowledge Base on:
https://connectedautomateddriving.eu/cad-knowledge-base/
Details on EU projects and thematic reports are also available on **TRIMIS**:
https://trimis.ec.europa.eu/projects

[7] http://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-transport_en.pdf

5.2. European initiatives

5.2.1. EU Policies

5.2.1.1. EU Mobility Strategy

The 3rd Mobility Package[8] published in 2018 by the European Commission reaffirmed the EU road safety ambition towards Vision Zero and included a Communication "On the road to automated mobility: an EU strategy for mobility of the future"[9], providing objectives and actions to accelerate the deployment of Connected, Cooperative and Automated Mobility, with the ambition of making Europe a world leader in this domain. The Smart and Sustainable Mobility Strategy[10] published in 2020 strengthened further the importance of connectivity and automation in the future EU transport system. It highlighted use cases that will be particularly relevant from the public policy perspective in the next decade, and listed intended actions in the areas of technology development, regulation, certification and impact assessment. One of the actions recommended was the establishment of a new European Partnership for CCAM in the Horizon Europe programme for research and innovation.

5.2.1.2. EU Digital Strategy

In March 2021, the European Commission presented a vision and avenues for Europe digital transformation by 2030. This vision for the EU digital decade refers to four focus areas: skills, infrastructures, business, and government. These four areas are part of Europe Digital Compass, which will translate the EU digital ambitions for 2030 in concrete terms via targets and key milestones, a robust joint governance structure including a traffic light monitoring system to identify successes and gaps, multi-country projects combining investments from the EU, Member States and the private sector. Particularly the area of secure and sustainable digital infrastructures directly relates to the digital technologies that are critical to enable and further advance CAD: connectivity, cutting edge semiconductors, data, edge and cloud and computing[11]. Ways of implementation include various kinds of partnerships, such as the Key Digital Technologies (KDT) partnership under Horizon Europe, the European Alliance on Processors and Semiconductor technologies launched in July 2021, and partnerships looking into the strengthening of the EU capacity to assert its own interests and deliver global solutions while fighting against unfair and abusive practices and ensuring the security and resilience of EU digital supply chains.

5.2.1.3. European Green Deal

The European Green Deal[12] is the EU policy initiative aiming at making Europe climate neutral by 2050. Connected and automated mobility is acknowledged within this policy for its enabling role towards new sustainable mobility services: well-integrated into the transport system, connected automated driving can bring positive environmental impacts by reducing emissions and congestion, through optimised capacities, smoothened traffic flows, and avoidance of unnecessary trips. Shared mobility services, integrated with public transport, will accelerate the shift to sustainable and smart mobility with a reduced carbon footprint. In addition to air pollution and CO2 emissions reduction, a modification of land use for road infrastructure can also be expected thanks to connectivity and automation, enabling further sustainability benefits.

[8] Europe on the move – Sustainable mobility for Europe: safe, connected, and clean, COM(2018) 293 final, https://eur-lex.europa.eu/resource.html?uri=cellar:0e8b694e-59b5-11e8-ab41-01aa75ed71a1.0003.02/DOC_1&format=PDF
[9] On the road to automated mobility: An EU strategy for mobility of the future, COM(2018) 283 final, https://ec.europa.eu/transport/sites/transport/files/3rd-mobility-pack/com20180283_en.pdf
[10] Sustainable and Smart Mobility Strategy, COM(2020) 789 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789
[11] 2030 Digital Compass: the European way for the Digital Decade, COM (2021), 118 final. https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52021DC0118
[12] The European Green Deal, COM(2019) 640 final, https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf

5.2.2. EU instruments and platforms

5.2.2.1. CCAM Platform

In the frame of the 3rd mobility package and the associated communication, the European Commission established the single EU-wide platform[13] for Open Road Testing and Pre-deployment of CCAM. The expert platform launched in June 2019 grouped all relevant public and private stakeholders with the main aim to coordinate open road testing of CCAM. The objectives included the development of a European research programme in the field of CCAM and the preparatory work on the European Partnership which were discussed in Working Group 1. Working Group 2 focusing on the "Coordination & Cooperation of R&I and testing activities" has analysed key challenges and identified actions regarding the development of a common evaluation methodology (CEM) and a data sharing framework and has provided a first outline of a European CEM. The other four Working Groups focused respectively on physical and digital infrastructure, road safety, cybersecurity and access to in-vehicle data and connectivity. Each group has developed a scoping paper analysing State of the Art and gaps and identified actions and recommendations to address remaining challenges in these different areas for testing and deployment of CCAM in Europe.

5.2.2.2. Horizon Europe & CCAM Partnership

Horizon Europe[14] is the multi-annual EU framework supporting Research and Innovation, with a budget of €95,5 bn over 7 years, from 2021 to 2027. Horizon Europe provides research funding for initiatives to improve on key societal challenges:

- tackling climate change,
- helping to achieve the UN' Sustainable Development Goals,
- boosting the EU competitiveness and growth in the European Research Area.

European Partnerships[15] are a key implementation tool of Horizon Europe, bringing the European Commission and stakeholders together to address some of Europe's most pressing challenges, through coordinated research and innovation initiatives. By bringing private and public partners together, the Partnerships help to avoid the fragmentation of investments and contribute to improve the efficiency of the research and innovation landscape in the EU.

The 23 June 2021 saw the officialization of the CCAM Partnership[16] with the signature of the Memorandum of Understanding between the European Commission and the CCAM Association, who gathers the CCAM stakeholder community. The CCAM Partnership aims to promote and facilitate pre-competitive research on Connected, Cooperative and Automated Mobility (CCAM), by bringing together the different actors of the CCAM value chain, and by mapping the upcoming R&I challenges, which have been commonly defined in the Strategic Research and Innovation Agenda (SRIA). The general objectives of the CCAM Partnership are:

- Increasing safety in road transport.
- Ensuring inclusive mobility and goods access for all.
- Reducing negative impacts from road transport on environment.

[13] https://ec.europa.eu/transparency/expert-groups-register/screen/expert-groups/consult?do=groupDetail.groupDetail&groupID=3657
[14] https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en
[15] https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/european-partnerships-horizon-europe_en
[16] https://www.ccam.eu/

- Strengthening competitiveness of European industries.
- Capitalising knowledge to accelerate development and deployment of CCAM solutions.

During the lifetime of the Partnership, the different CCAM stakeholders will discuss together the next priorities and needed actions to be supported by collaborative research projects at EU level. In addition to industry and research stakeholders, the CCAM Partnership also involves public authorities, from national and local levels, which are key to support the implementation of CCAM based infrastructures and services.

All details on the governance and membership are available on the website www.ccam.eu

5.2.2.3. Other related European Partnerships

In addition to the CCAM Partnership, which is fully focused on connectivity and automation of road transport, a number of other European Partnerships funded by the Horizon Europe programme address important research fields that will impact and provide key enabling technologies for CCAM.

- Key Digital Technologies (KDT), succeeding ECSEL[17], is focused on Electronic Components and Systems as enabling technologies for multiple application fields, including mobility as a high priority area, e.g. delivering performant and reliable sensors, actuators and controllers that are enablers for environment detection and decision-making. The importance of the mobility applications was already demonstrated during ECSEL by the Lighthouse Initiative Mobility.E[18].
- Smart Networks and Services (SNS), succeeding the 5G PPP[19], aims to enable the full digitization of vertical industries, including mobility: the SNS research agenda investigates innovative connectivity solutions to provide network and device enhancements, which are necessary to support the development and deployment of automated mobility solutions.
- The Partnership on AI, Data and Robotics[20] includes research fields linked to the development of CCAM solutions, as they build upon the progress and directions taken in these key technologies, such as Machine Decision Making, AI for situational awareness and predictive perception, Data quality, combining data from multiple sources, data privacy and protection, etc.
- The European Partnership on Photonics[21] is addressing developments of key enabling photonics technologies that are of importance for CCAM, towards sensing capabilities efficiently integrated in automotive platforms and performant under all real-world environmental conditions. Also new solutions of in-vehicle sensing enable new human machine interactions usable in higher levels of automation.
- 2Zero[22] - Towards zero emission road transport - is the Partnership following-up the EGVI - European Green Vehicles Initiative - with as core objective the acceleration of the introduction of zero emission road vehicles, using a system approach. Linking 2Zero and CCAM can help to seek the integration of the decarbonisation and digitalization challenges, opening additional opportunities to improve the efficiency, both at vehicle level and at mobility system level. Zero emission powertrains combined with connectivity and automation can enable innovative climate neutral mobility services and logistics operations.
- Driving Urban Transitions to a Sustainable Future[23] (DUT) is a co-funded Partnership addressing urban development with a cross-sectoral and integrated approach: it includes the transformation of the urban mobility system as one of three pillars of sustainable urban development. DUT

[17] https://www.ecsel.eu
[18] https://www.mobilitye.eu
[19] https://5g-ppp.eu
[20] https://ai-data-robotics-partnership.eu
[21] https://www.photonics21.org
[22] https://www.2zeroemission.eu
[23] https://jpi-urbaneurope.eu/driving-urban-transitions-to-a-sustainable-future-dut/

is interested by the implementation of automated mobility, to ensure that technologies, infrastructures and services are developed with a sound understanding of their implications on the wider urban context. The DUT programme can support CCAM by mobilising a wider set of actors in the participating countries, contributing to experimentation in cities and urban areas with different local conditions, covering aspects related to governance, the integration into mobility systems, behavioural issues and needs, as well as relationships to other sectors and systems (e.g. energy).

- Connected and Automated Mobility is also within the scope of the Mission on 'Climate-neutral and Smart Cities'[24], which aims at reaching 100 climate-neutral cities by 2030.

5.2.2.4. IPCEIs

Established in March 2018, the Strategic Forum on Important Projects of Common European Interest (IPCEI) was a high-level expert group representing Member States, industry and the research community, who identified key strategic value chains in Europe and proposed a common vision for joint actions and investments between EU, Member States and industry, e.g. in the form of an IPCEI. IPCEIs are addressing disruptive and ambitious research and innovation, beyond the state of the art in the sector, and particularly first industrial deployment, i.e. the short period where very important R&D&I is still necessary (e.g.: to scale up a pilot line). They are expected to generate positive spill-over effects throughout the EU on the knowledge and results they generate. In 2019, the Forum published its report on strengthening the Strategic Value Chains for a future-ready EU Industry. The report identifies enabling actions for six selected strategic value chains, one of which is connected, clean and autonomous vehicles.[25]

5.2.2.5. ITS Directive and C-ITS

Aiming at accelerating and coordinating the deployment and use of Intelligent Transport Systems, the ITS Directive[26] is paramount to a set of subsequent Delegated Regulations (in order of appearance) on eCall[27], information services for safe and secure truck parking[28], safety-related traffic information (SRTI)[29], real-time traffic information (RTTI)[30] and multimodal travel information services (MMTIS)[31]. Currently, the ITS Directive is being revised (target date: November 2021, together with revised TEN-T Guidelines).[32] The revision will assess the availability of infrastructure and traffic/travel data across the whole EU transport network (leading to amended Delegated Regulations for RTTI and MMTIS) and it will also cover new developments such as CCAM and online platforms allowing users to access several modes of transport. In order to provide legal certainty for the deployment of Cooperative Intelligent Transport Systems (C-ITS) the European Commission had proposed a Delegated Regulation in March 2019. This legislative act did however not come into force as a result of the Council objection, for legal and technology reasons.[33] The C-ITS deployment hence misses this keystone for legal certainty. Instead, deployment relies on a "coalition of the willing" (C-ITS Deployment Group) to make C-ITS part of vehicles in the market and part of road infrastructure in regular operation.[34] In a recent report, the EU Radio Spectrum Policy Group flags that "additional work is on-going in ETSI in

