Connected Automated Driving Roadmap

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ERTRAC Working Group
"Connectivity and Automated Driving"

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As a European Technology Platform, ERTRAC gathers experts from the industry, research providers and public authorities. This roadmap was prepared by the Working Group "Connectivity and Automated Driving", under the leadership of four co-leaders: Armin Graeter (BMW), Mats Rosenquist (Volvo Group), Eckard Steiger (Bosch), and Manfred Harrer (ASFINAG). The previous "Automated Driving Roadmap" of ERTRAC was issued in 2017 and provided updated definitions and development paths, an updated list of EU and international activities, and an extended list of R&D challenges. This new 2019 version presents again a full update of these chapters, and given that the topic of connectivity is becoming progressively more important, it includes connectivity related aspects and the addition of infrastructure related topics. A collaboration with the CEDR CAD work group helped a lot to bring these additional aspects into the document. This new version also builds on the STRIA CAT Roadmap developed by the European Commission.

The following European projects have provided extensive support for the realisation of this roadmap:
ARCADE
FUTURE-RADAR

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1. SCOPE AND OBJECTIVES

The main objective of the ERTRAC Roadmap is to provide a joint stakeholders view on the development of Connected Automated Driving in Europe. The Roadmap starts with common definitions of automation levels and systems, and then identifies the challenges for the implementation of higher levels of automated driving functions. Development paths are provided for three different categories of vehicles.

The Key Challenges identified should lead to efforts of Research and Development: ERTRAC calls for pre-competitive collaboration among European industry and research providers. The key role of public authorities is also highlighted: for policy and regulatory needs, and support to deployment, with the objective of European harmonisation.

Note about Connectivity: the scope of this roadmap is by purpose limited to not cover all aspects of connectivity in Transport. Connectivity will be addressed only when it is used to support the automation of driving functions.

Why Connected Automated Driving?

Connected Automated Driving is seen as one of the key technologies and major technological advancements influencing and shaping our future mobility and quality of life. The main drivers for higher levels of Automated Driving are:

- **Safety:** Reduce **accidents** caused by human errors.
- **Efficiency and environmental objectives:** Increase **transport system efficiency** and reduce time in congested traffic by new urban mobility solutions. Also, smoother traffic will help to decrease the energy consumption and emissions of the vehicles.
- **Comfort:** Enable user's **freedom** for other activities when automated systems are active.
- **Social inclusion:** Ensure **mobility** for all, including elderly and impaired users.
- **Accessibility:** Facilitate access to city centres.

Connected Automated Driving must therefore take a key role in the European Transport policy, since it can support several of its objectives and societal challenges, such as road safety, congestion, decarbonisation, social inclusiveness, etc. **The overall efficiency of the transport system can be much increased thanks to automation**. Traffic safety is of key importance for connected automated driving: to ensure safe interaction with all road-users in mixed traffic environments, in particular with vulnerable road users (VRU) and motorcycles. See the new 2019 ERTRAC roadmap for "Safe Road Transport", which was developed in coordination with this roadmap.

Moreover, automated driving should be understood as a process taking place in parallel and possibly in integration with other important evolution of road transport: the electrification of the powertrains, and the multiplication of mobility offers, especially shared mobility concepts. This roadmap for Connected Automated Driving therefore contributes to the long-term vision of ERTRAC for the transport system. **In one sentence: by 2050, vehicles should be electrified, automated and shared.**

2. COMMON DEFINITIONS

2.1. Levels of Automation

ERTRAC acknowledges the definitions of SAE J3016 defining the Levels of Automated Driving. Their latest version shall be used, after the revision adopted in June 2018, as accessible on: https://saemobilus.sae.org/content/j3016_201806 The figure below is a summary of these definitions and can be used for visual presentations, but experts shall always refer to the full standard text.

Level	Name	Narrative definition	DDT		DDT fallback	ODD
			Sustained lateral and longitudinal vehicle motion control	***OEDR***		
Driver **performs part or all of the** ***DDT***						
0	No Driving Automation	The performance by the *driver* of the entire *DDT*, even when enhanced by *active safety systems*.	*Driver*	*Driver*	*Driver*	n/a
1	Driver Assistance	The *sustained* and *ODD*-specific execution by a *driving automation system* of either the *lateral* or the *longitudinal vehicle motion control* subtask of the DDT (but not both simultaneously) with the expectation that the *driver* performs the remainder of the *DDT*.	*Driver* and *System*	*Driver*	*Driver*	Limited
2	Partial Driving Automation	The *sustained* and *ODD*-specific execution by a *driving automation system* of both the *lateral* and *longitudinal vehicle motion control* subtasks of the *DDT* with the expectation that the *driver* completes the *OEDR* subtask and *supervises* the *driving automation system*.	***System***	*Driver*	*Driver*	Limited
ADS **("*****System*****") performs the entire** ***DDT*** **(while engaged)**						
3	Conditional Driving Automation	The *sustained* and *ODD*-specific performance by an *ADS* of the entire DDT with the expectation that the *DDT fallback-ready user* is *receptive* to *ADS*-issued *requests to intervene*, as well as to *DDT performance-relevant system failures* in other vehicle systems, and will respond appropriately.	*System*	***System***	*Fallback-ready user (becomes the driver during fallback)*	Limited
4	High Driving Automation	The *sustained* and *ODD*-specific performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*.	*System*	*System*	***System***	Limited
5	Full Driving Automation	The *sustained* and unconditional (i.e., not *ODD*-specific) performance by an *ADS* of the entire *DDT* and *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*.	*System*	*System*	*System*	**Unlimited**

Figure 1: SAE Levels of Driving Automation for On-Road Vehicles (June 2018, copyright SAE); terms: dynamic driving task (DDT) operational design domain (ODD); object and event detection and response (OEDR); Automated Driving System (ADS)

2.2. Operational Design Domain

According to the SAE Definition, ODD are "Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics." (SAEJ3016-201806)

Operational design domain (ODD) is a description of the specific operating conditions in which the automated driving system is designed to properly operate, including but not limited to roadway types, speed range, environmental conditions (weather, daytime/night time, etc.), prevailing traffic law and regulations, and other domain constraints. An ODD can be very limited: for instance, a single fixed route on low-speed public streets or private grounds (such as business parks) in temperate weather conditions during daylight hours.

The ODD is relevant to all levels of automation except for 0 (No Driving Automation) and 5 (Full Driving Automation), since the attributes of the ODD are directly connected to the way the automated driving system works. It is up to the manufacturers of the system to specify the ODD for their automated driving system, but a coordinated approach is the most promising. Many different use cases have been analysed and evaluated by EU EIP Activity 4.2, a work group of the European ITS Platform.[1]

Typical ODD differentiation is based on different types of roads: some roads and areas are more suitable to introduce systems involving high level of automation, before they can be deployed to open roads.

- **Confined areas** with restricted access control, such as terminal areas and ports.
- **Dedicated road/lane** where vehicles with specific automation level(s) are allowed but the area is not confined, such as parking areas and dedicated lanes.
- **Open road** with mixed traffic in single or multiple lane operation on local, regional, and highway operation, for use by vehicles with any automation level. Local, regional, national and European and cross border regulation need to be taken into consideration when targeting automation level.

2.3. Vehicle and infrastructure interaction

Long term vision

The road infrastructure can support and guide automated vehicles by using physical and digital elements. The infrastructure support levels for automated driving (ISAD) can be used to inform automated vehicles about the road capability on certain road segments. The underlying exchanged information from sporadic connectivity to cooperate guiding support are described. Several research activities are started to develop new infrastructure elements as well as new traffic management strategies for supporting automated vehicles in critical situations. In order to evaluate and test the new infrastructure concepts several AD test sites are deployed whereof

[1] https://www.its-platform.eu/

the latest status in Austria and Spain is presented. Further the infrastructure data can be aligned with automotive safety integrity level.

The users' driving and travel experience will be explored to provide an incentive for OEMs to cooperate with the infrastructure, since it can provide additional information for on-board decisions of CAVs. This requires answering the question as what the prerequisites towards the infrastructure from vehicle side are. The most basic step, a classification of infrastructure is needed, which ISAD levels can provide. Still, a common understanding between OEMs, automotive industry and road operators is to be established.

2.3.1. ISAD

The environmental perception of automated vehicles is limited by the range and capability of on board sensors. Road infrastructure operators already employ numerous traffic and environmental sensors and provide information that can be perceived by automated vehicles. In order to classify and harmonize the capabilities of a road infrastructure to support and guide automated vehicles, we support a simple classification scheme, similar to SAE levels for the automated vehicle capabilities, following the work of the EU research project INFRAMIX[2]. This project is preparing the road infrastructure to support the transition period and the coexistence of conventional and automated vehicles. Its main target is to design, upgrade, adapt and test both physical and digital elements of the road infrastructure, ensuring an uninterrupted, predictable, safe and efficient traffic. Although INFRAMIX is targeting mainly highways, since they are expected to be the initial hosts of such mixed traffic, its key results can be easily transferred to urban roads.

The levels we support and which are being developed in INFRAMIX are called Infrastructure Support levels for Automated Driving (ISAD) and can be assigned to parts of the network in order to give automated vehicles and their operators guidance on the "readiness" of the road network for the coming highway automation era.

Figure 2 "ISAD levels" shows the description of the five ISAD levels, along with the information that is provided to automated vehicles.

	Level	Name	Description	Digital map with static road signs	VMS, warnings, incidents, weather	Microscopic traffic situation	Guidance: speed, gap, lane advice
Digital infrastructure	A	Cooperative driving	Based on the real-time information on vehicle movements, the infrastructure is able to guide AVs (groups of vehicles or single vehicles) in order to optimize the overall traffic flow.	X	X	X	X
	B	Cooperative perception	Infrastructure is capable of perceiving microscopic traffic situations and providing this data to AVs in real-time	X	X	X	
	C	Dynamic digital information	All dynamic and static infrastructure information is available in digital form and can be provided to AVs.	X	X		
Conventional infrastructure	D	Static digital information / Map support	Digital map data is available with static road signs. Map data could be complemented by physical reference points (landmarks signs). Traffic lights, short term road works and VMS need to be recognized by AVs.	X			
	E	Conventional infrastructure / no AV support	Conventional infrastructure without digital information. AVs need to recognise road geometry and road signs.				

Figure 2: "ISAD Levels"

[2] https://www.inframix.eu/

Infrastructure support levels are meant to describe road or motorway sections rather than whole road networks. This reflects common practice of infrastructure deployment: Traffic control systems (sensors and VMS) are usually deployed on motorway sections where traffic often reaches the capacity limit (e.g. in metropolitan areas), whereas other motorway sections need no fixed installations of traffic control systems because traffic flow is rarely disrupted. The five levels increase in added support from E to A. This example (Figure 3) illustrates how ISAD levels can be used for a simple description of what automated vehicles can expect on specific parts of a road network.

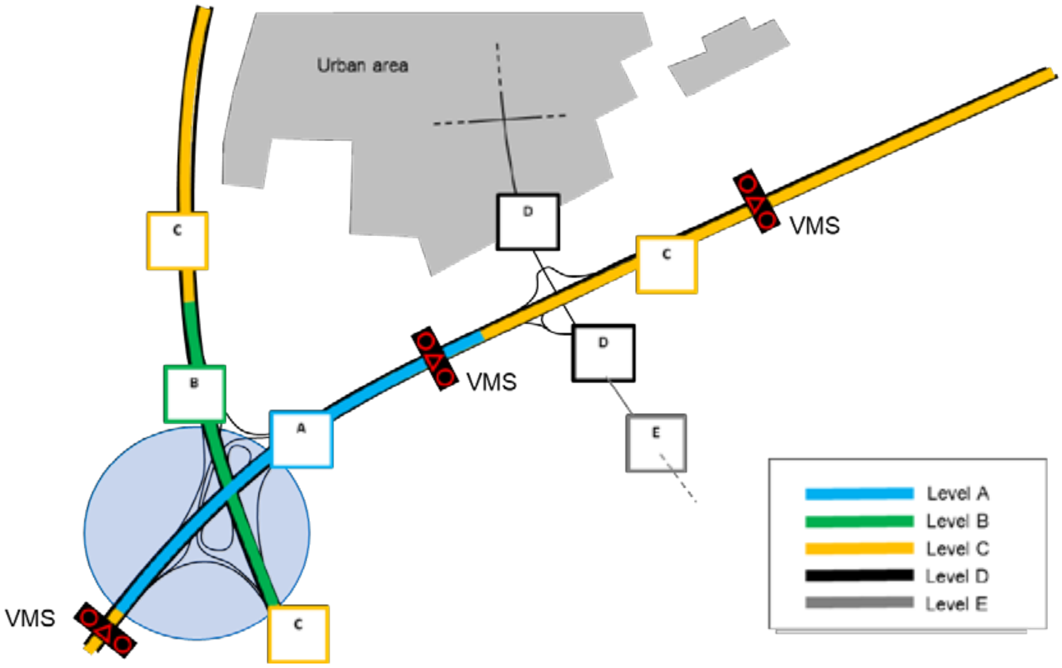

Figure 3: "ISAD Example"

2.4. Regulatory and standardisation framework for Automation

The vehicle operates under two major regulations: the homologation framework and the traffic regulation framework. The new concepts of ODD and ISAD need to comply with the constraints defined by these frameworks. The status today forms constraints for the implementation of automation. It is clear that both frameworks at the same time have to evolve themselves to cater properly for future traffic with higher automation levels and mixed traffic.

Additional research needs to be carried out and a joint approach between telecom and vehicle industry as well as cross-border pilot projects and the adaptation of road traffic rules in Member States can all support to reach a consensus in this field. The deployment of CAD may be hampered if there are no collaborative actions towards a coordinated and quick development of

European-wide regulations and laws enabling testing and use of automated vehicles on public roads. By solving regulatory issues, the public will start to accept and use automated vehicles sooner, leading to a better market penetration and a competitive advantage for the EU on the field of automated driving.

Traffic regulations describe the concrete constraints under which a vehicle is allowed to move on the road, covering aspects like speed, allowed vehicle characteristics like width, height, weight and permissible movements like lane change, right/left turn, overtaking, etc. Traffic regulations apply independent of the automation level, so they can provide an important input to the ODD assessment.

Traffic regulations are implemented traditionally in the ISAD level E world via “road signs” placed on, above or near the road, where the term sign includes road markings. Vehicles detect traffic regulations via sensors (e.g. cameras), but the detection probability may be limited in difficult environments (adverse weather conditions, sign “forest” in urban scenarios), hence the currently valid traffic regulations at the same time form an important part of the ISAD content. In future Level 5 scenarios independent of traditional visualisation means more dynamic traffic regulations become possible – e.g. access regulations based on certain vehicle criteria that only apply if certain conditions are met – which would make traffic regulations as an element of ISAD mandatory.