[24] https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/missions-horizon-europe/climate-neutral-and-smart-cities_en
[25] Strengthening Strategic Value Chains for a Future-Ready EU Industry. Report of the Strategic Forum for Important Projects of Common European Interest. European Commission 2019. https://ec.europa.eu/docsroom/documents/37824
[26] 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
[27] Commission Delegated Regulation No 305/2013 on harmonised provision for an interoperable EU-wide eCall
[28] Commission Delegated Regulation No 885/2013 on the provision of information services for safe and secure parking places for trucks and commercial vehicles
[29] Commission Delegated Regulation No 886/2013 on data and procedures for the provision, where possible, of road safety-related minimum universal traffic information free of charge to users
[30] Commission Delegated Regulation 2015/962 on the provision of EU-wide real-time traffic information services
[31] Commission Delegated Regulation 2017/1926 on the provision of EU-wide multimodal travel information services
[32] https://www.europarl.europa.eu/legislative-train/theme-a-european-green-deal/file-intelligent-transport-systems-directive-review
[33] Commission Delegated Regulation .../... supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the deployment and operational use of cooperative intelligent transport systems, Council Decision to raise objections to the delegated act, 5 July 2019
[34] https://c-its-deployment-group.eu/

order to address co-channel and adjacent-channel co-existence methods between ITS G5 and LTE-V2X. In case of lack of results of this standardisation process, there could be a need for the European Commission to consider relevant action in order to ensure a long term efficient usage of road ITS."[35]

5.2.2.6. CEF and C-Roads

The Connecting Europe Facility (CEF) is the EU funding instrument for targeted infrastructure investments at European level: to support the development of high performing, sustainable and efficiently interconnected trans-European networks in the fields of transport, energy and digital services.[36] CEF plays an important role to take the infrastructure part of (sufficiently mature in terms of technological readiness, i.e. TRL 8-9) CCAM systems and services to the next phase of pilot deployment and deployment. Program synergies with Horizon Europe will be explored in a similar manner like R&D and FOTs in C-ITS (FPs 6&7) and handover to CEF from 2015 onwards. In this CEF context, C-Roads is a flagship initiative for Member States driven pilots and deployment of C-ITS services.[37] Member States and the European Commission have launched the C-Roads Platform in 2016 to link C-ITS deployment activities, jointly develop and share technical specifications and to verify interoperability through cross-site testing. 18 European countries successfully collaborate under the C-Roads umbrella for cross-sector harmonised and tested specifications, as it has been demonstrated in the C-ITS Roadshow in June 2021. The first wave of pilots now approaches the end of the project lifetime. Deployed services become increasingly part of the regular operation (see C-ITS Deployment Group). The second wave of C-Roads pilots (ending 2023) focuses on urban C-ITS services with approx. 50 cities involved.

5.2.2.7. Digital Europe

The Digital Europe Programme (DIGITAL)[38] is the new EU funding programme for the period 2021-2027, focused on bringing digitalisation to businesses, citizens and public administrations. DIGITAL will support projects in five key capacity areas: in supercomputing, artificial intelligence, cybersecurity, advanced digital skills, and ensuring a wide use of digital technologies across the economy and society, including through Digital Innovation Hubs. With a planned overall budget of €7.5 bn, it aims to accelerate the economic recovery and shape the digital transformation in Europe. DIGITAL will not address these challenges in isolation, but rather complement the funding available through other EU programmes, among others the Horizon Europe programme for research and innovation and the Connecting Europe Facility for digital infrastructure, the Recovery and Resilience Facility and the Structural funds.

5.2.2.8. European Regional Development Fund

The European Regional Development Fund (ERDF)[39] finances programmes in shared responsibility between the European Commission and national and regional authorities. The ERDF aims to strengthen economic, social and territorial cohesion in the European Union by correcting imbalances between its regions. In 2021-2027 it will enable investments in a smarter, greener, more connected and more social Europe that is closer to its citizens: this scope can include investments into transport and mobility. The programme Urban Innovative Actions[40] (UIA) supports investments into first-of-a-kind innovations in various fields including mobility. Several projects are funding automated vehicles for public transport.

5.2.2.9. European Territorial Cooperation – Interreg

Interreg is the Union's instrument to support cooperation across regions and countries: a new generation of Interreg programmes in and outside the EU will further develop joint services and

[35] https://rspg-spectrum.eu/wp-content/uploads/2021/06/RSPG21-026final_RSPG_Report_on_Climate_Change.pdf
[36] https://ec.europa.eu/inea/en/connecting-europe-facility, https://cinea.ec.europa.eu/news/connecting-europe-facility-2021-2027-adopted-2021-07-20_en, https://cinea.ec.europa.eu/connecting-europe-facility/transport-infrastructure_en
[37] https://www.c-roads.eu/platform.html
[38] https://digital-strategy.ec.europa.eu/en/activities/digital-programme
[39] https://ec.europa.eu/regional_policy/en/funding/erdf/#1
[40] https://www.uia-initiative.eu/en

strengthen solidarity. Interreg provides funding for projects between Member States, their outermost regions, the EU acceding countries and the neighbourhood countries. In 2021-2027, Interreg will continue to support cross-border mobility, and efforts to develop environmental protection, emergency services, skilled jobs and access to public services. Projects in the field of CCAM can be funded by Interreg e.g. for coordinating cross-border initiatives.

5.2.3. Coordination and Support Actions

5.2.3.1. ARCADE

ARCADE[41] is a Coordination and Support Action funded by the European Commission focussing on supporting the alignment of Research & Innovation activities in Europe and on building consensus among stakeholders for a harmonised deployment of Connected and Automated Driving. It started in 2018 for a duration of 3 years, building on the legacy of the VRA (Vehicle Road Automation, 2013 - 2016) and CARTRE (2016 – 2018) actions.

The project federates a large network of stakeholders and contributes to the Trilateral EU-US-Japan Working Group on Automation in Road Transport (ART)[42]. The project co-organised with the European Commission the EUCAD2019 and EUCAD2021[43] conferences. It supported ERTRAC with the development of the CAD Roadmap through the organisation of joint stakeholder workshops. A series of workshops in 2020 and 2021 were more specifically aimed at supporting the work of the CCAM Platform Working Group 2 and the CCAM Partnership SRIA development on topics of the Common Evaluation Methodology, Data sharing, edge cases and international cooperation on vehicle technologies. One of the main outcomes of ARCADE is the development and publication of an online EU-wide Knowledge base[44] as the one-stop shop for all activities related to CCAM in Europe and beyond. It includes overviews of R&I projects and piloting initiatives including lessons learned, roadmaps, strategies, standards, and guidelines on evaluation methodologies and data sharing.

5.2.3.2. COSMOS

The COSMOS project supports the Mobility.E Lighthouse of the Joint Undertaking on Electronic Components and Systems (ECSEL) with the continuous identification and prioritisation of technical and non-technical research topics for electric, connected and automated (ECA) driving within a strategy development process. Within a first step, research activities and strategies have been mapped to define the ECA mobility ecosystem and the corresponding R&D&I gaps have been analysed. Building upon these results, research priorities have been validated and revised with experts of the field to finally derive an implementation plan, containing concrete actions to accelerate the implementation of ECA mobility solutions and to provide input to (updates of) European ECA strategies. The Mobility.E Lighthouse of the ECSEL JU is a networking and collaboration platform serving to connect stakeholders along and beyond the automotive value chain, bringing together the Electronic Components and Systems (ECS) and application side as well as non-technical experts to ensure European competitiveness for Electric, Connected and Automated (ECA) mobility and to meet the demands of the 2030 customer. The COSMOS project supports the Lighthouse with a strategy development process (including the prioritisation of research topics) and network support activities.[45]

5.2.3.3. FUTURE-HORIZON

FUTURE-HORIZON[46] is a Coordination and Support Action funded by the Horizon 2020 programme with the objective to identify future research needs for a sustainable and efficient road transport system in Europe. Preceded by FOSTER-ROAD (2013-2016) and FUTURE-RADAR (2017-2020), FUTURE-

[41] https://www.connectedautomateddriving.eu/about/arcade/
[42] See Chapter 5.4
[43] https://www.connectedautomateddriving.eu/eucad2021/
[44] https://www.connectedautomateddriving.eu/
[45] https://www.mobilitye.eu/
[46] FUTURE-HORIZON has received funding from Horizon 2020 research and innovation programme under grant agreement No 101006598.

HORIZON started in February 2021 and will last until January 2023. The project provides support to the ERTRAC activities including for the development of the ERTRAC research roadmaps such as the one presented here on CCAD, and others such as Road Safety, Urban Mobility, etc. Other objectives include the assessment of road transport research strategies in Europe and in other established and emerging markets; and support for capacity-building for local policy makers and practitioners to generate and implement innovative sustainable mobility solutions. The project also supports the communication strategy of ERTRAC, in order to disseminate widely and openly activities and publications.

5.3. EU Member States initiatives

5.3.1. Declaration of Amsterdam and High Level Dialogue

On 14 April 2016 at the Informal Transport and Environment Council in Amsterdam, 28 EU Ministers of Transport endorsed the "Declaration of Amsterdam"[47] to work towards a more coordinated approach enabling the introduction of connected and automated driving. Close cooperation between Member States, the European Commission and industry partners is seen as an important prerequisite for the widespread introduction of innovative and interoperable connected and automated driving technologies and services in Europe. The Declaration of Amsterdam on Connected and Automated Driving was an important first step towards a common European strategy in this field and includes a joint agenda for further action to support the shared objectives. Key action points for Member States mainly involve the need to address legal and practical barriers to the testing and deployment of connected and automated vehicles. The Declaration of Amsterdam also called for the establishment of a high level structural dialogue for Member States to exchange views and best practices regarding the development of connected and automated driving and to monitor progress.

The inaugural High Level Meeting, organized by the Netherlands which took place on 15 February 2017 in Amsterdam[48] was followed on ministerial level by the second meeting in Frankfurt[49], Germany, on 15 September 2017 and the third meeting in Gothenburg, Sweden[50], on 18/19 June 2018. Two expert meetings were subsequently organised in Vienna[51], Austria, in 2018 and Vilnius, Lithuania, in 2019. The next round on ministerial level was planned to be organised in Barcelona in October 2019, but was postponed to be held in Helsinki[52] on 7 October 2020. The core themes for the fourth High-Level Ministerial Meeting on Connected and Automated Driving established by the Spanish Presidency and further elaborated by the Finnish Presidency included:

1. the need to develop and deploy transport automation in a human-centric manner,
2. the need to enhance data sharing between the various stakeholders in the ecosystems of transport automation and
3. the need to reform the regulatory landscape concerning transport automation.

[47] https://www.rijksoverheid.nl/documenten/rapporten/2016/04/29/declaration-of-amsterdam-cooperation-in-the-field-of-connected-and-automated-driving
[48] https://www.government.nl/documents/leaflets/2017/05/18/on-our-way-towards-connected-and-automated-driving-in-europe
[49] https://www.bmvi.de/SharedDocs/EN/Documents/DG/action-plan-automated-and-connected-driving.pdf?__blob=publicationFile
[50] https://www.government.se/articles/2018/06/third-high-level-meeting-on-connected-and-automated-vehicles-led-to-common-conclusions/
[51] http://www.smart-mobility.at/hlm2018/
[52] https://www.lvm.fi/-/high-level-meeting-on-connected-and-automated-driving-aims-at-strengthening-cooperation-1234725

5.3.2. CEDR Transnational Research Programme (TRP)

The Conference of European Directors of Roads (CEDR) is the organization of European national road authorities (NRAs) that promotes excellence in the management of roads. The members of CEDR are the General-Directors and CEOs of the NRAs and are supported by NRA experts from over thirty countries. Knowledge and innovation are part of CEDR's strategic objective "to help national road authorities to keep ahead of the curve, anticipate future trends and prepare them to face new challenges", understanding that innovation will shape future core business as well as the legislation framework.

CEDR recognises the importance of research in the development of sustainable transport and has established working groups aimed at the analysis of relevant and specific topics of interest. These topics range from safety, operations, nature and environment, logistics to multimodality, as well as developments such as connectivity, automation, data and digitisation. Through this process, CEDR members work together to identify needs for research collaboration and manage research activities.

The aim of the CEDR Transnational Research Programme (TRP) is to support cooperation between European national road administrations in addressing common challenges through research and innovation. Since 2006, CEDR has cooperated on a series of annual transnational calls on topics that address the needs of European road authorities. The goal is to produce implementable research results, which are not produced elsewhere, and that support European road authorities in meeting their objectives. It is funded by CEDR members and their partners on a voluntary basis and open to bids from research providers from the whole world, provided that a consortium leader is from Europe. By doing this, duplication of national funding is avoided, and synergies are generated. One of the foundations of the CEDR programme drives from EU support through ERA-NET collaborative funding arrangements. This has included pilot activities with funding from international partners such as the USA.

The process is optimised to ensure a short timescale from the Description of Research Needs to actual contracting projects. Further information on all previous and current CEDR research calls are available at https://www.cedr.eu/research-and-innovation

5.3.2.1. Current CEDR research Calls of relevance to CCAM

CEDR Call 2020 has two research programmes: Impact of Connected and Automated Driving (CAD) on Safe Smart Roads and Resource Efficiency and the Circular Economy. The aim of Impact of CAD on Safe Smart Roads research programme is to prepare the national road authorities on future challenges of connectivity, digitalization and automation to get to an autonomously well-managed traffic flow. NRAs need to act proactively to contribute to the automation of traffic flows, in order to optimise investments and safeguard NRAs' objectives. NRAs goals and roles in the Cooperative, Connected and Automated Mobility of the future must be clear. Exchange of data, digital twins and the digital road operator are now key topics. This research programme has three sub-themes: Digital infrastructure, Connectivity and Traffic management. Funding for the 2020 CAD Call comes from Belgium – Flanders, Ireland, Israel, Netherlands, Norway, Sweden and the United Kingdom.

CEDR Call 2021 is planned to be launched in September 2021 with the following two programmes: Climate Change Resilience and Remote Condition Monitoring of Physical Road Assets. More details on Descriptions of Research Needs (DoRNs) for two research programmes within Call 2021 are available at https://www.cedr.eu/news-data/1638/DoRNs-for-CEDR-Call-2021-published

CEDR Call 2022 is currently in the process of preparation, where current considerations indicate addressing data processing and sharing, which are relevant for CAD.

5.3.3. Austria

The BMK Ministry has issued an Action Programme on Automated Mobility 2019-2022.[53]

Automated systems can currently only be tested to a very limited extent in a strictly controlled environment. Testing on public roads - under real conditions - and also in selected and re-usable test environments is, as well as the virtual environment, an important prerequisite for the continued development of automated driving. In order to be able to test automated or networked vehicles or their technologies whilst complying with the strictest safety regulations, the BMK is following two approaches:

- Testing on public roads with a corresponding certificate, as a possibility for testing advanced, automated vehicles/functions. The Regulation[54] presently allows the testing of the usage cases like motorway pilot scheme with lane-change assistant, self-driving minibuses and self-driving military vehicles.

- Testing in special test environments, in order to carry out extensive test running for research development and validation projects and so to make it possible for all participants to learn together.

In order to enable a pooled build-up of expertise in automated driving, it is intended to create integrated research, development and test environments. The establishment of an efficient operator structure should secure the operation of these test environments for the medium and long term. The long-term possibility for systematic testing should enable a common learning process for all involved (suppliers, OEMs, infrastructure managers, public sector, service providers, and research institutes).

The first Austrian test environment is presently being created in Styria. Research institutes and industrial companies from the Styrian automotive cluster are grouping together their expertise here under the title ALP.Lab[55]. The many possibilities here are unique: besides tests on private routes, test runs on motorways are also possible. In addition, modern simulators and testing facilities are available.

DigiTrans[56] is another test environment being created in Upper Austria. This has the aim of setting up an interdisciplinary test region for automated and networked driving in the North Central region of Austria (Linz – Wels – Steyr). In the process, the project addresses requirements from industry and infrastructure managers, including digitalisation and logistics aspects. DigiTrans focusses on requirements and usage cases of commercial and special vehicles, especially in the area of logistics hubs and on the common use of the infrastructure of test environments for fully automated driving.

5.3.4. Belgium

In 2018, the Flanders' government set up a framework[57] for a connected automated mobility strategy involving both its Innovation (EWI) and Mobility (MOW) Ministries. Its main focus was an analysis of the Belgian traffic regulations to be adapted, and an investment program for smart intelligent traffic infrastructure and cloud applications, the Mobilidata[58] program.

The Belgian traffic regulation was amended in 2018 in order to allow experiments with automated vehicles. For those experiments, exemptions to the traffic rules may be granted. A code of practice for testing autonomous vehicles in Belgium had been released earlier.[59]

[53] https://www.bmk.gv.at/en/topics/mobility/alternative_transport/automated/publications/automatedmobility.html
[54] https://www.bmk.gv.at/en/topics/mobility/alternative_transport/automated/framework/roads.html
[55] https://www.alp-lab.at/
[56] https://www.digitrans.expert/
[57] Conceptnota Geconnecteerde en geautomatiseerde mobiliteit in Vlaanderen
[58] https://mobilidata.be/en/about-mobilidata
[59] https://mobilit.belgium.be/en/resource/code_practice_autonomous_vehicles

A Belgian platform coordinates the CCAD activities among policy entities of the different levels, to provide input to the EU Single Platform on CCAM.

Flanders' Mobility department was part of the CEF funded project CONCORDA, together with IMEC and the KU Leuven, to work on the preparation of motorways for automated driving thanks to connectivity technologies.[60] The testing was further developed in the Smart Highway project supported by the Flemish government.[61] Also the Research Centre Flanders Make is active in automated driving research and pilots.

5.3.5. Czech Republic

The Czech Republic has several governmental strategies in force. The most crucial one is the Vision of Autonomous Mobility Development (Resolution No. 720, 11th of October 2017), that defines the main goals for proper introduction of autonomous mobility in the Czech Republic. The Vision commits to create a Plan which will set concrete steps for further successful development of autonomous mobility in the longer term. Also, the National Artificial Intelligence Strategy of the Czech Republic is considered as a strategical material for AI functions support in the transport area.

An Ethics Committee for CCAM was established by the Ministry of Transport aimed at assessing tasks and comprehensive issues related to autonomous mobility in the Czech Republic. The main areas the commission deals with include human-machine interaction, the issue of artificial intelligence behaviour in the event of accidents, the availability and security of shared data or the issue of responsibility for the software and infrastructure used in the Czech Republic.

The Working group Autonomous Driving is a wide expert platform set up by Ministry of Transport and based on the Memorandum on the Future of Automotive Industry in the Czech Republic. It includes members of the Automotive Industry Association of the Czech Republic and other stakeholders from public and private sector.

The Transport Research Centre (CDV), a public research institution under the jurisdiction of the Ministry of Transport, is a partner in the SHOW project funded by HORIZON 2020: a pilot operation for testing in real environmental is being carried out with autonomous shuttles in the City of Brno.

5.3.6. Denmark

In 2017, the parliament passed a legislation[62] regarding experiments with self-driving cars to allow experiments with self-driving vehicles in Denmark. The legislation makes it possible to carry out vehicle tests on public streets up until SAE level 4. To get approval, the test project must be assessed by a third-party safety assessor before permission can be granted. An evaluation of the legislation is planned in 2022.

In 2015, the Ministry of Transport received requests to use self-driving vehicles to streamline the production of municipal services. Existing legislation, however, requires the physical presence of a driver in such cases. But with the bill, it is proposed that different experiments with self-driving motor vehicles can be permitted. The expectation is that self-driving motor vehicles - under specific traffic conditions - e.g., on a fully striped motorway or at low speeds in a path system - would be able to drive safely without a driver actively participating. Experiments with self-driving vehicles will be limited to specific vehicle types and specific road sections. 4 projects have been granted a test approval. Until now, all projects have been focusing on last mile transport in slow driving shuttles in urban areas.

[60] https://trimis.ec.europa.eu/project/concorda
[61] https://www.flandersmake.be/en/projects/smart-highway
[62] Link to the test legislation (in Danish): https://www.ft.dk/samling/20161/lovforslag/L120/som_fremsat.htm

These projects include: Smartbus, Aalborg[63]; Nordhavn, Copenhagen[64]; Linc Project, DTU Campus[65]; Slagelse sygehus Fase 2, Movia[66]. Further test applications are expected in the coming year.

5.3.7. Finland

Based on a national automation strategy for all transport modes in 2015, the Road Transport Automation Road Map and Action Plan 2016–2020 was published in early 2016. In 2019-2021, a governmental resolution on the promotion of transport automation has been prepared. The resolution applies to all modes of transport. It is based in legislation and the action plan of key measures on transport automation prepared at the Ministry of Transport and Communications. The resolution contains five sets of measures: the development of regulation; the development of physical infrastructure; the development of digital infrastructure; the utilisation of knowledge; and an increase in experimentation and testing. Specific attention is given to safety and cybersecurity aspects.

The existing Finnish legislation is liberal, allowing automated vehicle operation on open roads by a driver also outside the vehicle i.e. in remote control. The Finnish Transport and Communication Agency Traficom is issuing test plate certificates for stakeholders wishing to test and validate automated vehicles and driving functions on Finnish roads.

A national platform of the public stakeholders has been set up under the Ministry of Transport and Communications.

Finland has further developed the ISAD classification to the national motorway network and tested it in practice on E12. The Finnish Transport and Infrastructure Agency is developing the digital twin to serve also the needs of automated vehicles. Automated public transport, adverse road weather use cases, truck platooning have been piloted in various test sites in cities and open roads to assess and improve their technical performance, user acceptance, impacts, benefits and costs. In addition, a pilot plan for the digitalisation of traffic rules for specific use cases and how to realise them is starting. The use of 5G is also a pivotal topic in projects like LuxTurrim5G and 5G-MOBIX.

5.3.8. France

In May 2018 was published[67] the strategic framework that structures the French government's policy actions for to the development of automated vehicles. Based on tree main principles: security, progressivity and acceptability, the national strategy has placed technical and regulatory innovation at the centre of all its actions. The strategic document sets four main objectives:

- Establish the legislative and regulatory framework allowing the circulation of automated vehicles in France by 2022.
- Support innovation, mainly through experimentation.
- Prepare the security validation framework at the national, European and international scales.
- Assess more precisely the acceptability issues and the economic outlook for deployment.
- Actions which have been carried out so far include:
- Extension of the scope of the experiments to use cases with the operator outside the vehicle, with specifications regarding the liability regime and the safety requirements.

[63] https://smartbus.dk/
[64] https://www.letsholo.com/nordhavn
[65] https://lincproject.dk/
[66] https://www.moviatrafik.dk/foererloes-bus/test-paa-sygehuse
[67] https://www.ecologique-solidaire.gouv.fr/sites/default/files/18029_Développement-VA_8p_EN_Pour%20BAT-3.pdf

- More than 120 authorizations to experiment have been granted since 2015 and a coordinated program (EVRA) was launched in 2019 to pool the lessons learned from experiments, specifically with regard to safety evaluation and acceptability.