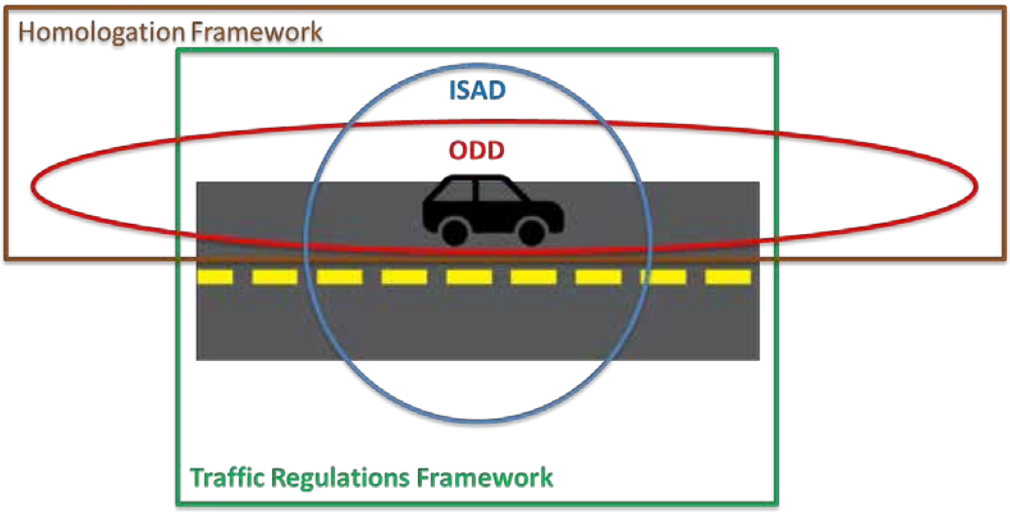

Figure 4: Regulatory and standards framework for Automation

Elaboration of ODD and ISAD should be performed collectively in a pre-competitive environment between automotive and infrastructure sectors. ISAD will provide important elements for ODD definitions, regarding digital infrastructure (e.g. availability of electronic traffic regulation) as well as physical infrastructure (e.g. about road marking quality or standardised road layouts in roadworks). The ISAD interface needs to be standardised based on ODD requirements.

2.5. Connectivity as a requirement for vehicle-infrastructure interaction

Whilst the automation side is heavily discussed, one should not overlook the connectivity aspects of CAD. For higher automation levels, connectivity is a pivotal aspect given the necessary interactions between all involved parties. To ensure a productive development of CAD, each participant must also be aware where he is located not only geographically but also digitally in relation to the other stakeholders in this connected network. The understanding and development of connectivity can and should of course be further elaborated and supported by the involved stakeholders.

The currently developed communication profiles and services connect all involved parties via short range communication. To further improve this connectivity between them, there is also the option to support hybrid profiles. The same content can be sent out through different media, compatible and interoperable.

An overview of the data exchange of national road authorities can be seen in Figure 5 “Stakeholders in NRA data exchange”.

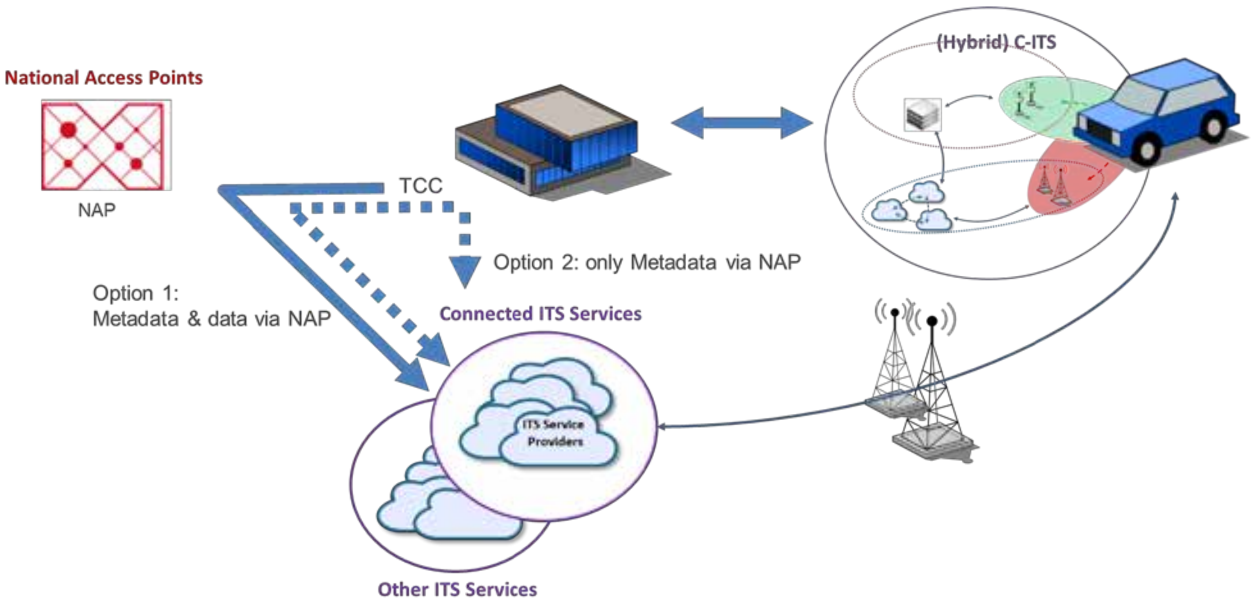

Figure 5: “Stakeholders in NRA data exchange”

This can further be supported by multi-channel communication to upgrade existing ITS services using conventional standard system architectures and message formats. It is important here to use standardised mappings from C-ITS data structures to existing standards (e.g. DATEX II) to ensure interoperability. This adds another layer to connectivity.

A major factor for the future evolution of connectivity will be the emergence of 5G networks. The 5G technology will be much more powerful than today's 3G/4G networks. In the current practice mobile networks are mainly used as simple access networks to the mobile internet. Mobile stations (vehicles, smartphones, etc.) have point to point links to services. Although proposed hybrid communication architectures de-facto provide geographical addressing via message brokers, the underlying communication technology is still based on point to point communication. 5G may potentially change this with sophisticated architectural features like mobile edge computing and unprecedented bandwidth and latency characteristics. This may allow connectivity patterns that go beyond what is possible today.

3. DEVELOPMENT PATHS

Stakeholders involved in ERTRAC share the vision of a progressive step-wise increase of automation levels during the upcoming decade. The main development paths for the different automation levels are shown in the Figure 2 below.

Major collaborative projects funded by the EU are currently looking at the first levels of automation and organizing testing in order to prepare their roll-out in Europe: the L3Pilot[3] project for automated passenger cars, and the ENSEMBLE[4] project for multi-brand truck platooning. These projects were strongly promoted by the previous versions of the ERTRAC roadmap. **The focus for this version of the roadmap is on High Automation - Level 4.**

The development paths indicate the timeframe to reach levels of TRL 7-9, to be understood as ready from a technology perspective. We refer to the TRL levels definition used within the Horizon 2020 programme[5]:

- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified
- TRL 9 – actual system proven in operational environment

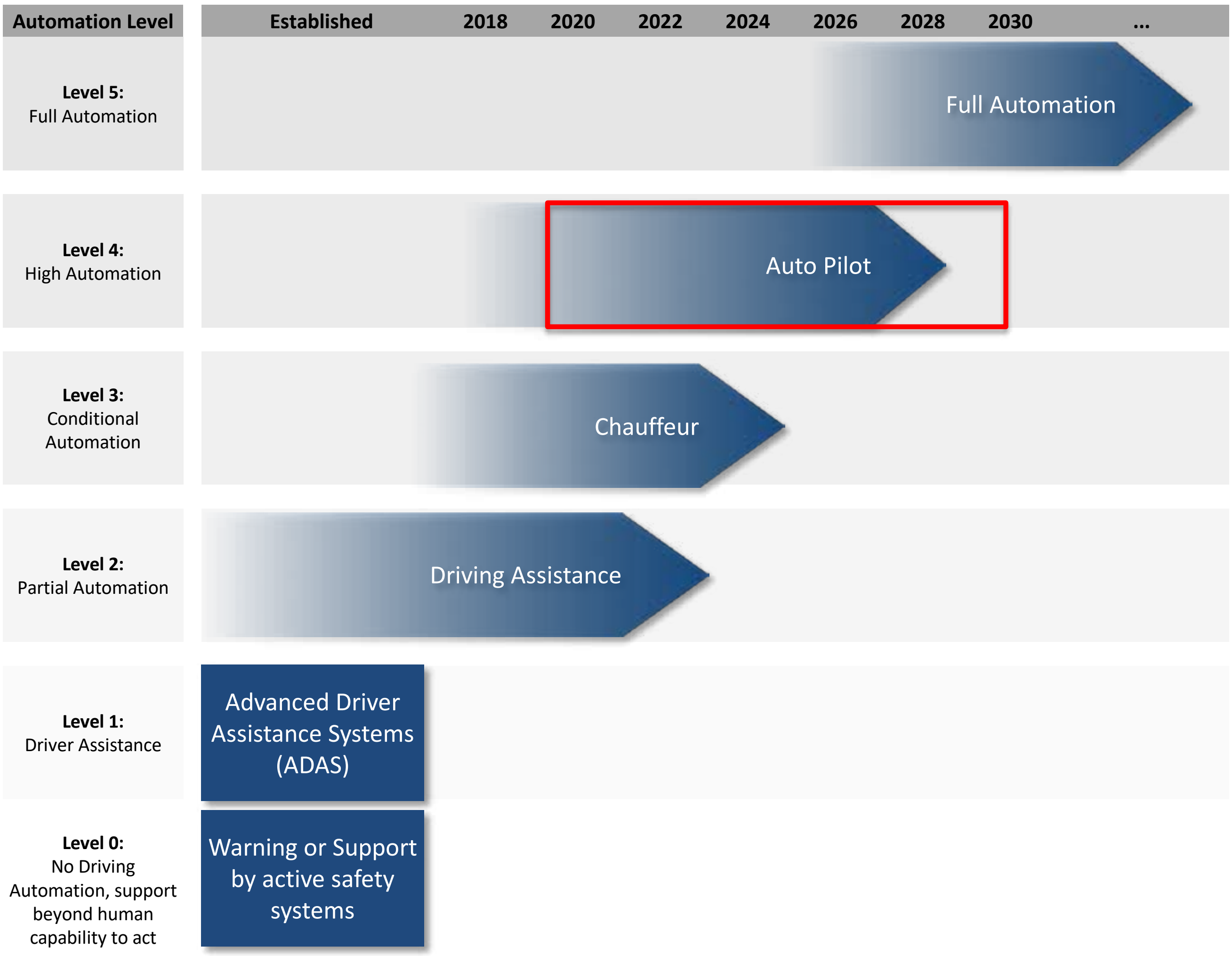

Figure 6: The vehicle automation development paths

[3] https://www.l3pilot.eu
[4] https://platooningensemble.eu
[5] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

Since road transport includes various types of vehicles, it is important to detail the development paths into specific roadmaps reflecting the different opportunities of each vehicle category. The following subchapters present three different roadmaps providing a specific outlook for: passenger cars, freight-vehicles, and urban mobility vehicles and buses.

3.1. Automated Passenger Cars Path

Passenger cars are the main driver of the development towards automated driving, as with their high volume in the market, they can afford to develop the necessary technologies. They evolve level by level with more sensors, connectivity and computing power on- and off-board and can be distinguished by parking and driving use cases. All level 0 to 2 systems definitions have now been placed in the Annex of this roadmap version, as well as the automated parking assistance systems.

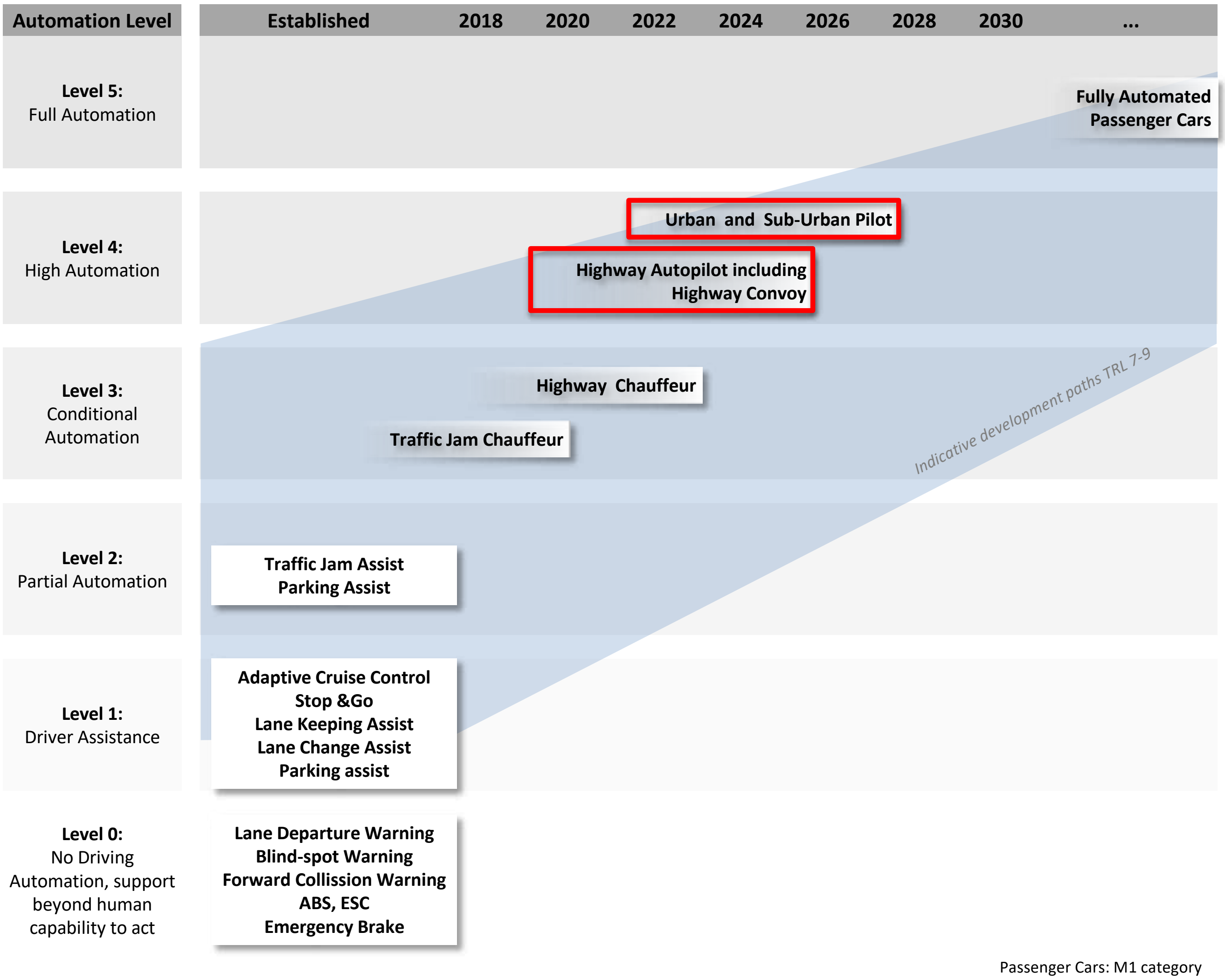

Figure 7: The Automated Driving development path for passenger cars

3.1.1. Traffic Jam Chauffeur (Level 3)

Conditional automated driving in traffic jam up to 60 km/h on motorways and motorway similar roads. The system can be activated in case of a traffic jam scenario. It detects slow driving vehicle in front and then handles the vehicle's both longitudinal and lateral. Later version of this functionality might include lane change functionality. The driver must deliberately activate the system, but does not have to monitor the system constantly. The driver can at all times override or switch off the system. In case of a takeover request to the driver from the system, the driver has sufficient time reserve to orientate himself and take over the driving task. In case the driver does not take over, the system will go to a reduced risk condition, i.e. bring the vehicle to a safe stop.

3.1.2. Highway Chauffeur (Level 3)

Conditional Automated Driving up to 130 km/h on motorways or motorway similar roads. From entrance to exit, on all lanes, including overtaking. The driver must deliberately activate the system, but does not have to monitor the system constantly. The driver can at all times override or switch off the system. In case of a takeover request to the driver from the system, the driver has sufficient time reserve to orientate himself and take over the driving task. In case the driver does not take over, the system will go to a reduced risk condition, i.e. bring the vehicle to a safe stop. If possible depending on the traffic situation and system capabilities, the reduced risk conditions will include the necessary lane changes to stop at the hard shoulder e.g. emergency lane or side of the road.

3.1.3. Urban and Suburban Pilot (Level 4)

Highly Automated Driving up to limitation speed, in urban and suburban areas. The system can be activated by the driver in all traffic conditions. The driver can override or switch off the system at all time.