- Setup of a legislative framework resulting from the Mobility Orientation Law (26 December 2019) which will allow the circulation of automated vehicles beyond the experiments, thanks to an adapted liability regime, by setting the safety requirements.

- Adaptation of the international driving regulation (Vienna Convention) to allow the circulation of highly automated vehicles from 2022, subject to compliance with technical regulations.

On 1st July 2021, France published a decree[68] adapting the provisions of the Traffic and Transport laws to allow the circulation on French roads of vehicles equipped with driving delegation systems as soon as they are homologated, and automated road transport systems on predefined routes or zones from September 2022.

The national strategy takes into account a reassessment of the use cases, their accessible operational domains and the steps necessary for their deployment. Priority actions include the intensification of the support for innovation (considering the evolution of use cases, connectivity, infrastructure, business models), mobilise more the European approach, accompany local stakeholders, and pre-regulatory and normative technical work. A second edition of the national strategy is in the planning, with the objective to amplify the momentum in favor of automated road mobility services, structured around tree main priorities: establish partnerships between sectors, entrench the new services in the territories, and act on a European scale.

The French automotive & mobility platform (PFA), with its "France Autonomous Vehicles" program, committed to the development of this ecosystem of autonomous vehicle with large scale experimentations. Several groups have been set by platforms addressing technologies and safety and security demonstrations. Two projects have been selected through the coordinated program (EVRA) launched in 2019 to support the national strategy. These include 16 experimentations with a duration of 3 years and a total budget of 120M€ including 42 M€ of subsidies.

- SAM (« Sécurité et Acceptabilité de la conduite et de la Mobilité autonome »): Experiments of roll-out on dual carriageways, parking valet, on-demand transport in urban areas, regular transport complementary to existing networks, establishment service from a remote car park, use of a railway right-of-way, autonomous delivery vehicles.

- ENA (« Expérimentations de Navettes Autonomes »): Experiments of autonomous shuttle services complementary to the urban transport network and rural service.

5.3.9. Germany

The Federal Government strategy for Automated and Connected Driving (2015)[69] has been pivotal for numerous actions on developing the legal framework, promoting research and innovation as well as digital test beds. An implementation report is available summarizing the achievements of the 18th legislative period (ending 2017).[70] The Automated Driving Round Table as an interdisciplinary and cross-institutional expert body coordinated by the Federal Ministry of Transport and Digital Infrastructure has proved its worth as a central platform for societal participation.

[68] https://www.interieur.gouv.fr/Actualites/Communiques/Pour-la-premiere-fois-en-Europe-le-code-de-la-route-et-le-code-des-transports-s-adaptent-a-l-arrivee-des-vehicules-a-conduite-automatisee-sur-les-routes-de-France
[69] https://www.bmvi.de/SharedDocs/EN/publications/strategy-for-automated-and-connected-driving.html
[70] https://www.bmvi.de/SharedDocs/EN/Documents/DG/report-implementation-of-acd-strategy.pdf?__blob=publicationFile

Even more broadly, the Concerted Action Mobility – an initiative chaired by the Federal Chancellor - has addressed the mobility transformation including the transformation of the automotive industry contributing to the mobility ecosystem.[71]

The legal framework for Automated and Connected Driving has been shaped by two legislative initiatives. The Act on Automated Driving (Eighth Act amending the Road Traffic Act) which entered into force in June 2017 has regulated the rights and obligations of drivers using automated driving functions (BGBl 2017 I No. 38, 20.06.2017, pp. 1648-1650).[72] The Act on Autonomous Driving (Act amending the Road Traffic Act and Obligatory Insurance Act) provides the legal basis for operating Level 4 vehicles in defined operating areas (BGBl 2021 I No. 48, 27.07.2021, pp. 3108-3114).[73] The new Act focuses on flexibility as the operation of driverless motor vehicles will be made possible for as many deployment scenarios as possible (including shuttle services from point A to point B, people movers (buses operating on an established route), hub2hub services (e.g. between two distribution centres), demand-driven offers in off-peak hours; transport of persons and/or goods on the first or last mile and dual mode vehicles such as in automated valet parking (AVP). The different use cases will only be geographically limited to a determined operational area but not yet exhaustively regulated. Individual approvals, exemptions and conditions such as the presence of a security driver, who is ready to intervene at all times, are thus no longer necessary. The Act on Autonomous Driving is an interim solution until internationally harmonised provisions enter into force. With a view to harmonised markets and standards, Germany is taking great interest in creating overarching rules and the Ministry will strongly advocate evolving the legal framework at EU and UNECE levels. As an example, the level 3 lane keeping assistance system (ALKS — Automated Lane Keeping System) up to a speed of 60 km/h on motorways, which may be used in traffic jams, has been adopted at UN level. Germany is also currently actively involved in amending the UN regulation on ALKS. The aim is to change the legal system in a way as to allow for speeds of up to 130 km/h and to enable it to perform lane changes.

The promotion of research and innovation on Automated and Connected Driving by the Federal Government is executed as a joint responsibility of the Federal Ministries of Education and Research (BMBF), of Transport and Digital Infrastructure (BMVI) and for Economic Affairs and Energy (BMWi) which follows the action plan on research for autonomous driving (2019).[74] The topics covered in the German public funding programs span from electronic components and software systems via AI and data processing to vehicle cooperation and connectivity, testing and human-machine interaction. The action plan also provides short descriptions of project examples (UNICARagil, PEGASUS, IMAGinE, PROVIDENTIA).[75] These four projects alone have received support of 66 M€. As a result of two calls in 2019 and 2020 (third call closes in September 2021) BMVI supports 26 projects with a total amount of 123 M€. Summary information on the projects is available.[76]

An essential element of the Federal Government's research and innovation funding are Digital test beds in the public road environment. Examples of motorway test beds are the Digital Motorway Test Bed (A9) and the Franco-German-Luxembourg Digital Test Bed. There is also a substantial number of urban and rural testbeds. Information on all testbeds is available from a dedicated website (Testfeldmonitor).[77]

[71] https://www.bmwi.de/Redaktion/EN/Pressemitteilungen/2020/20200616-transformation-dialogue-for-the-automotive-industry-has-started.html; https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2021/08/20210816-1-mrd-euro-fur-die-zukunftsthemen-der-automobilindustrie-expertenausschuss-legt-seine-forderempfehlungen-vor.html
[72] https://www.bgbl.de/xaver/bgbl/start.xav?start=%2F%2F*%5B%40attr_id%3D%27bgbl117s1648.pdf%27%5D#__bgbl__%2F%2F*%5B%40attr_id%3D%27bgbl117s1648.pdf%27%5D__1632141920599
[73] https://www.bgbl.de/xaver/bgbl/start.xav?startbk=Bundesanzeiger_BGBl&start=//*[@attr_id=%27bgbl121s3108.pdf%27]#__bgbl__%2F%2F*%5B%40attr_id%3D%27bgbl121s3108.pdf%27%5D__1632143439894
[74] https://www.bmvi.de/SharedDocs/DE/Anlage/DG/aktionsplan-forschung-fuer-autonomes-fahren.pdf?__blob=publicationFile
[75] https://www.unicaragil.de/en/; https://www.pegasusprojekt.de/en/home; https://www.imagine-online.de/en/home, https://www.fortiss.org/en/research/projects/detail/providentia
[76] https://www.bmvi.de/DE/Themen/Digitales/Automatisiertes-und-vernetztes-Fahren/AVF-Forschungsprogramm/Projekte/avf-projekte.html
[77] https://www.testfeldmonitor.de/Testfeldmonitoring/DE/Home/home_node.html

5.3.10. Greece

Automated Driving is a thematic area considered in the ITS National Strategy and recognized as an important element for the future public transport planning (in connection with existing transport means) in close connection with other key national priorities like electromobility. Greece has decided to allow the circulation of fully automated driverless vehicles in urban areas and on public roads for research/pilot implementations. The framework requires a thorough analysis of the proposed routes, a certification process for the vehicles, a proper training for the operators (remote or on-board), supervision by appropriate specialized research or academic bodies and an active support by local authorities. These specific conditions were defined in detail in a ministerial decision that was published on 13th June 2015.

At the beginning of 2021, Greece further adapted its legal framework to support and facilitate the permanent circulation of autonomous vehicles. The current legislation framework of autonomous driving has been enhanced and updated with new legal provisions and ministerial decisions to be signed per case, that enable the autonomous operation of shuttles as well as N1 and M1 vehicles (only for pilot operation) in mixed traffic, with increased speed according to the area of deployment (urban/peri-urban), and under the supervision and monitoring of a remote operator for more than one vehicles. This new legal framework was voted in Q1 of 2021. Ministerial decisions that will explicitly define the relevant operational details of the autonomous vehicles are also in progress, to be signed within 2021.

The national project AVINT[78] deals with automated vehicles integrated in the urban context. The goal of the project is to enhance the public transport system of the city of Trikala with a fleet of automated buses in a fully integrated way.

5.3.11. Hungary

Hungary supports CCAM via the C-ROADS Platform and further by creating an urban CCAM testbed in the town of Zalaegerszeg, linked to the Automotive Proving Ground Zala. It is called ZALAZONE and is unique in its integration of both classic vehicle dynamic- and the multiple testing possibilities for autonomous vehicles in its newly developed autonomous vehicle proving ground modules. It is more than just an ordinary automotive and information communication test track, as this initiative is the pioneer project of the Hungarian Autonomous Ecosystem, which includes the public road testing of automated vehicles as well. As of 12th April 2017, testing automated development vehicles on public roads is permitted by national law, with the relevant regulation having been updated in December 2018 according to the recommendations of the vehicle developers and function designers. The so-called “Traffic Cloud”, a large-scale project aimed at assisting automated traffic is currently in the process of planning.

The Mobility Platform, a professional discussion forum for university, industrial and authority partners, was established in March 2018 to provide support for the development of the Hungarian Autonomous Ecosystem.

Trilateral cooperation has been set up (ASFINAG, DARS, Magyar Közút) in order to exchange knowledge and experiences, and to harmonize activities in the field of CCAM. The idea is to provide testing possibilities to open road conditions, which can even be simulated and analysed within the Test Zone later on.

5.3.12. Ireland

The Irish government approved legislation to enable new provisions to facilitate testing, within strict guidelines, of cars in autonomous mode on Irish roads in December 2019.[79] Work has begun on a strategic roadmap and plan for CAVs, which will set out at high level the actions needed across the

[78] https://www.avint-project.eu/index.php/en/
[79] https://www.gov.ie/en/press-release/2dd62e-cabinet-approves-legislation-to-test-autonomous-vehicles-on-public-r/

entire system over the coming years to drive the development of the connected and automated mobility sector in Ireland and to prepare for the introduction of CAVs. Work is also ongoing in relation to connected (rather than automated) vehicles: Transport Infrastructure Ireland recently received funding under the Connecting Europe Facility to run a C-ITS (Co-operative Intelligent Transport Systems) pilot project[80] focused on connected vehicle services.

Future Mobility Campus Ireland[81] (FMCI) was established in August 2019 for the purpose of creating and delivering future mobility testbed facilities for stimulating research, development and innovation in the area of Autonomous, Connected, Electric, and Shared Vehicles (ACES). The testbed is located in the Limerick-Shannon metropolitan area. FMCI is supported under the Department of Business, Enterprise & Innovation's Regional Enterprise Development Fund administered by Enterprise Ireland. FMCI is also backed by Multinational Companies, SMEs, Local Authorities and (Semi-)State Agencies. FMCI is building a CAV test facility immediately adjacent to Shannon Airport (to be complete in Q4 2021) located in real-world settings, providing technology companies and researchers the ability to test and enhance their innovations in mixed traffic with conventional vehicles and other road users and modes of transport.