3.1.4. Highway Autopilot (Level 4)

Highly Automated Driving up to 130 km/h on motorways or motorway similar roads from entrance to exit, on all lanes, including overtaking and lane change. The driver must deliberately activate the system, but does not have to monitor the system constantly. The driver can at all times override or switch off the system. There are no request from the system to the driver to take over when the system is in normal operation area (i.e. on the motorway), so sleeping is allowed. In case a situation occurs, when average human driver would try to end the journey or simply stop at the motorway (e.g. extreme weather) and the driver does not take over, the system has the capability to leave the motorway and park the vehicle safely.

3.1.5. Highway Convoy (Level 4)

Electronically linked vehicles of all types on motorways or similar roads in the same lane with minimum distance between each other. Depending on the deployment of cooperative systems, ad-hoc convoys could be created if V2V communication is available with a realtime performance that allow vehicles of different makes to reduce safety distances far below today´s manually driven distances. By this, especially in large urban areas, highway traffic could develop to be much more efficient (traffic space per person, energy consumption per vehicle).

3.1.6. Autonomous private vehicles on public roads (Level 5)

The fully automated vehicle to handle all driving from point A to B, without any input from the passenger. The driver can at all-time override or switch off the system. Note: only a rough time estimation can be given for this system at the moment. The technology approach as well as map availability to handle country road conditions (narrow lanes without road markings, diverse road users etc.) is not yet foreseeable.

3.2. Automated Freight Vehicles Path

This path focus on highly automated (Level4) commercial vehicles for operation in dedicated areas), Hub-to-hub, on Open Roads or in/through Urban areas. These vehicles could be either vehicles with driver-cabin for selective manually driven and automated operation or cab-less vehicles for unmanned operation with remote monitoring and control. In both cases, the integration with the freight logistics flow, road traffic network and operators is important to consider.

Refer to the **ERTRAC Roadmap for "Long Distance Freight Transport"** for details regarding the needs and implications of automation for the freight transport domain both from a logistics and road operator perspective.

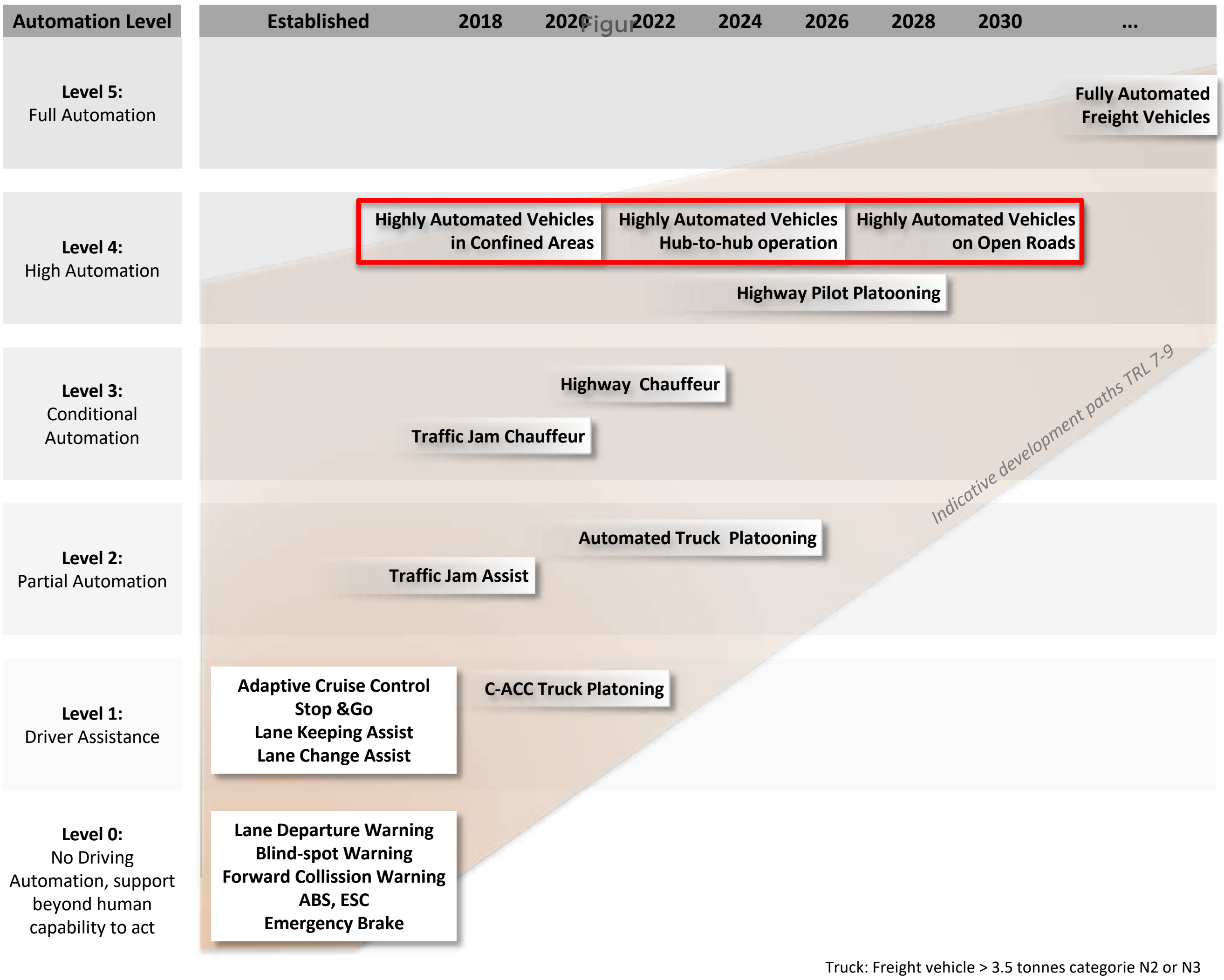

Figure 8: The Automated Driving development path for freight vehicles

3.2.1. Highly automated freight vehicles in Confined Areas (Level 4)

This use case covers highly automated freight transport vehicles in confined areas such as freight hubs, logistics consolidation terminals and ports. Confined area operation would make it possible to use un-manned and remotely supervised vehicles, also without driver cabin. A control tower will monitor and supervise control of the vehicles. In confined areas, specific regulations and standards may apply to enhance intermodal freight transhipment.

3.2.2. Highly automated freight vehicles in Hub-to-Hub operation (Level 4)

Highly automated freight transport vehicles in hub-to-hub operation will operate in designated corridors. Either highly automated trucks with driver cabin will be used or potentially also un-manned vehicles without driver cabin. Hub-to-hub operation could also include longer transport corridors that connects hubs using designated open roads. For highly automated freight, hub-to-hub transport flows operation specific rules and regulations may apply such as speed limits. This makes hub-to-hub operation a good case to perform tests and pilots in real operation. The road infrastructure, traffic management and logistics systems needs to be adapted. The vehicles needs to operate without driver intervention according to pre-defined ODDs.

3.2.3. Highly automated freight vehicles on Open Roads and Urban (Level 4)

Highly automated freight vehicles for automated operation on open roads and in urban environment is a next challenge. These vehicles need then to handle operation in mixed traffic in all typical scenarios (ODDs) without driver intervention. For highly automated freight on open roads, traffic rules and regulations would apply as for non-automated vehicles. Vulnerable road users need to be anticipated. Integration with fleet, transport and traffic management. For highly automated vehicles in platoons, driver supervision could be transferred to other vehicles in the platoon.

3.3. Urban Mobility Vehicles

This path covers high automation for the urban environment. In specific areas in Europe today high automation in transit areas exist with specific solutions requiring low vehicle speed and/or dedicated infrastructure. For this roadmap, two categories are used to indicate the development paths;

Personal Rapid Transit (PRT) including Urban Shuttles for smaller urban mobility vehicles primarily for transport of people, for last-mile use, but potentially also for longer distances, on confined, dedicated and open roads. Models of operation of collective and individual (”taxi”) character should be considered both.

City-buses and coaches with various types of automated functionality like; driver assistance, bus-stop automation, bus-platooning, traffic-jam assist on confined, dedicated and open roads.

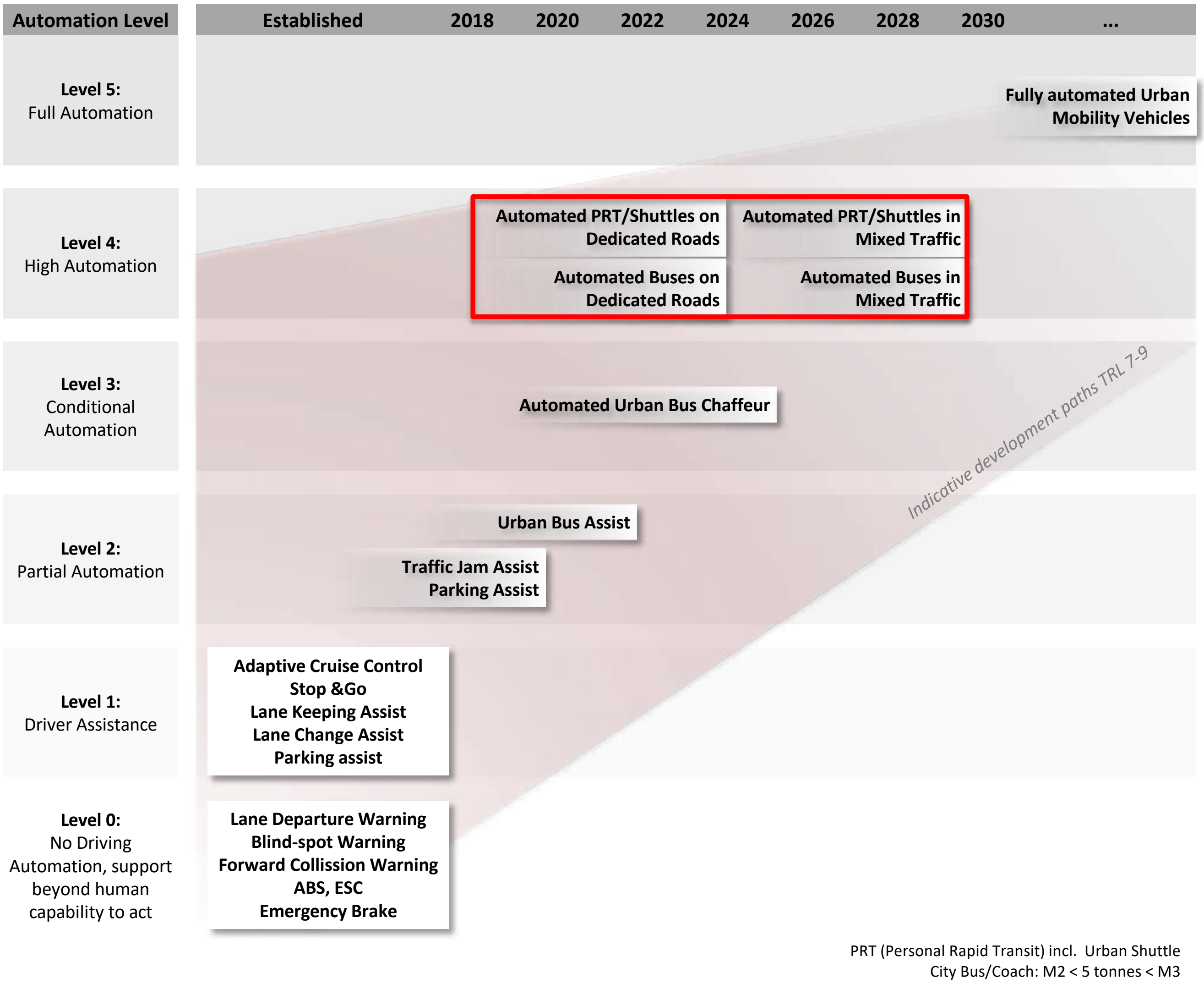

Figure 9: The Automated Driving development path for urban mobility vehicles

3.3.1. Automated PRT/Shuttles on dedicated roads (Level 4)

The automated PRT/Shuttle drives in designated lanes / dedicated infrastructure. This may be combined with automated functions for enhanced safety, traffic flow and network utilization. So, the services based on these kind of vehicles will be most probably integrated with traditional public transport services.

3.3.2. Automated PRT/Shuttles in mixed traffic (Level 4)

Automated PRTs or shuttles will be used both individually and collectively. SAE level 4 meaning that there will be no passenger intervention in driving task is prerequisite for economic efficiency. The automated PRT/Shuttle drives in mixed traffic in same speed as other traffic. These will be most probably integrated into a smart, seamlessly connected ecosystem by mobility services which will include booking, sharing, and networking platforms, parking and charging services, and software solutions for managing and maintaining the vehicles.

The emergence of the shuttle segment is a result of rising demand for ridesharing services, and could be available 24/7. Working behind the scenes, an algorithm identifies the vehicle closest to the requested location and finds other users who wish to travel a similar route. The more passengers a single shuttle can transport, the cheaper the journey for everyone. This approach has the potential to reduce the amount of traffic in cities and mitigates the impact on the environment.

A crucial prerequisite for the safety of automated shuttles is a map-based localization service, with which automated vehicles can accurately determine their position in the lane down to a few centimeters. Another prerequisite is security: data connectivity with the outside world and software updates efficient security solutions are key enablers.

Level 4 automated PRTs or shuttle fleet solutions will need specific backend structures like control centers and data cloud support. Control centers 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.

3.3.3. Highly Automated Buses on Dedicated Lane (Level 4)

The highly automated bus operates in dedicated bus lanes together with non-automated buses in normal city bus speed. Functions may include bus-trains, following and bus-stop automation for enhanced productivity, safety, traffic flow and network utilization. For dedicated lane operation, specific rules and regulations may apply including speed limits. The vehicles will operate without driver intervention according to pre-defined ODDs.

3.3.4. Highly Automated Buses in Mixed Traffic (Level 4)

The highly automated bus operates in mixed traffic on open roads together in normal mixed city traffic. Functions may include bus-trains, following and bus-stop automation for enhanced productivity, safety, traffic flow and network utilization. The vehicles will operate without driver intervention according to pre-defined ODDs.

4. EU AND INTERNATIONAL INITIATIVES

4.1. European research projects

The European Union has a strong history of funding collaborative research contributing to automated driving, 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 more than 10 years ago in the 6th Framework Programme and intensified in the 7th Framework Programme. It continued in the current Horizon 2020 Programme, with from 2016 the launch within the Transport Programme of a specific call on "Automated Road Transport"[6], which should provide about 300 Mn € of EU funding in the successive calls up to 2020. The first editions of this Roadmap provided recommendations on the topics to be addressed by this "ART" call for projects. Note that only the most prominent projects are included in the picture below: the reader should consult the online database for a complete and up-to-date list of all projects funded by the EU. The picture gathers the projects using acronyms in four research fields: Networking, Coordination & Support, Infrastructure, Connectivity and Cooperative Systems, Driver Assistance Systems and Partial Automation and Highly Automated Road Transport.

For a comprehensive list of projects see: https://connectedautomateddriving.eu/cad-knowledge-base/ and for EU projects see https://trimis.ec.europa.eu/projects

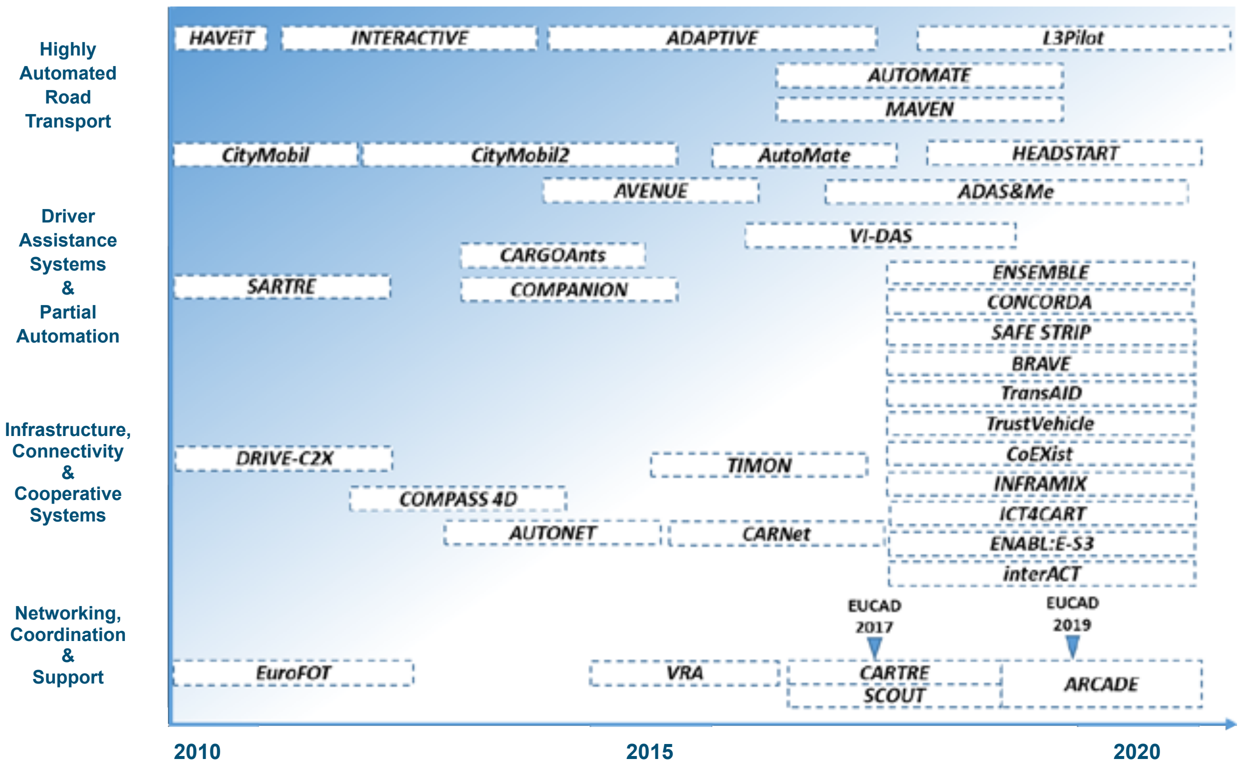

Figure 10: Overview of a subset of EU funded projects that support development of automated driving.

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

4.2. European initiatives

4.2.1. The European Union strategy on connected and automated mobility

The European Commission adopted in May 2018 the 3rd Mobility Package[7], including legislative and policy initiatives, among which a Communication entitled "On the road to automated mobility: an EU strategy for mobility of the future"[8]. The Strategy proposed a comprehensive series of measures to be implemented in the next years to: 1) develop the necessary technologies and infrastructure in Europe, 2) ensure that automated mobility is safe and 3) to cope with societal issues such as jobs, skills and ethics. As vehicle safety is key for consumer acceptance, the Commission proposed as part of the 3rd Mobility Package a legislative proposal to provide the legal framework for the approval of automated and connected vehicles (the so-called vehicle general safety regulation).

The legislative proposals include new vehicle type-approval rules that will require, for instance, that new models of cars are equipped with advanced safety features, such as advanced emergency braking and lane-keeping assist system. Separately, under the amended rules on infrastructure safety management, road signs and markings must be designed in a way that they are reliably recognisable by vehicles equipped with driver assistance systems or higher levels of automation. In order to become law, however, these legislative proposals will need to be approved by the European Council and the European Parliament, and may change during the legislative process.

The Commission strategy on automated mobility sets out further steps that need to be taken to prepare for the roll-out of these technologies, including by making further changes to the EU regulatory framework. New automated vehicles will need to comply with certain additional requirements relating to:

- systems replacing the driver's control of the vehicle;
- systems providing the vehicle with real-time information on the state of the vehicle and the surrounding area;
- driver readiness monitoring systems;
- accident data recorder for automated vehicles;
- harmonised format for the exchange of data for the purposes of multi-brand vehicle platooning;
- update of rules on road infrastructure safety management.

The European Commission is therefore working on various aspects of the legal framework:

- New vehicle type-approval rules
- Proposal for new safety measures for driver assistance systems and autonomous driving
- Proposal for new safety requirements for roads to support automated vehicles
- Proposal for mandatory black box in automated vehicles

[7] https://ec.europa.eu/transport/modes/road/news/2018-05-17-europe-on-the-move-3_en
[8] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0283&from=EN

- Upcoming guidelines on the product liability framework
- Develop a balanced and fair framework for the sharing of vehicle data
- Adopt rules to ensure secured communication, data protection and interoperability
- Set recommendations on the use of spectrum for 5G large scale testing

Regarding societal and ethical aspect, the European Commission will:

- Assessment of the medium and long term socio-economic and environmental impacts
- Support to the reskilling of the workforce
- EU forum on ethics to address issues related driverless mobility
- Set up ethical guidelines on the development of artificial intelligence

4.2.2. GEAR 2030

The European Commission has launched in 2016 a new High Level Group for the automotive industry called GEAR 2030: it gathers industrial representatives and European associations with EU institutions and national ministries. The objective is to address the challenges faced by the automotive industry and anticipate the future needed regulatory frameworks. A special attention is given to position the European industry as a technology leader and ensure its competitiveness on world markets. By principle of transparency, working documents of the group are accessible on the European Commission website[9].

A specific working group on "Highly automated and connected vehicles" has been set up, stressing the importance of the domain for the future of the European industry. The group is developing a roadmap with three pillars: Legal and policy issues; Coordination of financing support issues; and Competitiveness/International aspects. The overall objective is to identify the possible actions at European level to ease and fasten the implementation of automated driving systems.

The group has delivered first recommendations in February 2017, establishing that there is no major legal obstacle before 2020 for marketing vehicles with AD systems. However, GEAR 2030 considered that the fitting of event data recorders could help to assign liability, and vehicle legislation shall ensure that the vehicle will respect traffic rules and will prevent that the driver is confused or misuse the system. GEAR 2030 is now considering vehicles expected for the timeframe of 2030, which should include driverless vehicles (driver as a passenger). Large scale testing on open roads is considered a key tool to make progress on the technology, foster cooperation amongst the different actors and facilitate public acceptance. GEAR 2030 is looking at possible additional tools that could be used to support future large scale testing as well as the appropriate framework to ensure public confidence, in particular the certification approach, liability issues, automotive data issues and societal issues like the impact of automation on public transport, jobs or skills.

GEAR 2030 adopted its final recommendations on 18 October 2017. These recommendations have been taken over by the Commission as part of its strategy for connected and automated vehicles

[9] https://circabc.europa.eu/w/browse/5db96d01-27d7-4e0c-b0fa-5b8b90816446

4.2.3. STRIA Roadmap on Connected and Automated Transport (CAT)

The EC Communication on Automated Mobility[10] proposes to develop a strategic planning of R&I actions and to better coordinate national and multinational funding programmes. The need for a coordinated approach and priority setting for funding research, demonstration and pre-deployment activities was also stated by the EU Member States in the 'Declaration of Amsterdam'[11] and in the recommendations of the GEAR 2030 High Level Group[12].

With this regard, the European Commission is developing, in close cooperation with representatives of the EU Member States and stakeholders from industry, academia, and national authorities, a roadmap for short, medium and long-term research and innovation initiatives and actions in the area of Connected and Automated Transport (CAT). As the individual transport modes have specific R&I needs, their respective roadmaps and actions have been developed separately for the road, rail and waterborne sectors. They will be combined into a common final document where cross-cutting topics are identified, and recommendations are given on how to make use of technology transfer opportunities, and to exploit synergies.

The mode-specific roadmaps are structured along technical and non-technical thematic areas, and they identify a number of effective initiatives that work hand in hand to advance innovation. Each of these initiatives is supported by a sequence of actions that mainly relate to necessary research and innovation activities but also other measures to accelerate deployment. These actions are put on a timeline indicating whether they are needed in the short, medium or long term, meaning until 2023, until 2030, or beyond 2030.

The STRIA roadmap on CAT proposes ways of sharing responsibilities between European Union, the Member States and the industry and recommendations are derived accordingly. At the same time, potential synergies, overlaps and possible fields for cooperation between and common actions of Member States and the European Commission are highlighted. The roadmap also defines measures for a better coordination of national and multinational funding programmes in connected and automated road transport.

For the road part, the following thematic areas and associated initiatives have been identified:

- In-vehicle enablers
- Vehicle Validation
- Large scale demonstration pilots to enable deployment
- Shared, connected and automated mobility services for people and goods.
- Socio-economic impacts/ User/public acceptance
- Human factors
- Physical and digital infrastructure & Secure connectivity
- Big data, Artificial Intelligence and their applications

The STRIA roadmap on CAT is expected to be published in spring 2019.

[10] Communication "On the road to automated mobility: An EU strategy for mobility of the future" (COM(2018) 283 final), published on 17 May 2018

[11] Declaration of Amsterdam "Cooperation in the field of connected and automated driving", signed on 14 April 2016 by transport ministers of all 28 EU member states.

[12] High Level Group on the Competitiveness and Sustainable Growth of the Automotive Industry in the European Union, Final Report – 2017. European Commission, 2017.

4.2.4. ARCADE, CARTRE and SCOUT Coordination and Support Actions

ARCADE is a Coordination and Support Action (CSA) funded by the Horizon 2020 Programme. Started in October 2018 for a duration of three years, it follows up on the CARTRE Support Action which has been running for two years before. Similarly, to CARTRE, the goal of ARCADE is to coordinate consensus-building across stakeholders for sound and harmonised deployment of CAD in Europe. It supports the development of clearer and more consistent policies for EU Member States, in collaboration with industry players, research and the public sector, to ensure that automated road transport systems and services are compatible at EU level and are deployed in a coherent way. Its objectives include the creation of a knowledgebase of all European and international activities; to setup a platform for sharing and re-using data and experiences from different automated road transport systems; to actively support Field Operational Tests (FOTs) and pilots carried out at National and European levels; and to work on future visions, potential impacts and research gaps in the deployment of automated road transport with a focus on 12 Thematic areas covering challenges related to CAD. ARCADE will look more into important aspects related to regulations, standardisation and freight. A main objective will remain the contribution to the definition of future research and innovation priorities in Europe. ARCADE also includes support to international cooperation at global level, in particular with the US and Japan within the Trilateral ART Working Group.

SCOUT ("Safe and Connected Automation in Road Transport") was a Coordinated and Support Action funded by the European Commission under Horizon 2020 from 2016 to 2018.[13] The main outcome of the project is a comprehensive cross-sectorial roadmap describing the pathways for an accelerated proliferation of safe and secure high-level CAD by 2030 in Europe.[14] The roadmap, which has been developed in a co-creative manner with the involvement of a diverse group of stakeholders, is taking into account technical, economic, legal, societal and human factors. It highlights opportunities to leapfrog hurdles for innovation in SAE level 4/5 automated driving by a coordinated interplay of actions that are described for five specific use cases: automated on-demand shuttle, truck platooning, valet parking, delivery robot, and traffic-jam chauffeur. Eventually, advice for policies and regulatory frameworks is given. The topic is now being further elaborated in the framework of the follow-up project COSMOS ("Coherent Support for MObility.E Strategy") which is being funded in the framework of the ECSEL Joint Undertaking to support its Mobility.E lighthouse with an implementation plan that bridges white spots and funding gaps, particularly in the enabling technologies for CAD.

The CARTRE and SCOUT projects have supported the European Commission in the organisation of the first European Conference on Connected and Automated Driving, which took place in Brussels on 3 and 4 April 2017. ARCADE is currently supporting the organisation of the second European CAD Conference EUCAD2019 which will take place on 2 and 3 April 2019.

A single website has been developed to gather and share information. It hosts the CARTRE and ARCADE knowledgebase:
http://connectedautomateddriving.eu

CARTRE, SCOUT and ARCADE have strongly contributed to the preparation of this Roadmap.

[13] https://cordis.europa.eu/project/rcn/204978/brief/en?WT.mc_id=exp
[14] J. Dubbert et al., Roadmap for Accelerated Innovation in Level 4/5 Connected and Automated Driving. In: J. Dubbert, B. Müller, G. Meyer (Eds.), Advanced Microsystems for Automotive Applications 2018: Smart Systems for Clean, Safe and Shared Road Vehicles. Springer 2018

4.2.5. European Automotive-Telecom Alliance

In September 2016, at a Roundtable on Connected and Automated Driving initiated and chaired by Günther Oettinger, at that time European Commissioner for Digital Economy and Society, the automotive and telecom industries announced the creation of Europe's first Automotive-Telecom Alliance[15]. EATA comprises six sectorial associations: ACEA, CLEPA, ETNO, ECTA, GSMA and GSA as well as 32 leading European companies, including telecom operators, vendors, automobile manufacturers and automotive suppliers, all giving their commitment to support and contribute[16]. The main goal of the Alliance is to facilitate and accelerate the EU-wide deployment of connected and automated driving, with the following objectives:

- Facilitate and accelerate the EU-wide deployment of connected and automated driving
- Remove potential roadblocks and highlight needed technical and regulatory measures
- Identify the business models underlying connected and automated driving
- Provide a platform for knowledge-sharing between the automotive and telecommunications sectors to develop a 'common language'
- Create societal benefits by improving road safety and traffic efficiency
- Promote the European digital economy

At the Digital Day in Rome on 23 March 2017, 29 European countries, Members of the European Union and of the European Economic Area, have signed a Letter of Intent to intensify cooperation on testing of automated road transport in cross border test sites. In this Letter of Intent, they express their regard and acknowledge to support reaching the goals formulated by EATA[17].

Members of EATA and beyond have developed CONCORDA (Connected Corridor for Driving Automation). The project, co-funded by the Connecting Europe Facility, will prepare European motorways for automated driving and high-density truck platooning with adequate connected services and technologies. While EATA transferred management to an external party, the alliance was key in coordinating the sectors. The two CONCORDA use-cases, truck platooning and highway chauffeur, require ultra-reliable, low latency communication between vehicles. Experts meet regularly to evaluate the trials, focusing on interoperability and interconnectedness between different systems. Shaping and agreeing on a common view of available solution concepts is a first step for reaching the goal of defining a holistic end-to-end solution for European C-ITS.

A core aim of CONCORDA is also to enhance interoperability of technologies, services and implementation in the EU (test sites are located in the Netherlands, Belgium, France, Germany, and Spain). By early 2020, the partners in CONCORDA will present the outcomes, including recommendations on regulations, policies and standardisation.[18]

4.2.6. Cooperative Intelligent Transport Systems & C-Roads

Cooperative Intelligent Transport Systems (C-ITS) connect vehicles with each other and with the road infrastructure, allowing road users and traffic managers to share information and use it to coordinate actions. This cooperative element is expected to bring significant benefits for road safety, traffic efficiency and driving comfort, as stated by the European Commission: "significantly improving road safety, traffic efficiency and comfort of driving by helping the driver to take the right decisions and adapt to the traffic situation". It is considered important to increase the safety

[15] http://www.acea.be/press-releases/article/37-leading-companies-join-forces-in-european-automotive-telecom-alliance
[16] http://clepa.eu/wp-content/uploads/2017/02/20170227-Connected-and-automated-driving.pdf
[17] https://ec.europa.eu/digital-single-market/en/news/eu-and-eea-member-states-sign-cross-border-experiments-cooperative-connected-and-automated
[18] http://erticonetwork.com/new-project-driving-automation-kick-off-brussels/

of future automated vehicles and their integration in the overall transport system, in particular as these will be expected to negotiate increasingly complex traffic situations. The vision is that cooperative ITS, connectivity and automation are complementary technologies and shall reinforce each other and converge over time.