5.3.13. Italy

The "Smart Road" Ministerial Decree[82] authorizes the experimentation of technological solutions to adapt the Italian infrastructure network to new smart services and for automatic vehicles. Tests on Automated Driving vehicles on Italian public roads are regulated by the "Smart Road" Decree and pilot test authorization shall be requested to the Road Operator/s and successively to the Italian MIT. The so called "supervisors" are the only allowed to drive and shall be compliant to specific requirements, e.g. at least 5 years' license, safe driving course for AD vehicles at an accredited body, at least 1000 km of tests with AD in a protected area or on public roads. Before pilot tests, it's necessary to have already carried out experiments with AD vehicles in simulation for at least 3000 km and tests in a protected location or on public roads for at least 3000 km. Any applicant who wishes to conduct an experiment for vehicles provided with AD functions on Italian public roads should follow the procedure: require and obtain the clearance from the car manufacturer and from the road operator for one or more road sections indicated by the applicant, require the authorization c/o Italian Ministry of Infrastructure and Transport.

A memorandum of understanding[83] was signed on 15th May 2020 by the Ministers for Technological Innovation and Digitization (MID), and for Infrastructure and Transport (MIT) in order to support the "development of innovative mobility through research and experimentation of autonomous and connected driving vehicles". The protocol aims to develop and support applied research, experimentation and prototyping, production and training of new professionals in the field of innovative vehicles and means of transport with autonomous and connected driving, as well as the interest in creating services with a social impact for the country. The agreement also supports and encourages collaboration and partnership between public institutions, companies, universities and research bodies.

MIT has established the Technical Support Observatory (TSO) for Smart Roads and for the connected and self-driving vehicle. The role of the TSO is to provide an update on the activity carried out and on the state of the art of the initiatives identified on the national territory in the field of smart roads and connected and self-driving vehicles.

C-Roads Italy has implemented and tested a set of "Day 1" and "Day 1.5" C-ITS services in real traffic conditions. Moreover, cooperative systems based on V2X technologies have been deployed and tested for the following automated driving applications: truck Platooning and Highway Chauffeur.

[80] https://www.tii.ie/technical-services/research/c-its/
[81] https://futuremobilityireland.ie/about/)
[82] https://www.gazzettaufficiale.it/eli/id/2018/04/18/18A02619/sg
[83] https://www.mit.gov.it/comunicazione/news/mit-e-mid-accordo-per-lo-sviluppo-della-mobilita-autonoma-e-connessa

5.3.14. Netherlands

The national strategy can be described with the following 4 themes: Encouraging the use of existing products and services (e.g. safe use of ADAS), Responsible introduction of new generation of vehicles (automated functions, in cooperation with industry and EC), Future-ready infrastructure and road management (with a focus on data exchange) and Careful use of data exchange and connectivity. This approach stimulates investments both at the public and private side, in order to increase the impact and the efficiency of the efforts made. All in order to make the step from experimenting and testing to use in the daily practice.

Through cooperation initiatives like krachtenbundeling and LVMB (see below) strategies are aligned between national, regional and local government partners.

The Ministry of Infrastructure and the Water management (I&W) has opened the public roads to large-scale tests with self-driving passenger cars and trucks. The Dutch cabinet has adopted a bill which makes it possible to conduct experiments with self-driving vehicles without a driver being physically present in the vehicle. The "Experimenteerwet zelfrijdende auto" (law governing the experimental use of self-driving vehicles) removes legal impediments.[84]

Furthermore, studies have been done and are still ongoing into the interplay between smart vehicles and infrastructure and the need to adapt current road guidelines, taking account the mixed fleet for the coming decades.

A formal cooperation between many different governmental bodies has been created in 2018 in order to increase the scale and impact of smart mobility activities. National, regional and local authorities joined forces to ensure top-level preconditions for the digitalization of mobility. The cooperation is called Bundling Forces ('Krachtenbundeling'). The goal is to make it easy and appealing for national and international enterprises to introduce – in a responsible manner – mobility services that enhance the travel experience and contribute to solving the challenges that are being faced: reducing the number of road casualties, sustainability, and keeping the country liveable, accessible and affordable for everyone. Topics include automation and connectivity but also MaaS and data exchange.

Furthermore, the 'LVMB' initiative brings together government stakeholders specifically for traffic management including a focus on the automated vehicle future.

5.3.15. Norway

Norway's strategy aims to facilitate appropriate research, development and piloting, both in the transport activities and through the established policy instruments, in collaboration with technology-related EU research in Horizon Europe. The national Transport plan includes a section on technology, under which it is possible to plan technology deployments to support CAD.

Norway has established a testing law and 50 applications for projects have been received and approved so far. The Norwegian Public Roads Administration (NPRA) has an ITS program which includes a thematic area on readiness for automation. Hence there are ongoing small projects that explore where the NPRA needs to focus efforts to ensure the progression of automation. Under this umbrella, three core services are explored: location, communication and human machine-readable infrastructure. As the focus is on services to support automated driving, the Norwegian pilot activities are made up of smaller activities but linked together in the umbrella organization known as the ITS pilots. The national research projects LambdaRoad and TeaPot focus on connectivity services and location services respectively. In these projects, the NPRA has partnered with researchers, industry and other relevant national authorities like the Norwegian Communications Authority and the Norwegian Mapping Authority.

[84] https://www.government.nl/topics/mobility-public-transport-and-road-safety/self-driving-vehicles

Norway is also carrying out larger internal projects, like the E8 Borealis project, that focus on source data to enable CAD under Nordic conditions. Field tests are mainly conducted in the northern part of Norway in the Tromsø region. In the southern and eastern part of Norway, projects like Sohjoa Baltic and Sohjoa Last Mile are running with vehicles integrated in the public transport system.

In addition, Norway has played a role in the NordicWay string of projects (1-2-3), which aimed at testing future services to support connected and automated driving.

5.3.16. Poland

The AV-PL-ROAD project, Polish Road to Autonomy of Road Transport[85], is the most important activity devoted to autonomous transport at government level in Poland. Activities scheduled for 3 years (2018-2021) include creating a roadmap and legal regulations for the introduction of autonomous vehicles in Poland. The national project is implemented by the Ministry of Infrastructure, the Motor Transport Institute and the Warsaw University of Technology.

Automated driverless vehicles are contrary to current Polish regulations[86], although Polish law does not explicitly state that every vehicle must have a driver, it includes various provisions establishing obligations for the driver (who must be a physical person).

In theory, the automated vehicle tests in traffic on public roads are permitted, provided that safety requirements are met, and a special permit has been granted. The permit does not imply consent to permanently register such a vehicle: it is simply an agreement to conduct tests on a special basis. The requirements are described in Article 65k–65n of the road traffic code[87] .

One of the results of the AV-PL-ROAD project is the creation in June 2021 of the Competence Centre for Autonomous and Connected Vehicles (CK PAP)[88]. As a specialized unit of experts, CK PAP will perform tasks in the field of monitoring research works and the implementation of regulations in Poland, at the same time being an advisory body in the field of industry and technology development. Cooperation with institutes of the Visegrad Group is also planned.

The Sohjoa Last Mile[89] project, supported by Interreg Baltic Sea Region, plans to implement an automated, electric shuttle remote operating pilot in Gdansk in 2021. This project is a continuation of the Sohjoa Baltic[90] project which tested a self-driving, electric shuttle bus on the route to the city zoo in Gdansk in 2019.

5.3.17. Spain

The Spanish R&D Strategy for the period 2021-2027 (2020) has been designed to maximize coordination between state and regional planning and to facilitate the assemble of our R&D policy with Horizon Europe. Indeed, the national strategic lines are framed in the thematic groups of Horizon Europe, where climate, energy and mobility is one of the priorities.

Also, the first of the Strategic Projects for the Recovery and Economic Transformation (PERTE) is the one dedicated to the Electric and Connected Car. It is a project based on public-private collaboration and focused on strengthening the value chains of the Spanish automotive industry, a strategic sector for Spain.

[85] https://pie.net.pl/wp-content/uploads/2020/05/PIE-Raport_Autonomiczny-transport-przysz%C5%82o%C5%9Bci.pdf page 21
[86] https://www.ikem.de/wp-content/uploads/2020/06/20200526_Sohjoa_The-Legal-Framework_Final.pdf
[87] https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU19970980602/U/D19970602Lj.pdf
[88] https://www.its.waw.pl/11164,pl,AV-Poland-2021-relacja-wideo.html
[89] https://www.sohjoalastmile.eu/
[90] https://www.sohjoabaltic.eu/gdansk-pilot-started/

The Directorate General of Traffic (DGT) promotes the use of a technological platform (DGT 3.0 - Connected Vehicle Platform) that allows being connected and offers traffic information in real time to road users. The DGT also issued a regulation to permit full automated driving test (2015). This regulation permits field operational test in all the territory in different test sites that are already equipped to host field operational test (controlled Test Sites, Urban and InterUrban). Among others, the following are available:

- C-ROADs Spain: Following the C-ROADS framework several corridors are being deployed in several locations in Spain: Madrid C-ROADS M-30 Cooperative; SISCOGA Extended (city of Vigo); Cantabrian corridor in the northern area of Spain; Mediterranean corridor (Catalonia and Andalusia).

- SISCOGA^{4CCAM} is a permanent European CCAM corridor to test future CCAM solutions. SISCOGA^{4CCAM}, comprehends more than 200 km equipped with different connectivity technologies including ITS-G5 and cellular (3G/4G, MEC, PC5 and 5G), including urban and interurban scenarios and cross-border capabilities.

- Madrid AUTOCITS A-6 Cooperative Corridor is located in the Northwest Madrid Urban Node access, a 16 km stretch of highway between the M30 and M40 the main urban and interurban nodes in Madrid, equipped with ITS-G5 continuous communications and cellular communications.

- Catalonia Living Lab is a public-private framework for development and testing CAD technologies. Its primary goal is to cover international needs related to CAD development and testing through the comprehensive aggregation of Catalan public and industry infrastructures and services.

- 5G-MED is deploying a scalable, cross-border and multi-stakeholder 5G and AI-enabled system architecture supporting CCAM and FRMCS services that can be replicated along European corridors.

- IDIADA has deployed a private cellular network including 2G/3G/4G and 5G communications, the Connected Vehicle Hub in its test tracks in Tarragona together with Orange and ERICSSON in order to provide connectivity services focused on CCAM development in urban and interurban environments.

- AutoMOST project aims in the design and implementation of an automated electric bus for people transportation within the port of Malaga and its connection with the city center on normal road conditions. The scenario presented some challenging environment with pedestrians, vehicles, roundabouts and intersections.

5.3.18. Sweden

Research and innovation for connected and automated vehicles in Sweden are mainly covered through national programs integrated into the Swedish innovation system. There are many projects, field-tests and pilots ongoing supported by different established programs, platform and centres of which a selection is mentioned here.

FFI[91] is the main program for automotive research in Sweden funded by the Swedish innovation agency Vinnova, the Swedish Energy Agency, the Swedish Transport Administration and the main automotive stakeholders in Sweden. The FFI program covers several important areas related to CCAD, such as “Road Safety and Automated Vehicles”, “Electronics, Software and Communication”, “Efficient and Connected Transport System”, “Systems-of-systems”, “Cyber-security for automotive” and Electro-mobility.