The C-Roads Platform[19] is a joint initiative of European Member States and road operators which are in the phase of installing C-ITS for the testing and operation of "C-ITS Day-1 services". In accordance with the C-ITS Platform recommendations, harmonised specifications are being developed and the first harmonised communication profile for C-ITS services is already finalised. All developed specifications will be publicly available and form the basis for pilot installations on the road network. In accordance to the European strategy on Cooperative Intelligent Transport Systems (COM(2016) 766) the C-Roads Platform supports the use of hybrid communication technologies. The starting point for pilot deployments will be the combination of ETSI ITS-G5 and existing cellular networks.

This first generation of services for Cooperative Intelligent Transport Systems (C-ITS) is ready for deployment. They are based on a set of standardized messages developed by ETSI[20] or CEN/ISO[21] which have been used to implement a first set of use cases to increase traffic safety in general, like e.g. road works warning, hazardous location notification, in-vehicle signage or intersection safety. Implementations and tests of such "Day 1" C-ITS services have taken place in several countries and/or C-ITS initiatives throughout Europe. To guarantee service interoperability, these services and messages have been harmonized in the C-ROADS initiative, providing common use descriptions and message profiles for infrastructure-based C-ITS messages. This C-ROADS "Infrastructure Profile" complements the CAR 2 CAR Communication Consortium's "Basic System Profile", which defines message profiles for vehicle-based C-ITS messages. Both these efforts are major contributions for the preparation of a Delegated Act on C-ITS, which, after publication (currently planned for early 2019) will be the guideline for harmonized "Day 1" C-ITS deployments in Europe.

4.2.7. Related Public-Private Partnerships

A number of Public-Private Partnerships (PPPs) set up at the European level address important innovation areas that are enablers for road vehicles automation. These PPPs provide funding for research and development through the Horizon 2020 programme and the involvement of the industry. The three PPPs mentioned below have interesting links with connected and automated driving: even though they do not address as such the development of vehicle systems, they work via a multi-sectoral approach on enabling technologies that are necessary for the enhanced connectivity and increasing automation of vehicles. **Their objective of technology leadership for the European industry is also of high interest in order to provide a high-quality European sourcing of components and systems to the automotive industry, contributing to the independence and competitiveness of Europe.**

ERTRAC calls for cooperation between these European activities, through exchange of information, common members, and invitations to workshops. ERTRAC is also involved in the preparation of the next EU Framework Programme called "Horizon Europe", which will fund research from 2021. A reorganisation of this landscape of Partnerships is expected, with some being continued, some merged, and some newly created. ERTRAC follows closely the potential creation of Partnerships in the field of connectivity and automated mobility and promotes a strong EU funding for

[19] https://www.c-roads.eu/platform.html
[20] ETSI (2013). Cooperative ITS (C-ITS); Release 1. TR 101 607 V1.1.1 Available online: http://www.etsi.org/deliver/etsi_tr/101600_101699/101607/01.01.01_60/tr_101607v010101p.pdf
[21] CEN/TC278 ITS Standardization, Available online: https://www.itsstandards.eu/cits

collaborative research in this field. But more cannot be written at the time of this roadmap publication, as the preparation of "Horizon Europe" will be ongoing during 2019.

ECSEL

ECSEL is a Joint Undertaking formed by the European Union (through the European Commission), EU Member States and three associations: EPoSS, AENEAS and ARTEMIS-IA, representing the actors from smart integrated systems, micro- and nano-electronics, and embedded/cyber-physical systems. Electronic components and systems are Enabling Technology at the core of many industrial branches, including transport and automotive: they play a key role in digitalisation and connectivity, and are necessary components for automated driving systems. The objective of ECSEL is to ensure the availability of innovative electronic components and systems for key markets and for addressing societal challenges. The mission of the PPP is to bridge the gap between research and exploitation, align national strategies, and promote an increase in European and national investments. Within its multi-annual strategic plan, "Smart Mobility" is one of the key applications, and automation of vehicles has been set as an objective. Information on the PPP and its projects are available on the ECSEL website[22], including its latest Strategic Research Agenda (SRA) on Electronic Components and Systems published in 2019[23]. Here are some examples of research activities planned in ECSEL that can support the development of automated driving:

- Functional safety development for test procedure, and test systems including sensor fusion
- Improvement of sensor accuracy, as well as miniaturization
- Improvements of the architecture for vehicle electronic systems (Hardware and Software)
- Communication and interfaces between vehicles as well as vehicle-to-infrastructure including the security aspects.
- Communication in the vehicles, as well as deep learning (HMI)

5G

5G is family of mobile communication standards building upon the great success of 4G/LTE. The 5G New Radio promises advanced native features such as mobile broadband, reliable low latency and massive IoT. The 5G- PPP[24] is an initiative between the ICT industry and the European Commission to prepare the next generation of communication networks and services, with the objective of "ubiquitous super-fast connectivity and seamless service delivery in all circumstances". The Commission's 5G Action Plan[25] published in 2016 laid down the deployment timeline: 2020 for early roll-out in at least on major city in each member state, and, 2025 for uninterrupted coverage over all urband areas and major transport paths. Transport and vehicles are mentioned as a major field of opportunity to develop new services based on those new capacities. So-called "mission critical services" will become feasible thanks to the higher performances achievable by 5G: advanced services based on cloud, edge computing, vehicle-to-vehicle and vehicle-to-infrastructure connectivity are targeted, with a specific reference to automation. In February 2018, the 5G PPP issued "A study on 5G V2X Deployment"[26]. This white paper is the outcome of the 5G-PPP Automotive working group and provides insights into the deployment costs for 5G V2X and revenue analysis for financially and socially beneficial commercialization. Work is ongoing to integrate the specific technical requirements from the automotive industry towards

[22] https://www.ecsel.eu
[23] https://www.ecsel.eu/sites/default/files/2019-02/ECS-SRA%202019%20FINAL.pdf
[24] https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf
[25] https://ec.europa.eu/digital-single-market/en/5g-europe-action-plan
[26] https://5g-ppp.eu/wp-content/uploads/2018/02/5G-PPP-Automotive-WG-White-Paper_Feb.2018.pdf

future networks to be used for vehicles automation (in particular in the 5GCAR project). Together with the 5G Automotive Association (5GAA), standardisation, spectrum and regulatory work for 5G are ongoing, and business models are proposed. Through the PPP, the EU recently launched three Connected and Automated Driving cross-border innovation actions (5GCroCo, 5G-Mobix, 5G-Carmen). These activities are in line with international plans to exploit the potential of 5G for connected and automated driving. However, Europe tends to be slower to pick up the new opportunities offered by such breakthroughs. NGMN has recently published a full white paper on the potential of V2X[27] around the world.

Cyber-Security

As part of the EU cybersecurity strategy and the strategy on Digital Single Market (DSM), the European Commission and the European Cyber Security Organisation (ECSO) signed a PPP in July 2016: the aim of the partnership is to foster cooperation at early stages of the research and innovation process, and to build cybersecurity solutions for various sectors, explicitly including transport, while developing the European cyber security market and establish a competitive European industry in this field. The PPP should help to develop and implement European cyber security solutions in sectors where Europe is leading, to make the critical steps of trusted and valuable supply chains.

The EU announced to invest €450 million in this partnership, under Horizon 2020. Cyber security market players are expected to invest three times more.

The ongoing activities within the framework of this PPP, in particular those towards security regulation, will affect connected and automated driving: road vehicles, especially when enhanced with connectivity-based driver assistance and autonomous driving features, are clearly considered part of the Internet of Things and therefore in scope. The industrial input into this discussion aims to bridge the gap between capacity building and the deployment of trusted European cybersecurity and ICT solutions on European and international markets. With ECSO, the PPP drafts a cyber security radar showing over 600 solutions.

In essence, the following core activities are proposed for the automotive domain:

- To support the use of innovative trusted solutions and services for major societal and economic challenges in Europe, of which transport is one.
- Help to overcome the current fragmentation in the EU cyber security landscape and ensure any EU wide cyber security regulation shall be restricted to cases of clear market failure and address processes and people before technology.
- Establishment of thorough cybersecurity risk management across the value chain and over the whole product lifecycle, taking into account the particularities of the automotive domain with specific focus on automation use cases.
- Standardization of this approach in the upcoming standard ISO AWI 21434 “Road vehicles - Cybersecurity Engineering”. Similar to the automotive functional safety standard ISO 26262, this initiative is industry-driven and does not require regulatory intervention.

First calls drafted with the PPP’s inputs have been launched within the Horizon 2020 Work Programme Secure Societies.

[27] https://www.ngmn.org/fileadmin/ngmn/content/downloads/Technical/2018/V2X_white_paper_v1_0.pdf

4.3. EU Member States initiatives

4.3.1. 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" 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 declaration of Amsterdam can be found at:
https://www.rijksoverheid.nl/documenten/rapporten/2016/04/29/declaration-of-amsterdam-cooperation-in-the-field-of-connected-and-automated-driving

The first High Level Meeting, organized by the Netherlands, was held in Amsterdam on 15 February 2017: https://www.government.nl/documents/leaflets/2017/05/18/on-our-way-towards-connected-and-automated-driving-in-europe

The second High Level Meeting, organized by Germany, was held in Frankfurt on 15 September 2017: https://www.bmvi.de/SharedDocs/EN/Documents/DG/action-plan-automated-and-connected-driving.pdf?__blob=publicationFile

The third High Level Meeting, organized by Sweden, was held in Gothenburg on 18/19 June 2018: https://www.government.se/articles/2018/06/third-high-level-meeting-on-connected-and-automated-vehicles-led-to-common-conclusions/

The fourth High Level Meeting, organized by Austria, was held in Vienna on 28/29 November 2018: http://www.smart-mobility.at/hlm2018/

4.3.2. The Netherlands

The Dutch government has created new innovative and adaptive legislation to make large scale testing possible for self-driving vehicles on Dutch public roads, thus allowing Field Operational Tests (FOTs) with automated driving on all public roads in The Netherlands. A test procedure to grant an exemption by RDW, RWS and other relevant road operators is in place. As a next step in legislation, The Netherlands has parliamentary approval for the 'experiment law' that will enable 'driverless vehicle' experiments with automated driving systems in traffic without having to have an actual driver inside the vehicle. Supervision by a human then takes place somewhere outside the vehicle. The Netherlands is one of the frontrunners and wants to team up with other nations, partners and manufacturers who have similar high ambitions for the benefit of traffic safety. The development towards responsible introduction and a high level of safety requirements are key elements in the Dutch approach, which resulted in projects like WePod, Appelscha Pod, EU Truck Platooning Challenge, Daimler Future Bus City Pilot.

Current planned pilots are numerous. “Real-life cases Truck Platooning” and many “Last mile solutions” are in progress. Six locations have been identified as potential field lab for Automated Last Mile transportation: for each of these locations, existing public transport cannot answer the demand in a cost effective way, but it is expected Automated Vehicles will be able to solve this. Next to these six field labs, one research lab is established on the campus of the TU Delft which will trial (amongst others) the WEpod and create a better learning cycle to transfer relevant knowledge on procurement, business cases and technological advances, from one trial to the other. The European real-life truck platooning cases are a follow up of the 2016 EU Truck Platooning Challenge. The goal is to bring truck platooning to the next phase of the innovation cycle by implementing platooning into real-life logistics operation for different use cases running at different participating companies.

4.3.3. France

In May 2018, Ms. Idrac, former Minister, Head of the National Strategy for the Development of Autonomous Vehicles, published[28] the strategic framework that will structure the French government’s policy actions dedicated to the development of automated or driverless vehicles, covering the following areas: modes of use and local expectations, safety, acceptance, competitiveness and employment, and European and international cooperation.

In order to develop a solid framework (legislative and regulatory, safety validation, infrastructure, connectivity,…) and provide a transportation ecosystem for autonomous vehicles deployment by 2020-2022, France has committed to a system of controlled and responsible development, based on the following principles: progressiveness of the approach (“learning by doing”); priority given to safety; vigilance regarding impact on mobility, the environment and public acceptance; importance of experimentation in order to evaluate impact and risks, moving quickly towards large-scale projects; consideration of all types of vehicle use; close cooperation between public authorities and industrial groups supported by thorough analysis of impacts and risks, while also integrating employment issues; and importance of European cooperation, particularly with regard to vehicle approval and interoperability of systems, as well as for financing of research and innovation.

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.

First results of the National Strategy have already been achieved: a legal framework for experimentation with automated driving is in place, resulting in already 10.000 km of roads available, and more than 60 test trials. This framework is being adapted (draft law in Parliament) to higher levels of automation, with the possibility that the driver would not be in control of the vehicle during maneuvers, and the corresponding liability provisions. The current focus is on large scale experimentation on open roads for safety demonstration and acceptance, for which a dedicated innovation program has been set up under the "Programme des Investissements d'Avenir". Corresponding experiments shall start from 2019 onwards. A draft law (Loi d'orientation des Mobilités) has been proposed to Parliament to enact the future regulatory framework for

[28] https://www.ecologique-solidaire.gouv.fr/sites/default/files/18029_Développement-VA_8p_EN_Pour%20BAT-3.pdf

autonomous vehicles deployment in a permanent regime. France has proposed a revised version of the Vienna Convention and a new approach to safety validation at the UN-ECE level. Several working groups between regulatory authorities and the industry have been set up to assess challenges and propose adaptations on the topics of technical regulation, homologation, liability, driving rules, interaction with police forces, and acceptance. A focus will in 2019 be given to regulatory framework for automated public transport in dedicated areas or paths, and to setting a relevant framework for managing driving scenarios for validation purposes.

4.3.4. Germany

In 2013, the Federal Ministry of Transport and Digital Infrastructure established the “Automated Driving” Round Table, an advisory body that enables a close exchange of ideas and experience among stakeholders from industry, academia, associations and public administration. The Round Table pools the required know-how in such a way that a broad societal consensus can be achieved on all relevant aspects of automated and connected driving. It meets twice a year and has, among other things, determined which research areas are to be taken into account when developing automated driving.

In September 2015, based on recommendations made by the Round Table, the Federal Government published its **Strategy for Automated and Connected Driving - Remain a lead provider, become a lead market, introduce regular operations**[29]. This document lays out objectives adopted by the government for exploiting the opportunities for growth and prosperity inherent in automated and connected driving.

The implementation of this strategy has since triggered measures in the following six fields of action:

- Infrastructure
- Legislation
- Innovation
- Connectivity
- Cybersecurity and Data Protection
- Societal Dialogue

Highlights include a 2017 amendment to the Road Traffic Act (StVG) which defines the rights and responsibilities of drivers during an automated driving phase and the development of ethical guidelines for the programming of automated driving systems.

The project PEGASUS https://www.pegasusprojekt.de/en/ is to be emphasized as it is aiming to deliver standards for release of highly-automated driving functions. Funded by the Federal Ministry of Economics and Technology (BMWi), Pegasus is intended to close major gaps in testing and verification of these functions by mid-2019.

A broad spectrum of R&I activities ranging from fundamental research on relevant enabling technologies to the development, testing and validation of vehicle and systems technologies receive funding in a coordinated way between the federal ministries of Technology, Transport and Research, (BMWi, BMVI, BMBF). New funding initiatives in the field of artificial intelligence are currently under development.

[29] See: https://www.bmvi.de/SharedDocs/EN/publications/strategy-for-automated-and-connected-driving.html?nn=355056

A growing number of test beds for technologies, systems and vehicles have been established throughout Germany. Currently 15 in number, these facilities allow the testing and validation of automated driving functions and intelligent infrastructures on a variety of different road categories in real traffic situations and under real-life conditions. Together with France and Luxembourg, Germany has also established a cross-border test bed allowing the testing and validation of CAD technologies beyond national borders.