DriveSweden[92] is a national Strategic Innovation Program running from 2016 until 2027 with over 100 partners, aiming to design and pilot new mobility services based on connected, automated

[91] https://www.vinnova.se/en/m/strategic-vehicle-research-and-innovation/
[92] https://www.drivesweden.net/en

and shared vehicles. The program provides funding for projects and perform strategic work in five thematic areas, Society planning, Digital infrastructures, Business models, Policy development and Public engagement.

AstaZero[93] provides full-scale independent test environment for future road safety. The facility is unique in that the different traffic environments make it possible to test advanced safety systems and their functions for all kinds of traffic and traffic situations. This enables research, development and certification of future road safety systems, and functions as an international arena open for vehicle manufacturers, suppliers, legislators, universities and colleges from throughout the world.

SAFER[94] is the open research arena where researchers and expertise work together to create safe mobility. The traffic safety approach covers people, vehicles and the infrastructure to contribute to safer road transports and smarter, more sustainable cities.

5.3.19. United Kingdom

Established in 2015, The Centre for Connected and Autonomous Vehicles (CCAV)[95] works with industry and academia and leads the government's Future of Transport strategy. The Policy Paper "Future of mobility: urban strategy"[96] published In March 2019 outlines the government's approach to maximising the benefits from transport innovation, including Connectivity and automation for their potential to increase safety, decrease congestion and positively influence public health.

The CCAV has asked the Law Commission of England and Wales and the Scottish Law Commission to undertake a far-reaching review of the legal framework for automated vehicles, and their use as part of public transport networks and on-demand passenger services[97]. The review has been running from 2018 to 2021 and included three rounds of consultation. The final recommendations are expected in the last quarter of 2021. A public consultation has also been carried out in June and July 2021 on "The future of connected and automated mobility in the UK: call for evidence".[98]

The UK Code of Practice for testing automated vehicles on public roads was first published in 2015. A new version was issued in February 2019.[99] The code makes clear that tests of automated vehicles are possible on any UK road, without the need to secure permits or surety bonds, as long as they comply with UK law, including having: a driver (in or out of the vehicle) who is ready, able, and willing to resume control of the vehicle; a roadworthy vehicle; and appropriate insurance in place. The Code also notes that those planning tests should speak with the road and enforcement authorities, develop engagement plans, and have data recorders fitted. Additionally, those planning to conduct advanced trials should contact the CCAV in advance.

Building on the Code of Practice, in September 2019, the Government launched the CAVPASS Project (Connected and Automated Vehicle Process for Assuring Safety and Security), aimed at developing a world-first comprehensive safety and security assurance process to support the safe commercial deployment of automated vehicles. In June 2021, the "CertiCAV Assurance Paper"[100] was published as part of the project. This document is a framework approach for assuring the behaviour of highly automated vehicles.

[93] https://www.astazero.com/
[94] https://www.saferresearch.com/
[95] https://www.gov.uk/government/organisations/centre-for-connected-and-autonomous-vehicles/about
[96] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/846593/future-of-mobility-strategy.pdf
[97] https://www.lawcom.gov.uk/project/automated-vehicles/
[98] https://www.gov.uk/government/consultations/the-future-of-connected-and-automated-mobility-in-the-uk-call-for-evidence
[99] https://www.gov.uk/government/publications/trialling-automated-vehicle-technologies-in-public/code-of-practice-automated-vehicle-trialling
[100] https://1hir952z6ozmkc7ej3xlcfsc-wpengine.netdna-ssl.com/wp-content/uploads/2021/06/CertiCAV-Assurance-Paper-v1-4.pdf

Zenzic[101] was created by government and industry to focus on key areas of UK capability in the global connected and self-driving sector. Its roles include:

- Driving collaboration, leading and shaping a world-class CAM Testbed UK.
- Delivering a comprehensive UK Connected and Automated Mobility Roadmap to 2030 that guides decision makers, policy makers and investors. The second release of the roadmap was published in October 2020.[102]
- Championing the UK connected and self-driving vehicle ecosystem.

According to the "Connected and Automated Vehicles in the UK: 2020 information booklet"[103], the government, industry and academia have invested £240 million in a portfolio of more than 90 collaborative R&D projects. These projects are collaborative, with over 200 organisations from SMEs to OEMs and universities to insurance companies. Some of the main projects include:

- Project Endeavour[104] is a mobility project designed to accelerate and scale the adoption of autonomous vehicle services across the UK, and maximise the potential of this technology. The work is being done with local authorities and members of the public in London, Oxford and Birmingham to run advanced simulations alongside pilots on public roads.
- SWARM (Self-organising Wide area Autonomous vehicle Real-time Marshalling)[105]
- Aurrigo collaborated on the demonstration of pods 'swarming' like birds and insects, following each other without supervision, helping each other to drive and navigate through pedestrian areas.
- CAVForth:[106] creating Europe's first full-sized autonomous bus. Started in the second half of 2020, the autonomous bus service will operate on the trunk road network along a 14-mile route across the Forth Road Bridge between Fife and Edinburgh.

ServCity[107] is a major UK research programme to help cities solve an important problem: how they can harness the latest autonomous vehicle technologies and successfully incorporate them into a complex urban environment. Through simulation, end-user experience research and real-world testing, ServCity will inform how cities can exploit the potential of autonomous mobility solutions and accelerate their deployment. Testing will be conducted in test facilities prior to public road testing in London with state-of-the-art autonomous vehicles utilising the Nissan LEAF.

[101] https://zenzic.io/
[102] https://zenzic.io/content/uploads/2020/10/Zenzic_Roadmap_Report_v3.pdf
[103] https://www.gov.uk/government/publications/connected-and-automated-vehicles-in-the-uk-2020-information-booklet
[104] https://www.projectendeavour.uk/
[105] https://www.gov.uk/government/case-studies/aurrigo-makes-breakthrough-in-driverless-pods-technology
[106] https://www.transport.gov.scot/transport-network/roads/connected-and-autonomous-vehicles-cav/project-cavforth/
[107] https://www.ServCity.co.uk

5.4. Initiatives around the world

5.4.1. Trilateral EU-US-Japan Automation in Road Transportation Working Group

The European Commission (EC), the United States Department of Transportation (USDOT) and the Road Bureau of Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan have a long history of sharing information on ITS (Intelligent Transportation Systems) activities. This exchange was formalized in 2009 and 2010 with a series of three bilateral agreements among the three parties, officially authorizing exchange activities among them. The following four Working Groups focusing on high-priority areas for conducting collaborative research are currently in place, with topics addressed on a trilateral or bilateral basis, according to the interests of the parties:

- Architecture and Standards Harmonization (US-EU bilateral)
- Human Factors
- Automation in Road Transport
- Deployment (including a Sub-Working Group on Probe Data)

The collaboration is structured in a three-layer manner: namely a Steering Group, a Coordinating Group and several Working Groups, including one on Automation in Road Transport (the ART WG). The ART WG was established by approval of the Steering Group in October 2012 at the Vienna World Congress. The mission of the ART WG can be summarised as follows:

- Allow each region/country to learn from one another's programs,
- Identify areas of cooperation where each region will benefit from coordinated research activities, and
- Engage in cooperative research and harmonization activities.

The working group is focused on connected automation as a mean of achieving maximum benefits in safety, mobility and environmental impacts.

5.4.2. USA

The National Highway Safety Administration (NHSA) of the U.S. sees CAD as a technology that can deliver safety. Under this vision, fully automated cars and trucks shall become a reality following the six levels of driver assistance technology advancements.[108] The introduction of CAD in U.S. in the U.S. is led by private companies, though, starting with Google in 2011. A multitude of domestic and international companies have developed significant activities in the development and standardization of AV's in the meanwhile: By 2021, a total of 56 different companies tested their highly automated vehicles on the roads, just in California circa 2 Million miles have been driven without a driver. In June 2020, NHTSA launched the AV TEST initiative, a voluntary platform for AV testers to share information about their testing activities. NHTSA acts as a clearinghouse for that information.

The U.S. government has been focusing more on the development of regulations and facilitating multimodal automation research and collaboration focused on safety, infrastructure interoperability, and policy analysis. The Intelligent Transport Systems (ITS) Strategic Plan 2020-2025 was developed by the ITS Joint Program Office (JPO) and funded by the United States Department of Transportation (U.S. DoT).[109] It considers Automated Driving systems as one the six core elements of ITS and part of the safety strategic goals and related research topic areas of the U.S.

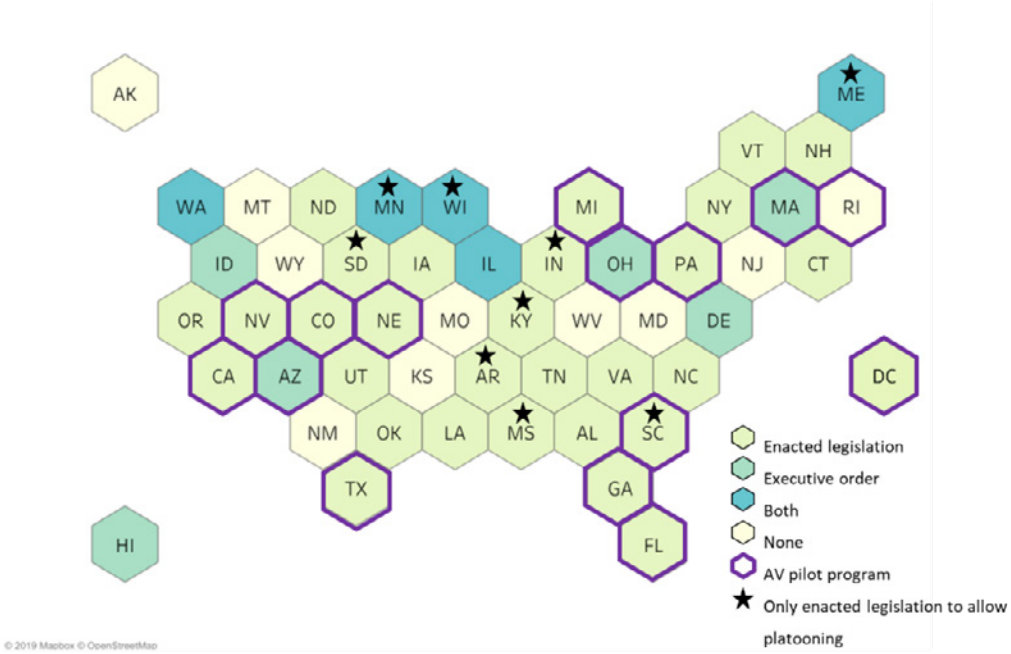
A recent example of the DoT's funding activities is the Automation Demonstration Grants programme launched in 2019. Four projects have been awarded since then and have begun at the engineering stage. In this context, macroeconomic impacts of automated driving systems in long-haul trucking are studied, focussed e.g. on employment issues.[110] DoT is increasing the focus on open data from testing, requiring it in most funded projects going forward, and it is setting up a clearinghouse website for that data.

Other examples of the U.S. DoT's funding activities are the Inclusive Design Challenge awarding a $5M prize for design solutions to increase accessibility in automated vehicles. The CARMA project focuses on collaborative automation (automation with V2V and V2I) for three use cases: traffic (looking at recurring congestion), reliability (incident-driven congestion), and freight (commercial vehicles and ports). CARMA is open-source and available internationally to those who join the CARMA collaborative.[111] Moreover, there are truck platooning field tests funded by a grant awarded in July 2020 to the University of California PATH team. They will be testing two-to-three truck platoons and running a single truck nearby to collect baseline data. The test route will run on a 1,400-mile segment of Interstate 10 between California and Texas, with data collection over a 12-month period.

As the goal is to advance safe, interoperable, and efficient integration of automation technologies into transportation systems, it is intended that public and private sectors work in partnership in a cross-modal effort to gather the expertise from different sectors around the U.S.: GM, Waymo, and Aptiv are main companies developing fully autonomous vehicles for the launch on the market.[112] Additionally, the Automated Vehicle Safety Consortium, a program of the SAE ITC, was formed to develop the safety principles for level 4 and 5 automated driving Systems. Toyota, Ford, GM, Honda, Daimler, VW, Aurora, Lyft and SAE are members of that consortium.

[108] https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety#topic-road-self-driving
[109] https://www.its.dot.gov/stratplan2020/ITSJPO_StrategicPlan_2020-2025.pdf
[110] https://rosap.ntl.bts.gov/view/dot/54596
[111] https://its.dot.gov/cda/
[112] https://www.autoinsurance.org/which-states-allow-automated-vehicles-to-drive-on-the-road/

California is the state leading to pass regulation for automated vehicle testing, Nevada, Arizona and Florida are following it. Even though the regulations are more restrictive in California, the state has the most private tests from USA and non-USA based companies. Companies such as Waymo and Phoenix are completing paid taxi trips with level 4 vehicle drives with public. The figure below maps the expansion on legislation in the country.[113]



State Legislation for CAD (Source: D'Agostino, 2021)

[113] M. D'Agostino et al., Policy and Regulation of Automated Vehicles: Spotlight on U.S. Federal and States. In: G. Meyer, S. Beiker (Eds.), Road Vehicle Automation 8. Springer 2021.

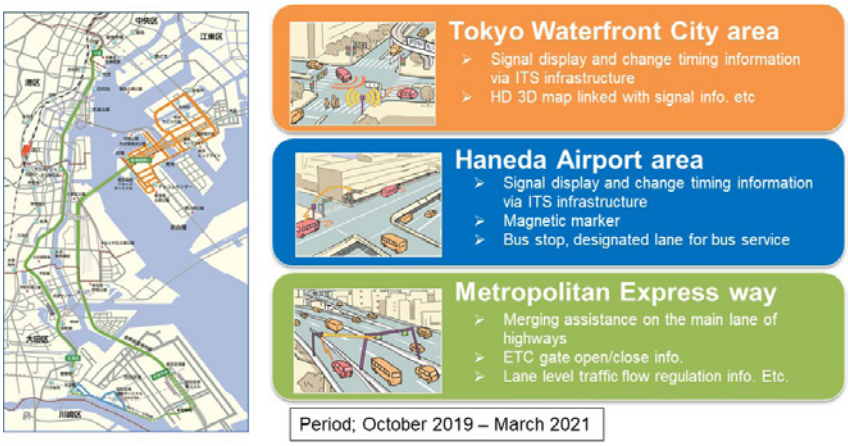
5.4.3. Japan

As part of its 5th Science and Technology Basic Plan, Japan is aiming to achieve a Society 5.0, i.e. a human-centered society that balances economic advancement with solving social problems by a system that highly integrates cyber and physical spaces. To achieve this vision, the government has established the Strategic Innovation Promotion Program (SIP), where an automated driving system for universal service (Adus) is considered as one of the 12 priority themes. SIP-Adus focuses on promoting cross-sector and industry-academia-government collaboration, R&D programs from fundamental research to practical and commercialization; and to promote a regulatory reform. Road safety assurance, cybersecurity and geospatial dynamic maps use are the technological objectives of that plan. For the financial year of 2020, about 3 bn Yen (24 m€) were invested for R&D in this program.[114]

Pioneer, Denso, Hitachi, Sony and another six organizations are part of the Driving Intelligence Validation Platform (DIVP) consortium, an association created to develop a feasible methodology to assess the safety performance of automated road vehicles. The project focuses on the precise duplication from real to virtual worlds and aims at verifying the consistency between the sensor models and the real-world condition. Its approach is based on data accumulation and utilization, physical models, and computing performance.

As safety and security in many aspects are a priority for Japan, the revised Road Act now states that an infrastructure-side supporting apparatus for automated driving which cannot be perceived with human senses, is an essential road equipment to be operated and maintained by the road administrator. The road administrator is also obliged to publicize the performance of this apparatus. Also an Intrusion Detection System (IDS) was developed to assure Cybersecurity on CAD. This initiative intents to develop a validation method for ideas, components and solutions provided by the different CAD security companies.

Additionally, 29 organization including the vehicle manufacturers and automotive suppliers BMW, Valeo, Honda, Nissan, Suzuki, Volkswagen, Bosch and Mitsubishi are working together in the CAD Field Operational Test in Tokyo Waterfront area (FOT).[115] This FOT is meant to develop signal display and change timing information through ITS infrastructure, merging assistance on the main lane of highways, HD 3D map linked with traffic info, etc. It was planned to be completed from October 2019 until March 2021, but an extra year has been added to the project with the objective to include new traffic environmental data.



FOT in Tokyo Waterfront Area (extended until March 2022, due to COVID-19, Source: Kuzumaki 2021)

Another FOT is prepared in Japan to test truck platooning on expressways with a focus on applying infrastructure-based sensors for e.g. merging control.

[114] https://en.sip-adus.go.jp/sip/file/sip_2020_plan_en_s-1.pdf
[115] S. Kuzumaki, The Challenges for Automated Driving Systems Realization in Japan: SIP-adus. In: G. Meyer, S. Beiker (Eds.), Road Vehicle Automation 8. Springer 2021.

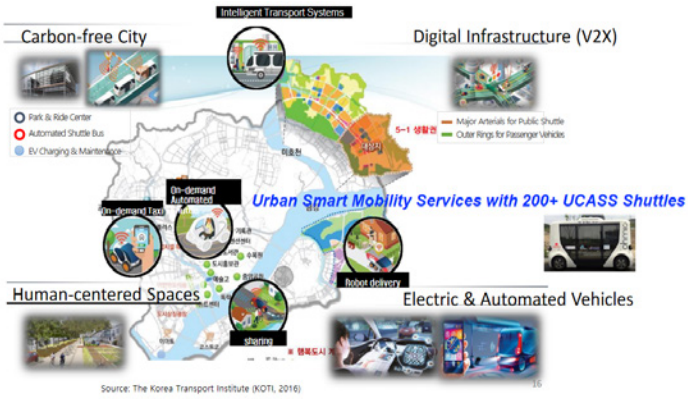
In Japan, a particular focus of the early deployment activities of automated driving systems is on rural areas, where public transport is at a decline. In the Michi-no-Eki Project, automated shuttle services are being operated in various regions, e.g. to deliver light cargo, transfer tourists to camp sites and to carry residents to hospitals or shopping centers in nearby towns. Technologies like e.g. electromagnetic induction lines are used to guide the vehicles.[116]

According to a White Paper by the Ministry of Land, Infrastructure, Transport and Tourism in Japan, in 2020 a secular crustal deformation correction system (POS2JGD) was developed to eliminate the discrepancy between map and high-precision positioning data. The objective is to create an environment where anyone can easily use high-precision location information, that contributes to the creation of new services such as autonomous driving and drone logistics.[117]

5.4.4. South Korea

With the support of CAD, South Korea aims to achieve a green transport system for the future generations. For Korea, this means a system that is safe, accessible, affordable, and environmentally friendly. The objective consists in reducing congestion, road accidents, emissions, air pollution and health problems by avoiding the need to use private vehicles, shifting to sustainable transport modes and improving the overall efficiency of the system.

The Korean Ministries of Transport, IT and Science Technology, Commerce and Industrial Legislation work together to run the plan and have announced an investment of $1 billion for the development of the core technologies for autonomous vehicles, aiming at the commercialization of level 4 CAD by 2027.[118] This investment is focused mainly on the develop autonomous vehicle technologies and build related infrastructure divided in 84 related projects in five specific areas: New vehicle convergence technology, new ICT convergence technology, new road traffic convergence technology, service creation, and the establishment of an industrial ecosystem.[119]



Sejong City Plan for Smart Mobility based on CADS & Digital Infrastructure[120]

The Cooperative Transport System (C-ITS) Pilot Project for Vehicle-to-everything (V2X) Connectivity is a vehicle and ICT convergence connectivity program meant as a communication network between cars, personal phones, roads and central (governmental) stations. The main focus is the digitalization of the infrastructure considering the physical, digital and logical infrastructures. In addition to the infrastructure elements, two types of vehicles are considered in the plan, namely passenger cars at high speed an on designated motorways (Level 3) and public and shared vehicles at low speed and in urban mobility systems (Level 4 / driverless).The program has been already piloted in cities such as Sejong-Yusung (Pilot until 2017), Seoul & Jeju (2018-2019) and Ulsan & Gwangju (2020).

[116] https://en.sip-adus.go.jp/evt/workshop2017/file/evt_ws2017_s5_HidenoriYoshida.pdf
[117] https://www.mlit.go.jp/hakusyo/mlit/r01/hakusho/r02/pdf/English%20Summary.pdf
[118] http://www.koreaherald.com/view.php?ud=20210121000807
[119] https://pulsenews.co.kr/view.php?year=2021&no=47159
[120] The Korea Transport Institute (KOTI, 2016)

In order to overcome stringent regulations for CAD that were blocking the development of the technology in the country, the Korean government has announced the 'Future Vehicle Industry Development Strategy' in October 2019. Thereby, it pretends to renovate the regulatory framework and infrastructure to fit autonomous driving by 2024, and to promote the commercialization of Level 4 autonomous vehicles by 2027. To achieve this goal, the government has set safety standards for Level 3 and Level 4 vehicles in 2020 and 2021, respectively, and plans to establish an insurance system for completely autonomous vehicles after 2021 and a verification system for the performance of autonomous vehicles by 2022.[121]

5.4.5. China

In December 2020, the Chinese Ministry of Transport announced its focus on the development of critical technologies for CAD, considering mainly the smart road infrastructure and cooperative systems between vehicle and the infrastructure. The industrialized application of autonomous driving technologies is meant to be deployed by 2025 in China.[122]

According to the State Council of China, a cooperation between carmakers, high-tech companies and telecommunications service providers have resulted on a series of start-ups that offer experimental services in cities such as Beijing, Shanghai, Changsha, and Hunan province. The figure below presents the leading joint ventures.

Leaders in China's self-driving race

Company	Investors	Highlight	Operating locations
Baidu Apollo	Baidu	Holds most Chinese permits for operating robotaxis	Changsha, Cangzhou, Beijing
Pony.ai	Toyota, Sequoia Capital	First to launch robotaxi operations in China	Guangzhou
WeRide.ai	Renault-Nissan-Mitsubishi Alliance, SenseTime	First to secure Chinese online ride-hailing license	Guangzhou
Didi Chuxing	SoftBank, IDG	Aims to deploy 1 million vehicles by 2030	Shanghai
AutoX	Alibaba, Dongfeng Motor	First Chinese company to win driverless car permit in California	Shenzhen, Shanghai
Momenta	Tencent, Daimler	Working with Toyota on camera-based automated mapping	Suzhou

Source: Nikkei Asia research

Startups leading Chinas AV's development

The State Council of China also announced that it would be planned to build a cloud-based pilot area for self-driving vehicles in the Beijing Economic-Technological Development Area by the end of 2021. The area known as E-Town, which will be 60 km2, is the first high-level automated driving demonstration area and China's first pilot zone for cloud-based self-driving vehicle policies. The area is meant to include integrated smart roads, intelligent vehicles, real-time cloud, reliable network and precise maps[123] for the trial operation of lower-level self-driving vehicles and the testing of Internet of Vehicles (IoV) applications.[124]

[121] https://www.ibanet.org/article/19FCDD11-A0B1-41F1-97AB-F32E144311F8
[122] http://english.www.gov.cn/policies/policywatch/202101/05/content_WS5ff39f9fc6d0f725769433b4.html
[123] http://english.www.gov.cn/news/topnews/202009/22/content_WS5f6a06d4c6d0f7257693c7a2.html
[124] http://en.people.cn/n3/2020/0922/c90000-9763223.html

In "The Status of the Road Testing for AV in China", the National Technical Committee of Auto Standardization (NTCAS) has indicated that up 2018 almost 20 cities have opened areas to do CAD road tests. It is confirmed too that some cities have already piloted autonomous taxis (Robotaxi) in selected areas [125].