4.3.5. United Kingdom

In 2015 the UK Government founded the Centre for Connected and Autonomous Vehicles (CCAV[30]) to secure the UK's position at the forefront of this change, focussing on the safe development, production, deployment and use of CAVs and their related technologies.

Regulation – The UK's flexible regulatory environment supports innovation and safety. The recently updated Code of Practice[31] for public trials of automated vehicle technology sets out that trials of any level of CAV technology are possible provided they comply with the law. This includes 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. It also presents plans to develop a process to support advanced trials, which will see truly self-driving trials on UK roads.

To help keep pace with technological developments, the Highway Code and regulatory framework were changed to enable the use of remote-control parking and provide clarity to UK motorists on the use of Driver Assistance Systems.

The UK also passed the Automated and Electric Vehicle Act 2018[32], which extends compulsory motor vehicle insurance to cover the driver when they are driving and when they have handed control to their self-driving vehicle. If the self-driving vehicle caused a collision, any victim would get quick and easy access to compensation. Building on this, CCAV has asked the Law Commission of England and Wales and the Scottish Law Commission to jointly undertake a three-year review of the UK's legal framework in the context of automated vehicles[33]. This review will report in 2021 and develop proposals to support the safe deployment of AV technologies and their use in new mobility services.

The UK worked with other countries at the UNECE on the recently adopted Resolution on the Deployment of Highly and Fully Automated Vehicles in Road Traffic[34]. This innovative resolution adapts the guiding principles of the 1949 and 1968 Conventions on Road Traffic to today's environment, paving the way for the safe mobility of the future, for the benefit of all road users.

Research and Development – The 2014 Four Cities Trials showcased Autonomous Vehicles and their integration into real-world environments. CCAV has followed that with funding for innovative research and leading-edge trials working with more than 200 companies including Original Equipment Manufacturers and Small and Medium Enterprises, Academics and Charities and local authorities and regional transport authorities[35].

[30] https://www.gov.uk/government/organisations/centre-for-connected-and-autonomous-vehicles
[31] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/776511/code-of-practice-automated-vehicle-trialling.pdf
[32] https://services.parliament.uk/bills/2017-19/automatedandelectricvehicles.html
[33] https://www.lawcom.gov.uk/project/automated-vehicles/
[34] https://www.unece.org/info/media/presscurrent-press-h/transport/2018/unece-adopts-resolution-on-the-deployment-of-highly-and-fully-automated-vehicles-in-road-traffic/doc.html
[35] https://www.gov.uk/government/publications/connected-and-autonomous-vehicle-research-and-development-projects

In November 2018, CCAV announced three large scale public trials, CAVForth, Apollo and ServCity which will see commercial services operating in Edinburgh and London by 2021.

Testbed (UK) – The £100 million government commitment is being matched by industry, creating a work leading ecosystem for the testing and development of CAV technologies and services under the banner of Testbed (UK).

The first four infrastructure projects were launched in 2017, developing two controlled testbeds and two public, open road, testbeds in the West Midlands and London to expand and compliment the substantial existing vehicle testing capability in the UK. The UK Government also founded Meridian Mobility[36] to facilitate partnerships, collaboration across sectors and to help secure global recognition of the UK's leadership in testing and development in this new arena.

This year will see an increase in testing facilities, including a controlled parking test facility and a new highway testing facility for highspeed junctions. An industry led data marketplace will help develop access to, understanding and exploitation of data generated by CAVs and related infrastructure.

Cyber Security – The UK published guidance for industry, the Principles of Cyber Security for Connected and Autonomous Vehicle, in 2017. Aimed at all parties involved in the manufacturing supply chain, the Principles provide a holistic approach to considering the security of vehicles and their wider ecosystem, throughout the whole vehicle life cycle.

In December 2018 the British Standards Institution (BSI) published a new standard on vehicle cyber security, which builds on the Principles of Cyber Security for Connected and Autonomous Vehicles.

Securing Public Desirability – The UK is undertaking social and behavioural research to understand public attitudes towards CAVs. The work, based on public dialogue and tracker surveys, is providing a useful insight for policy makers around current public understanding, aspirations and concerns relating to CAV. Research projects CAVForth, Apollo and ServCity will see a significant element of public exposure to these innovative new technologies, and additional social and behavioural research.

4.3.6. Sweden

Research and innovation for connected and automated vehicles is mainly covered through to programs, integrated into the Swedish innovation system. There are in addition a number of projects, field-tests and pilots ongoing supported by different established programs and platforms, of which only a selection is mentioned here.

The FFI partnership program is the main program for automotive research in Sweden funded by the innovation agency Vinnova, the Swedish Energy Agency, the Transport Administration and the main automotive stakeholders in Sweden. The FFI program covers several important areas for connected automated driving, 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.

[36] https://meridianmobility.tech

DriveSweden is a government-sponsored collaboration platform running from 2016 until 2027 with over 100 partners, aiming to design and pilot new mobility services based on connected, automated and shared vehicles.

AstaZero, is a full-scale test track environment for future road safety, active safety systems and connected, cooperative and automated vehicles.

The Swedish government has issued regulation to enable testing of automated vehicles (2017:309) and the public investigation (SOU 2018:16) provides guidance for introducing automated vehicles.

4.3.7. Spain

The Spanish R&D Strategy for the period 2013-2020 (2013) is totally aligned with the Horizon 2020 priorities where automated road transport is fostered including safety and vehicle networks within its objectives. The Spanish Ministry of Public Works and Transport has launched a Transport & Infrastructure Innovation Plan (2017) that develops the innovation strategy covering CADs. The Spanish Agenda for the Automotive Industry (2018) contains 20 priorities for 2020 and it will be the framework for the development of the R&D priorities for the automotive sector (2018).

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:

- SISCOGA^{4CAD} is a permanent European CAD corridor to test future CAD solutions. SISCOGA^{4CAD}, comprehends more than 150 km equipped with different connectivity technologies including ITS-G5 and cellular (3G/4G, MEC, PC5 and 5G).
- 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.
- 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).
- 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.

Spanish research organisations and industry are highly engaged (even coordinating) several on-going R&D projects at European level aiming for the development and testing of CAD vehicles in closed and open environments. These projects focus on different challenges of CAD: connectivity enabled automation (CONCORDA, 5GCAR, 5G-MOBIX, AUTOPILOT, C-MobILe), truck platooning validation and piloting (ENSEMBLE), testing, validation and certification (HEADSTART), safety and development (PRYSTINE), CAD enabling infrastructure (INFRAMIX), scenarios (CloudLSVA), safety features and driver monitoring (VI-DAS, PROSPECT, ADAS&ME), cybersecurity (SECREDAS).

4.3.8. Austria

As of 2016 Austria has built a comprehensive institutional framework for automated and connected mobility, addressing not just technological developments, but also legal issues and societal challenges. The first National Action Plan on automated driving "Automated – Connected – Mobile" was conceived for the period 2016-2018 with a total budget of 23 million Euro covering initial activities such as the adaption of the regulatory framework for enabling and regulating testing on public roads (including the amendment of the Motor Vehicle Act, establishment of the Automated Driving Regulation, Code of practice), the set-up of the National Contact Point Automated Mobility, the development of a technology funding portfolio and first studies addressing impact assessment and monitoring. Beyond that, also the establishment and expansion of technological and institutional competence has been achieved within the framework of both actin plans, i.e. programmes. The subject of automated mobility is always considered under the Austrian premise of a full systems approach, not just addressing technology but also institutional and societal issues. Starting with 2017, three testing environments (e.g. ALP.Lab) covering road and rail as well as three pilot projects (e.g. Digibus® Austria) were implemented. From the beginning of the process, various stakeholders ranging from the field of research to operations have been strongly represented and are actively involved in European initiatives and projects targeting automated and connected mobility.

In autumn 2018 the Action Programme on Automated Mobility[37] covering the period 2019 until 2022 was released. Additional 65 million Euro of public funding have been dedicated to follow-up actions on automated and connected mobility. It was developed by considering the perspectives of more than 300 stakeholders on national and international level and addressing all means of transport. The primary use cases ("New flexibility", "Security+ though an all-round view", and "Well supplied") from the first action plan in 2016 are still decisive for the alignment of testing and deployment activities regarding automated mobility in Austria. However, when it comes to better understanding technological and organisational matters as well as complex testing scenarios, even stronger efforts will be made addressing experimental frameworks ("sandboxing"). Among that, the current Action Programme Automated Mobility covers seven different thematic areas, such as transparent information, constant adaption of legal frameworks, public sector capacity, impact assessment, R&D, infrastructure as well as human-machine, i.e. user interactions.[38] Among these thematic areas more than 30 measures within the responsibility of different public and sector institutions are proposed.

4.3.9. 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. This document lists the transport administration actions in the domains of infrastructure, road superstructure and equipment, vehicle systems, services and functions, and driver. A major emphasis is on testing activities. In 2018, a national study investigated the impacts of highly automated driving on road operators and transport authorities in Finland by 2040. 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 & validate automated vehicles and driving functions on Finnish roads.

[37] National Contact Point Automated Mobility: http://austriatech.at/en/activities/point-of-contact-automated-driving
[38] For more details see figure 8 in the Austrian Action Plan on Automated Mobility, p.28

A 75 km Aurora test section with a specifically equipped 10 km instrumented section along E8 in Northern Finland is in active use. The Aurora test section provides facilities to stakeholders investigating the performance of automated vehicle technologies and developing new innovations which extend automated driving in harsh arctic conditions with having snow, slush and freezing temperature.

Automated public transport shuttles and buses as well as MaaS solutions are being evaluated in several Finnish cities to assess and improve their technical performance, impacts, benefits and costs. Truck platooning trials are being planned, as well as road works machinery automation in Oulu region. Passenger car urban automation is being developed and tested in the Tampere region. Kouvola-Kymi Ring motor circuit and training area is planned to be equipped with connected and automated driving testing facilities. Several locations (e.g. Sodankylä) have 5G networks to evaluate V2X supported automated driving.

4.3.10. Greece

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), a 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 June 13th 2015.

The first fully automated vehicles were officially licensed on October the 29th 2015 while they have been insured against third party liability (whilst insuring the operator, the passengers and the vehicle – again for the first time) and have been put on operation in the City of Trikala. The CityMobil2 large-scale demonstration in Trikala was officially launched on 10th of November 2015. The pilot successfully concluded its operation in February 2016 conducting around 1500 trips with more than 12.000 passengers.

Automated Driving is a thematic area and a technology considered in the recently launched ITS National Architecture (November 2015) and the ITS National Strategy (March 2015) docs where it is mentioned among other things that AD is contributing to the national strategic goals on safety, efficiency, sustainability in transport of both people and goods as well as to the creation of new business and job opportunities. Moreover, AD is recognized as an important element for the future public transport planning (in connection with existing transport means) in close connection with other key technologies like electromobility.

Greece is in the process of further adaptation of its legal framework to support and facilitate the permanent circulation of autonomous vehicles.

4.3.11. 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.

Beside the urban pilots and C-ITS services on motorways an expressway is under planning and construction (M76) linking Zalaegerszeg to M7. The main purpose is to create “ideal testing environment” for OEMs and to implement a prototype of a well-equipped “smart road” for everyone using the public road.

4.3.12. Slovenia

To support a future nationwide roll-out of automation, within the “C-Roads Slovenia” project, there is an on-going pilot implementation of C-ITS systems.

A project application based on testing the “Day-3”-ready autonomous vehicles has been confirmed by the Ministry of infrastructure. The aim of the application is to set up a minimal viable ITS “Day-3” deployment with SAE level 4 automated driving. It aims to deploy advanced ITS communication infrastructure along TEN-T corridors from Nuremberg via Salzburg to Ljubljana, thus connecting Germany with Austria and Slovenia. Although the project is still not confirmed and further communication about it should be limited, we would like to emphasize that the Slovenian Ministry encourages these kinds of projects as they will encourage the development of CCAM.

Finally, The Ministry of Infrastructure of the Republic of Slovenia is also a signatory of Memorandum of Understanding on Cross-Border Cooperation in the Development and Testing of Electric, Connected, and Autonomous Mobility Services together with The Federal Ministry for Transport, Innovation and Technology of the Republic of Austria and The Ministry of National Development of Hungary. Establishment of working groups and exchange of traffic information between the signatory countries are the first results of the memorandum in 2018.

4.4. Initiatives around the world

4.4.1. 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 addresses 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:

1. Allow each region/country to learn from one another's programs,
2. Identify areas of cooperation where each region will benefit from coordinated research activities, and
3. 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.

Areas of shared interest are addressed within Sub-Working Groups if topics are relevant for each country and a clear plan for cooperation exists, or as information sharing items otherwise. . Currently, three well established Sub-Working Groups are being maintained:

- Human factors: to share understandings of human factors in automated driving (a joint Sub-Working Group with the Human Factors WG)
- Impact assessment: to harmonize the high-level evaluation framework for assessing the impact of automation in road transportation and establish a unified list of potential direct and indirect socio economic impacts, and jointly try to quantify them
- Roadworthiness Testing: to coordinate efforts to identify necessary or appropriate tests required to allow the safe and reliable operation of automated vehicles on different road environment

Other topics are being worked on or have been considered for exchange of information to monitor the status in the different regions. These areas are regularly revised and updated.

- Next Generation of Transport: coordinate efforts to identify most promising shared and automated mobility services.
- Digital infrastructure: coordinate efforts to identify the static and/or dynamic digital representation of the physical world with which the automated vehicle will interact in order to operate;
- Connectivity: coordinate efforts to identify requirements that automated road - vehicle systems pose on vehicle – to - infrastructure and vehicle-to-vehicle communications
- Security : coordinate efforts to identify necessary or appropriate tests or assessments required to prevent automated mobility from being controlled by cyber-attackers
- Legal Issues : sharing regional information and opinions on legal frameworks and studying approaches

4.4.2. USA

The US DoT published its ITS Strategic Plan 2015-2019 describing “Realizing Connected Vehicle Implementation” and “Advancing Automation” as the primary technological drivers of current and future ITS work. The Automation Program is organised along 5 major research areas and includes 3 capability-based tracks: Human-in-the-loop (HITL) Connected Driving Assistance, Conditional Automation Safety Assurance and Limited Driverless Vehicle Operations:

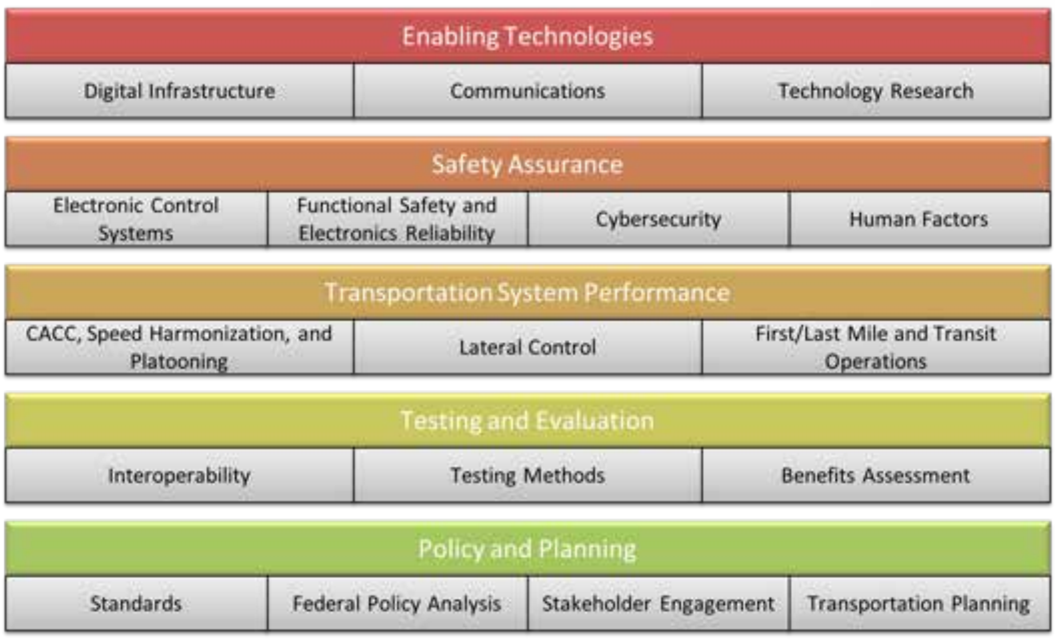

Figure 11: US DoT ITS JPO Automation Program research tracks

Since 2015, the ITS JPO has been supporting a series of small targeted studies addressing the different tracks of the programme. While some activities are directly managed by the ITS JPO, most of them are handled by the different US DoT agencies in a coordinated way e.g. FHWA, NHTSA, FMCSA, FTA, etc.