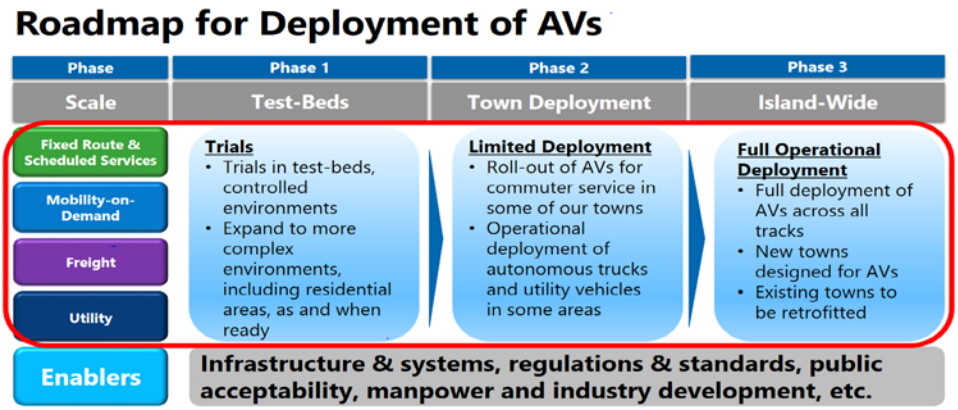
The Ministry of Public Security (MPS) and the Ministry of Industry and Information Technology (MIIT) are leading CAD regulations in China. The MPS published on March 2021 a Draft Proposed Amendments of the Road Traffic Safety Law (the "MPS Proposed Amendments"). It states the requirements for CAD testing as well as the regulations for traffic violations and accidents. The MIIT released on April 2021 its draft regulation for autonomous vehicles. The draft considers autonomous vehicles with conditional automated driving functions (L3) and highly automated driving functions (L4).

5.4.6. Singapore

The Singapore Land Transport Master Plan 2040 envisions a city, where the transport system is convenient, well connected and fast.[126] "20 minutes towns and 45 Minutes city" is one of the three main visions of this plan. To achieve this, CAD is essential, as it can reduce traffic congestion and land intake by offering effective public solutions that reduce the demand of car ownership, improve road safety by eliminating human-errors on the roads, and reduce the dependency on man power, as most of the bus drivers are from foreign countries.

The Committee on Autonomous Road Transport for Singapore (CARTS) was created to bring CAD developers and landplaning organizations together to develop the transportation systems for the next years. Governmental agencies such as the National Research Foundation, the Land and Transport Authority, the Ministry of Transport, as well as private organizations such as Toyota, Aptiv, Singtel, and Continental are members of the CARTS.

By May 2021, Singapore is entering on the phase 2 (Pilot deployments) of its automated vehicles deployment roadmap. This phase involves the pilot deployment of autonomous public transport services in three new towns (Punggol, Tengah and Jurong Innovation District), and the collaboration with industry to develop and test autonomous public transport solutions for Singapore.



Roadmap for Automated Vehicles Deployment in Singapore

The Centre of Excellence for Testing & Research of automated vehicles was launched on 22 November 2017, as a cooperation between LTA and CETRAN to replicate the different elements of Singapore's roads, and also features a rain simulator and flood zone to test automate vehicles' capabilities under different weather conditions.

[125] https://wiki.unece.org/download/attachments/87622683/VMAD-04-12%20Chinas%20Real%20World%20Testing.pptx?api=v2
[126] https://www.lta.gov.sg/content/ltagov/en/who_we_are/our_work/land_transport_master_plan_2040.html

Moreover, companies as Motional, Easymile, Inchcape, ST Engineer and Institutions as the Regional University of Singapore are testing open to public services such as fixed and scheduled services, and Point to Point on demand mobility services. On the other hand, (on path) parcel, grocery, food delivery and road sweeping services are being tested by different organisations and institutions including Continental, OTSAW, Veolia and Enway.

As part of the transition plan towards public automated vehicles, the Land Transport Authority (LTA) and Urban Redevelopment Authority (URA) in Oct 2020 launched an open call for design recommendations and strategies that facilitate automate vehicles operation at bus stops, taxi stands and pick up, drop off points (PUDOs). The objective of the call is to understand how these facilities can be re-designed and equipped to facilitate automated vehicles deployment and enhance user experience. Recommendations from the study will also contribute to the formulation and review of guidelines or standards.[127]

Moreover, the government, academia and industry have come together to develop a four-part Technical Reference (TR) 68 to support the development of SAE Level 4 and 5 AV technology and deployments, in the areas of basic behaviour, safety, cybersecurity principles and assessment framework, and vehicular data types and formats. TR68 was published in Jan 2019. It has since been undergoing revisions to keep pace with advances in AV technology and international standards, which resulted in the launch of the revised TR68 in Sep 2021. Through Singapore's participation in the International Organisation of Standardisation (ISO), the TR68 efforts also contribute to the global effort towards the harmonisation of technical requirements for AV technology.

Additionally, the government had introduced amendments to the Road Traffic Act (RTA) in 2017 to create an AV regulatory sandbox, which gives the necessary flexibility to adjust the rules to facilitate AV trials on public roads and keep up with the rapid changes in AV technology. The sandbox has since been extended to 2027, which allows the continuous support for AV trials as the technology continues to evolve.

5.4.7. Australia

Australia's National Land Transport Technology Action Plan for 2020-2023 considers how connected and automated vehicles will influence future infrastructure and land use planning. Safety, security and privacy, digital and physical infrastructure, data, standards and interoperability as well as positioning for disruption and change are the key issues considered in the plan.[128]

The main responsible partners to deliver the Action Plan are the iMove consortium, consisting of industry, government and research partners, such as the National Transport Commission (NTC) and Austroads, Baraja, Nayba, Mira, Volvo, Easymile, Arrb and Cohda Wireless.[129]

The Australian and New Zealand Driverless Vehicle Initiative (ADVI) was composed by 150 Organizations and stablished in 2015 with the objective to raise awareness and help grow the understanding of the opportunities around the safety and economic benefits that driverless technology can bring to the region. ADVI's main last initiative was to run a survey in the both countries regarding trust and willingness to pay and impacts that Covid19 might have on community acceptance.

The figure below illustrates the main automated vehicle related activities implemented in Australia and New Zealand. Australia is leading on the commercial deployment of driverless trucks for industrial and mine application. Local companies have been focusing on the development of systems, such as mining most mature automated application, drone medical supply delivery, Pilbarra driverless train or Level 4 automated trucks. A Survey capturing lessons from trials has been published by Austroads.[130]

[127] https://www.lta.gov.sg/content/ltagov/en/industry_innovations/development_funds/research_technology_grant_calls/Designing_Bus_Stops_Taxi_Stands_and_Pick-Up_Drop-Offs.html
[128] https://www.infrastructure.gov.au/transport/land-transport-technology/files/national_land_transport_technology_action_plan_2020-2023.pdf
[129] https://imoveaustralia.com/about-imove-australia/
[130] https://austroads.com.au/drivers-and-vehciles/connected-and-automated-vehicles

https://austroads.com.au/drivers-and-vehciles/connected-and-automated-vehicles

AD's Activities in Australia and New Zealand

The NTC works specifically on the development of the end-to-end regulatory framework that supports the safe deployment of automated vehicles on the roads and has developed the Automated Vehicle Program, a document that specifies the policies to be applied on topics such as motor accident injury insurance with automated vehicles, in-service safety, government access to vehicle generated data, and guidelines for trials. Three main reforms have been already implemented up to June 2021:[131]

- The regulation of government access to C-ITS and automated vehicle data to ensure that privacy data is appropriately addressed.
- The development of a safety assurance system for automated vehicles to support the safe, commercial deployment and operation of automated vehicles at all levels of automation.
- The implementation of changing driving laws that support automated vehicles to determine how automated vehicles and automated driving systems (ADS) should be treated.

5.4.8. Russia

In March 2021, the government of the Russian Federation approved an action plan for the testing and launch of highly automated vehicles "without an engineer on board".[132] It is planned to be implemented between 2021 -2024 and includes the development of the regulation for autonomous transport and the creation of the conditions for active development of the industry.[133]

SberAutoTech, a subsidiary of Russia's largest lender Sberbank, has developed a fully self-driving vehicle, FLIP. Yandex, the CAD leader in the country, has focused on robotaxis and already tested nine million miles in Russian cities and abroad, 2 million in 2020 and seven million in 2021. Most of the miles were tested in Moscow, but also in Innopolis, Russia.[134]

The Russian government also issued a plan for CAD testing and future commercial use on public roads without a safety driver in May 2021. CAD regulation is likely to be released by the end of 2021 or by 2022.

[131] https://www.ntc.gov.au/transport-reform/automated-vehicle-program
[132] https://interfax.com/newsroom/top-stories/71342/
[133] https://www.russia-briefing.com/news/russia-to-road-test-driverless-vehicles-2021-2024.html/https://www.russia-briefing.com/news/russia-to-road-test-driverless-vehicles-2021-2024.html/https://www.russia-briefing.com/news/russia-to-road-te st-driverless-vehicles-2021-2024.html/
[134] https://www.eetasia.com/whats-the-latest-on-av-regulation/

5.4.9. India

The shift towards autonomous driving in India might not be as fast and easy as other auto maker countries. India's automotive industry is at a very early stage in the developing and manufacturing of autonomous vehicles as country is facing many challenges that hinder the implementation of CAD on the streets. Poor data, traffic, infrastructure, regulatory hurdles and demographic conditions are the main problems.[135] Additionally, the Ministry for Road Transport & Highways in India announced that the government will not support driverless cars in the country, explaining that the government will not support any technology that comes at the cost of jobs.

However, many companies and startups are working on the development of driverless vehicles for the Indian context. Escorts, the tractor maker company, is trying to develop a Level-2 autonomous tractor, a tractor's prototype was presented in September 2019. The companies Mahindra & Mahindra, FishEyeBox and Flux Auto are looking to develop different levels of autonomous tractors too.[136] In the Indian Institute of Technology (IIT) different student teams are working on the development of driverless solutions that might help to reduce the number of accidents caused due to a human error.

5.4.10. Canada

For CAD, Canada is particularly aiming at cooperative truck platooning systems (CTPS). The CTPS work focuses on system reliability but also human factors concerns such as driver monotony. Human factors projects also include work on HMI and user interaction with Level 2 vehicles; on-road performance of ADAS safety; and a driving simulator study of integrating non-driving related tasks for L3 automated driving.

The National Research Council CAD research activities include benchmarking of ADAS performance; digital infrastructure (high-definition maps and digital twins of mapped roadways); and safety and security, such as for vulnerable road users.

[135] https://www.ipsos.com/sites/default/files/ct/publication/documents/2018-01/driving-mobility-through-autonomy-in-india.pdf
[136] https://gomechanic.in/blog/self-driving-cars-in-india/

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