As a major milestone, NHTSA released in September 2016 its Federal policy guidance for Automated Vehicles including a set of 15 vehicle safety performance criteria and a description of existing and new regulatory tools for the safe introduction of higher levels of automation.. In September 2017, USDOT released Automated Driving Systems (ADS) 2.0: A Vision for Safety, replacing the 2016 Federal Automated Vehicles Policy and including clearer guidance and more helpful information for States. The guidance focuses on two sections: **Voluntary Guidance for Automated Driving Systems;** and **Technical Assistance to States, Best Practices for Legislatures Regarding Automated Driving Systems**.

Recently, in October 2018, the USDOT released a new Federal guidance for automated vehicles building upon ADS 2.0 - **Preparing for the Future of Transportation: Automated Vehicles 3.0.** The guidance establishes a clear and consistent Federal approach to shaping policy for automated vehicles based on 6 principles: prioritize safety, remain technology neutral, modernize regulations, encourage a consistent regulatory and operational environment, prepare proactively for automation, protect and enhance the freedoms enjoyed by Americans. Five implementation strategies have been defined to translate these principles into actions: stakeholder engagement, best practices, voluntary standards, targeted research and regulatory modernisation. It provides guidance for States to consider for the training and licensing of test drivers as well as guidance for testing entities to consider driver engagement methods during testing.

The ITS JPO together with VOLPE has worked on a harmonised framework to impact assessment of ART, which has been further developed in the EU-US-Japan Trilateral Working Group on Automation. The framework takes a broad look at the impact of AV introduction with a classification in nine impact areas and mechanisms, including Safety, Mobility/energy/emissions, User response and Economic impacts. It is being used in a series of projects in US, Europe and Japan.

FHWA is conducting work on cooperative automation including speed harmonization, merge assist, and lane change assist. In October 2018, FHWA officially launched the Cooperative Automation Research Mobility Applications (CARMA) Platform which is at the core of its cooperative automation research. The open source software (OSS) platform manages all automated motions of test vehicles using wireless communication and decides how messages from vehicles and infrastructure are interpreted and used. It is built on a flexible framework designed to be easily shared and integrated into several vehicle models including passenger cars and heavy trucks. The most recent version enables research and development (R&D) capabilities to support Transportation Systems Management and Operations (TSMO).

NHTSA is funding a series of research activities focusing on Human Factors, Safety benefits and Electronic Control Systems, including among others the recently ended Naturalistic Study of Level 2 Driving Automation Systems, and projects on Target Crash Populations for Automated Vehicles, Driver's Assistant for Intelligent SafetY (DAISY), Automated Vehicle Intent and Status Communication with other Road Users, Driver Expectations for Control Errors, Engagement, and Crash Avoidance in Level 2 Mixed Function Vehicles, and Safety of the Intended Functionality (SOTIF).

FMCSA is conducting several projects on Commercial Motor Vehicles (CMV): the Platooning and automated CMV Evaluation (PACE) Program, development of Baseline Safety Performance Measures for Automated CMV and Sensor Guidelines for Automated CMV Applications.

FTA has finalized a Strategic Transit Automation Research plan which addresses automated buses of different types including low-speed low-capacity last-mile public transport. Seven demonstrations are planned through 2022.

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In January 2017, the US DoT has designated 10 proving ground pilot sites to encourage testing and information sharing around automated vehicle technologies.

US DOT also runs a series of research projects exploring how to ensure safe, accessible and efficient integration of automation. These include a programme addressing accessible transport named ATTRI (Accessible Transportation Technologies Research Initiative) as a joint initiative between FHWA, FTA and ITS JPO aimed at improving mobility options for all travellers, the Work Zone Data Exchange project in which US DOT is working with 6 industry partners to develop a harmonized specification for work zone data that infrastructure owners and operators can make available as open feeds for AVs, and several Automated Low Speed Shuttles pilots with findings consolidated in a recently published State of Practice report.

The Consolidated Appropriations Act of 2018, signed into law in March, reallocates a total of $100 million for automation activities, including $38 million for direct research and $60 million for demonstration grants.

It should be pointed out that European based companies, automotive manufacturers and suppliers, are engaged in the US in research activities, including partnerships with universities, and testing of automated driving in public traffic.

4.4.3. Japan

Japan's Cross-Ministerial Strategic Innovation Promotion Program (SIP) initiated a research and development plan in May 2014 called Innovation of Automated Driving for Universal Services (adus) as one of eleven priority policy issues. The plan included a budget of 2.8 billion yen for 2018. Initial targets included Level 2 systems in 2017, Level 3 and Level 4 from 2020.

There are three working groups which include both public and private members: system implementation, international cooperation, and next generation urban transportation. The System implementation working group included tasks on the development and verification of automated driving systems and on basic technologies to reduce traffic fatalities and congestion (see Figure 9). Only pre-competitive issues were addressed leaving the rest of the research to the competition to the industry.

The SIP-adus addresses a full list of research needs such as Human Factors, Dynamic Maps, Security, connectivity, which are directly in-line with the work of the Trilateral EU-US-Japan ART WG. The vision for the next generation transportation system is to integrate multimodal transportation into rural and urban environments, to serve Japan's aging population and those with disabilities. Once developed, the entire system could be exported to developing countries or other parts of the world.

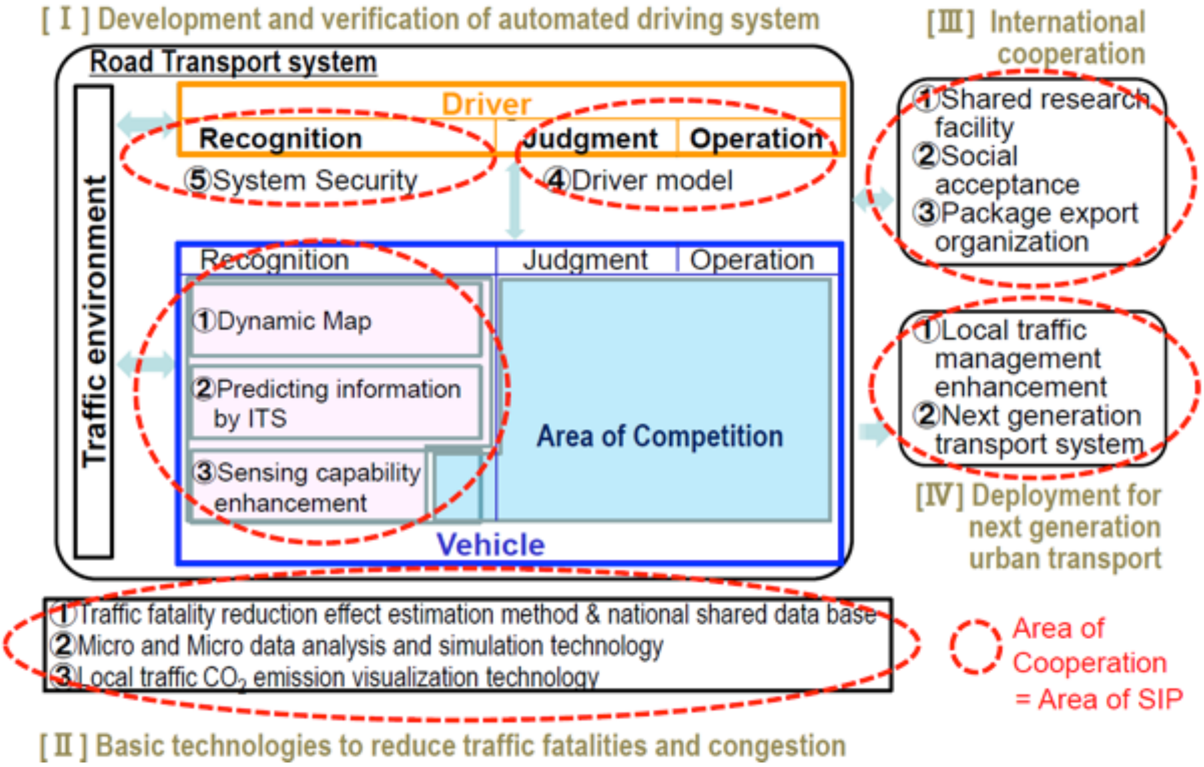

Figure 12: Japan Cross-Ministerial Strategic Innovation Promotion Program (SIP) Automated Driving System Research themes

After two years of research, SIP-adus has started a series of field tests in 2017 with the wide participation of the Japanese automotive industry. Different test sites include Arterial roads around the Olympic games area in Tokyo, the Express way around Tokyo and the JARI testing facilities.

The first phase of SIP-adus will be completed at the end of 2018 and a second phase has been approved in July 2018 and will start in 2019. While the first phase has been focussing on developing technologies, the second phase will give more attention to services and will look at how to ensure the safety of automated driving systems both for the vehicle side and infrastructure side. The target is for a 2020 deployment and thus a regulatory legal framework is needed before the end of 2020. As part of that effort, product liability laws, civil laws, criminal laws, and regulations need to be reviewed and modified.

4.4.4. South Korea

The South Korean government has designated autonomous vehicles as one of its top 13 Industrial Engine Projects. The focus is put on converging industries covering IT and automotive technologies. The main actors addressing this are the Korea Transport Institute (KOTI), the Korean Automobile Manufacturers Association (KAMA) and the Korean Auto Industries Cooperation

Association (KAICA). To organize governmental activities, a Smart Car Council was established to coordinate actions across different ministries, including the Ministry of Science, ICT and Future Planning, the Ministry of Land, Infrastructure and Transport, and the Ministry of Trade, Industry & Energy.

The main actor in research, development & innovation in South Korea for automated and connected driving is the Korea Transport Institute (KOTI) with eleven different research areas, including Intelligent Transport Systems: Highway, Aviation, Transport economics, Urban transport, Railway, Logistics, ITS, Traffic safety and disaster prevention, Government-project, Means of transportation, National strategy.

The Ministry of Land, Infrastructure and Transport revised the Automobile Management Act, making it possible for self-driving vehicles to be tested on designated routes on five national highways. The Ministry provides temporary licence plates to OEMs, universities and research laboratories.

The main research activities in South Korea are evolving from the car manufacturers. Hyundai for example planned to set aside KRW 2 trillion to develop and commercialize fully autonomous vehicles by 2030. This will be done by testing different autonomous car technologies in the Uiwang Choongang Laboratory (Hyundai's central research centre) and the Namyang R&D Center. Besides Hyundai, Unmanned Solution manufactured test cars for automated driving. The Connected & Automated Public TrAnsport INovation (CAPTAIN) project, focus on connected and automated driving (CAD) buses, including both large transit buses and smaller cut-away shuttle vehicles.

4.4.5. China

China is aiming at technical leadership in “intelligent vehicles”. Already in October 2016, the “Technology Roadmap for Energy-Saving and New Energy Vehicles” was released. This roadmap includes intelligent & connected vehicles (ICV) as important future mobility solution, reaching for an installation rate of driving assist and partial autonomous driving of 50% in 2020, 10%-20% highly automated vehicles in 2025 and 10% full automation in 2030.

The Ministry of Industry and Information Technology's (MIIT) strategy for the auto industry 2025, which is part of the larger “Made in China 2025” plan. In this, the government stresses the need for the development of intelligent connected cars with the objectives of reducing the number of traffic accidents by more than 30 percent, establishing a safe autonomous driving speed (120 km/h) and reducing energy consumption by more than 10 percent and greenhouse gas emissions by more than 20 percent. A specific (Draft) Strategy for Innovation and Development of Intelligent Vehicles was published by the National Development and Reform Commission (NDRC) in January 2018 and includes a 3-phase vision for CAD development.

The Chinese government and Society of Automotive Engineers of China (SAEC) have issued a roadmap for intelligent and connected vehicles that could have semi- or fully autonomous vehicles on sale as early as 2021. SAEC established the "China Industry Technology Innovation Strategic Alliance for Intelligent and Connected Vehicles" working on aspects of generic technical development, standards, testing, demonstration, communication and others.

China Automotive Technology and Research Centre (CATARC) assists the authorities and enterprises regarding research on industry policy and stakeholder involvement in the area of connected and automated driving.

A number of national test sites for connected and self-driving cars are established which aim to facilitate R&D, standard studies and policy formulation, as well as to test and certify connected car technologies. There are several established research centres, related to automated driving, for bilateral collaboration between Chinese and European OEMs, authorities and universities in China and in Europe.

4.4.6. Singapore

In Singapore, it is the government, rather than the industry sector, that has taken the lead when it comes to the deployment of autonomous vehicles, through the “Smart Nation” strategy. With the objective of “enhancing legislation to better support innovation while safeguarding commuter safety”, the government introduced amendments to the Road Traffic Act (RTA) in 2017. The amendments specifically target the solution of transportation challenges faced by commuters, such as a shortage of bus drivers. The law itself includes design and construction rules for autonomous vehicles as well as a requirement to capture and store sensor data and video footage from the vehicle, and to share these with government. The Land Transport Authority (LTA) has the responsibility for the supervision of AV with the necessary flexibility to amend rules to facilitate AV trials on public roads and keep up with the rapid changes in AV technology. The efforts are organized under a joint technical platform with the Agency for Science, Technology and Research (A*STAR), the Singapore Autonomous Vehicle Initiative (SAVI), which was launched in 2014. Trials has been ongoing since 2015 and various testbeds and trials have been established for automated taxis, cars, buses and trucks, with the objective of achieving full operational trials by 2018/2019 and pilot deployment in certain areas starting 2020.

The 26th ITS World Congress will be held in Singapore 21-25 October 2019 with the theme: “Smart Mobility, Empowering Cities”. https://itsworldcongress2019.com/

4.4.7. Australia

The National Policy Framework for Land Transport Technology 2016-2019 provides policy principles and guidance on governance and actions to support AV deployment in Australia. The document outlines a full action plan for the introduction of new transport technologies and cover key issues in deploying new transport technologies such as; Safety, Security and Privacy; Digital Infrastructure; Data; Standards and Interoperability; and Disruption and Change. The state government further backed its support for the development of automated road transport technology with an AU$ 10 million Future Mobility Fund for R&D projects over the three years period.

Australia is a federation, which allows for the definition of regulations on a state level. Several states have passed legislation to allow trials of automated vehicles. The first was South Australia, which passed the Motor Vehicles (Trials of Automotive Technologies) Amendment Act in 2016, to provide for on-road trials and the testing and development of unmanned vehicles of South Australian roads. New South Wales has passed legislation allowing trials of automated vehicles in the state in August 2017. Victoria amended its legislation in 2018 to allow for on-road trials of highly and fully automated vehicles implementing a performance-based permit scheme.

As part of the strategic plan for 2016-2020, Austroads is pursuing five active Connected Automated Vehicles (CAV) projects (as of May 2017) and has proposed six additional projects. The objectives are effectively supporting the introduction and use of CAV on Austroads networks and of optimising the potential societal benefits of CAVs with respect to road safety, transport efficiency, mobility services and the environment. There is close collaboration with the Commonwealth Department of Infrastructure, Regional Development and Cities (DIRDAC), the National Transport Commission and the state governments to achieve the objectives. The Royal Automobile Club of Western Australia (RAC) is trailing an automated shuttle bus and is considering expanding its trial. Another trial in Melbourne is testing automated vehicle interactions with signs. The National Transport Commission discussed reforms as they related to safety assurance, driving laws, accident injury review, and surveillance.

5. KEY CHALLENGES AND OBJECTIVES

Connected automated driving is the opportunity to address several important societal challenges of road transport: **safety, energy efficiency, congestion, urban accessibility and social inclusion**, in-line with the 2050 vision outlined in the ERTRAC Strategic Research Agenda. It is important to have systems approach of what the deployment of connected automated driving can bring. Both new technologies and new services enabled by connected automated driving have great potential to contribute to the societal challenges. New automated solutions for shared mobility and public transport could have very positive impacts on our future urban and inter-urban environments, making the system more accessible for elderly and people with disabilities. New automated logistics solutions will contribute to meeting the increased goods transport demands, improving resource utilization and environmental impact. In addition to technologies and vehicle aspects, there are important challenges of system integration for the deployment of new services. New business models need to clarify their data management and their integration with digital and physical infrastructures. To ensure proper user information and acceptance, policy and societal aspects must be addressed, and trigger the necessary regulatory adaptations.

The following chapter list the main challenges and objectives related to the development paths to higher levels of automation. Different types of actions are necessary, sometimes at local level, sometimes at European level, and sometimes also at the international level.

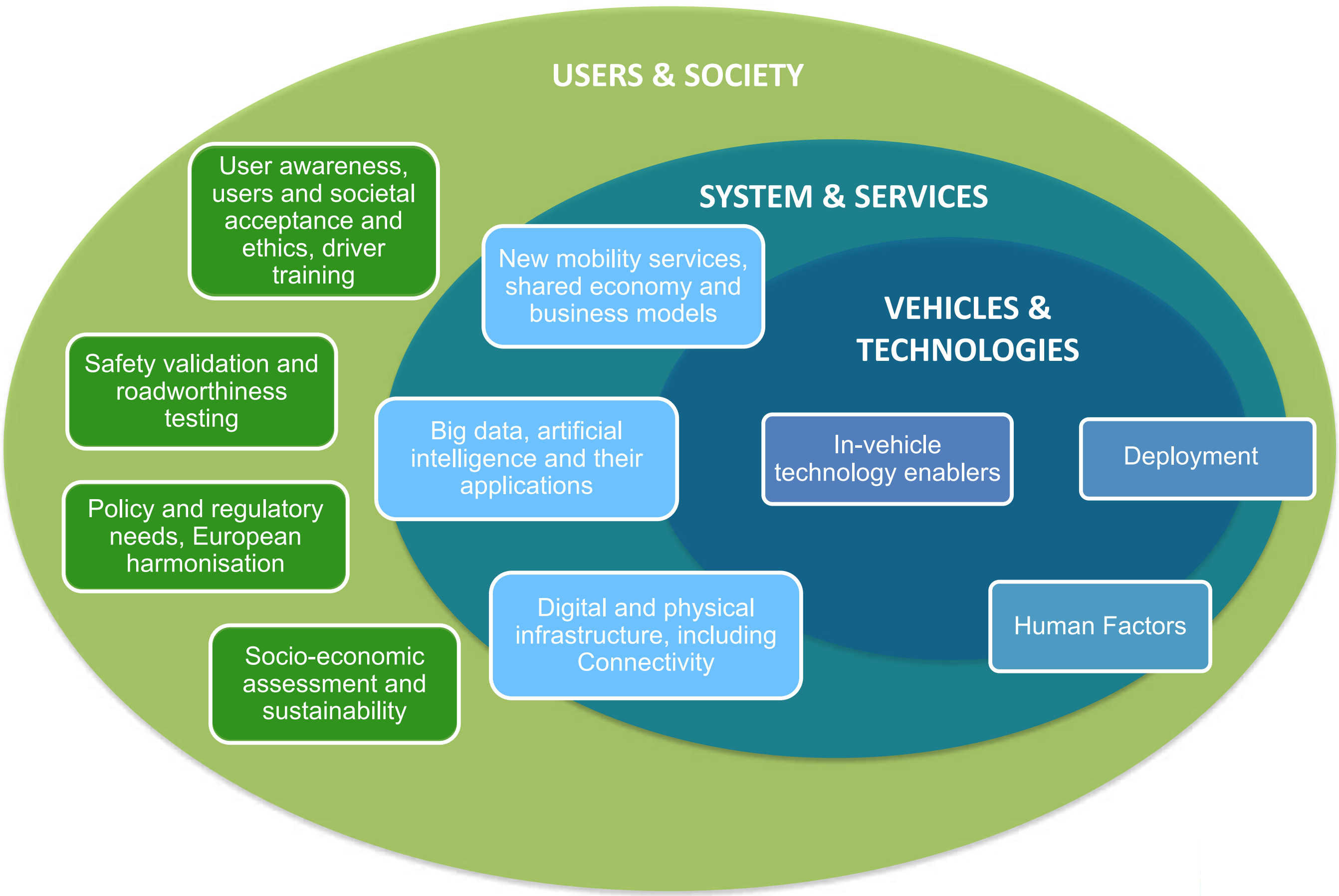

Figure 13: Key challenge areas

5.1. User awareness, users and societal acceptance and ethics, driver training

Reflecting the opportunities and problem solving capabilities of CAD, user requirements will be considered in their broadest sense and with elements influencing trust & acceptability of novel technologies, particularly also involving people in need of special attention (special needs, disabled, elderly people). More generally, potential impacts on driver attitude and behaviour, influencing traffic safety, will be analysed, and ethical and liability aspects related to CAD will be studied. It will also be assessed how the value chains and the work force in the European Union can adapt to new and fast changing framework conditions and technological evolutions of CAD.

How to assess socio-economic and environmental impacts of future mobility (and CAD, also in combination with electric mobility) analyzing citizen's needs (e.g. in terms of safety and inclusion)? How to assess ethical and liability issues of CAD and to propose regulations, standards and framework conditions with the involvement of national authorities?

How to explore the potential benefits and challenges of connected and automated driving and on-demand mobility on traffic system performance as well as energy consumption and emissions considering regional circumstances, sharing lessons learned and best practices and deriving recommendations for policy making on urban transport and spatial planning in order to avoid rebound effects?

Concrete questions of the public debate will need answers as well: How will ART challenge the desire for the driver to stay in control? How will automation change our mobility habits? Will automated mobility be more or less expensive in comparison to today´s road transport on a total system cost approach? In which situations will an automated car ever have to make an ethical decision? At last, how can this debate be brought to a socio-technical real-life knowledge base, away from theoretic intellectual discussion?

How will driver training and the driver licence handle the differences between the functionalities with which semi-automated cars are equipped and in which environments and conditions they operate? Will driver training decrease over time with increased levels of automation?

5.2. Human Factors

It is of key importance to understand and design the interaction between humans and automated vehicles (in-vehicle and outside vehicle) at different levels of automation without automation induced negative consequences; In-vehicle, Remote control (e.g. summing, dispatching) and Back-office (e.g. re-routing).

- Find design solutions and standards for human factor challenges such as unintended use, skill degradation, level of trust and acceptance, motion sickness and controllability in transitions.
- Adapt vehicle automation to different user needs and group.
- How to design the safe, intuitive interaction of automated vehicles with other road users?
- How to ensure driver is in the loop for L2 and below? How to ensure driver is able to transfer back into the loop for L3 and higher? How to ensure a safe transition phase without startling

effects, low situational awareness and a smooth stabilisation phase.

- How to ensure appropriate driver state (e.g. not asleep or intoxicated).
- How to derive interaction design concepts for the automated vehicles so that both the human driver and other humans in the surrounding sufficiently understand the capabilities and limitations of the vehicle?
- What part of the Human-Machine Interaction (HMI) design should be standardised and what needs to be left open for novel solutions?
- Should the Human-Machine Interaction (HMI) design should be standardised or open for disruptive solutions?

5.3. Policy and regulatory needs, European harmonisation

For deployment of automated vehicles, discussions concentrate on regulatory obstacles and missing provisions in current regulations. Research and testing shall provide evidence for functional safety validation procedures suitable for certification, either in EU type approval or in a global technical regulation regime. In addition, harmonised activities on traffic rules and traffic sign infrastructure in EU member states and at UN-ECE WP1 continue. As technology evolves, research and testing activities drastically increase. How can Europe bundle and coordinate all ongoing initiatives to speed up, be in the forefront of worldwide competition and contribute to global harmonisation?

The detailed regulatory requirements for type approval on Level 3 and higher are just starting in the new Working Party on Automated/Autonomous and Connected Vehicles (GRVA). How can type-approval processes evolve so that it will be in place when the technology is ready?

In some member states, there are first adaptions of traffic rules in progress or even in place (Germany´s new "Straßenverkehrsgesetz"). How and to what extent can traffic rules be harmonized for a quicker introduction of higher automation levels? This has to be done at international level, to avoid the necessity to develop different systems for different markets.

How to validate safety for level 4, or even level 5 automated vehicle functions without exceeding reasonable limits for time and costs? How can type-approval evolve with technological progress? How to adapt regulation quick enough to consider new technologies on the market? How to deal with software updates following the publication of the upcoming UN-ECE regulation on software OTA updates?

On Roadworthiness UN ECE is working on the level of 58 and 97 Agreement on provisions securing the roadworthiness of AV by adequate PTI (periodical technical inspections) provisions. How can roadworthiness of software be evaluated and internationally harmonized?

Furthermore, there may be other areas of regulation affected when it comes to new urban mobility businesses. What is the total scope of affected policy and regulation?

What liability framework needs to be in place to facilitate market penetration from a legal/liability perspective?

In the long term, research must also address, inter alia, a Pan-European approach on mobility solutions, a political framework for the rollout of electric autonomous shared mobility into rural areas and the safe coexistence of automated vehicles and non-motorized road users.

5.4. Socio-economic assessment and sustainability

How to get reliable evaluation results of socio-economic and sustainability impacts of connected and automated driving? How to build realistic future scenarios for the evaluation? How to assess the indirect impacts in addition to the direct ones?

Which will be the impacts of highly and fully automated driving on jobs, education and services compared to what we have today? E.g. deletion or evolution of employment in the logistics sector? E.g. workforce in garages, supposing that automated vehicles will have less bodywork damages to be repaired? E.g. evolving skills for the workforce: more into software, IT and services and less into mechanics? Is there a need to update the driver training?

How to assess the road safety benefits of increased automation? Understanding that major benefits will already been brought by ADAS and level 2 systems: which effectiveness on accidents and fatality/injury reduction can be further gained due to level 3 to 5 systems and at which cost-efficiency?

How to assess the environmental and transport network efficiency impacts of automated driving? How to assess the impacts that introduction of highly or fully automated vehicles will have on travel behavior (mode choice, route choice and timing)?

5.5. Safety validation and roadworthiness testing

Operational, functional and perceived safety and comfort as part of the development of a new function and/or a whole automation level are not yet described in a standardised way. How to handle initial release validation, real world awareness and functional validation?

How to achieve acceptable test coverage in reasonable development time and effort taking into account the uncountable variations of real-world scenarios in different environmental conditions? How do we include traffic rules in the process? How to handle development completeness?

For the time being, testing methods are evolving quickly with more and more virtualisation. How to include/adapt/improve existing development methodologies? How to validate human interaction for connected and automated driving? To what extent should virtual tools support safety validation?

How to ensure modularity and scalability to cover different levels: component level, function level, system level, vehicle level (including interaction with other road users and infrastructure) taking into account its specific characteristics, commonalities and differences (i.e. scenarios and/or raw data)?

How to handle vehicle updates, experienced situations, infrastructure functional updates and vehicle lifecycle?

To what extent should standard test procedures be defined and approved by certification agencies to grant type approval of automated vehicles? Also, how should certification agencies and garages issue road worthiness certificates?

5.6. New mobility services, shared economy and business models

One of the major challenges of such mobility services is the willingness to share the trip. The willingness to share depends on the trip purpose, the travel time, the comfort and the service reliability. In addition, by sharing the trip, passengers accept to travel with others. One inherent challenge will be then to create privacy areas within sharing mobility models. More generally, the privacy is an issue which is closely related to the data sharing objective, which should be overcome through regulation of data collecting and sharing.

- How will the area of shared vehicle and shared ride services evolve?
- How to handle and stimulate mobility services innovation?
- What are the new business models for private, commercial and public users of automated vehicles?

Public authorities should also be involved in early stages of the deployment of these services in order to ensure the balance between economic interests (e.g. jobs creation, profit of operators) and social needs (e.g. accessibility, public health, etc.). This public involvement is all the more crucial as several services providers could operate in the same territory. Regulation of these competing services would limit their negative externalities (e.g. congestion, pollution, higher fares, etc.) but would also contribute to increase the required trust between operators to work together.

The involvement of public authorities is a prerequisite to ensure inter-modality with a unique ticketing system and to create a common and interoperable service across countries of the Globe.

- How to handle management of professional driver services management such as driving/working/resting time operation?
- What role should local governments play in facilitating Mobility as a Service (Maas)?

5.7. Big data, artificial intelligence and their applications

In the various development stages of automated driving, it has been shown that conventional analytical procedures for environmental detection reach their limits, especially in complex urban scenarios. Consequently, all well-known companies such as Google, Tesla, Apple, etc., which are pushing the development of autonomous vehicles with enormous efforts, rely on artificial intelligence (AI) methods. AI technology is developing in particular under the premise that autonomous vehicles can interpret and predict traffic situations at least as well as humans, de facto to the key technology with no alternative.

Furthermore the sensors of automated and connected vehicles produce huge amounts of data. In addition, similar if not larger amount of information is gathered from road infrastructure sensors, e.g. cameras. This big amount of real-life traffic data can be analysed to enhance the rapid growth and development of smart road technologies and automated driving systems, enable much wider applications such as taxi services, car sharing or find-a-parking-spot services. In combination with

Big traffic Data AI techniques, such as machine learning including deep learning, play a major role in both data analytics and development of AI automated driving functions and applications.

On one hand, AI techniques are needed for analysing and annotating the collected Big Data and convert it to useful information. On the other hand, developing AI automated driving applications require collecting and analysing Big Data sets that are sufficiently representative for the development and training of these applications.

The areas of application of AI methods for automated driving functions need to be evaluated. The following functional blocks of the data processing chain have the highest potential: understanding traffic scenarios, predicting behaviour and determining driving manoeuvres and strategies. Answers are needed to the question of which architectures are required for integration and combination with classical algorithms and what effects they have on component and safety requirements. A particular challenge is the development of automotive-compatible safety and release methods for AI based functional components.

Here are some specific challenging questions listed:

- What data should be stored and shared and how can it be captured, converted and updated?
- How can a reliable and secure interface to large data stores be provided?
- How to deal with reducing the validity of large data over time, i.e. how to control the validity of deep learning?
- How should the format of data sets be standardised?
- What criteria are used to create the data sets for AI training and validation?
- How are AI algorithms integrated into an AD system focusing on modularity and maintenance?
- How is the basic truth and functional security and reliability of systems with AI content validated and verified effectively and legally? In this context, it is important to distinguish between AI functions for perception, control, security, comfort or pure data analysis.
- What are the requirements for the architectures of the underlying technological platforms?

5.8. Physical and Digital infrastructure (PDI) including Connectivity

Understanding PDI and its technologies will help to understand deployment opportunities to support CAD. How will PDI and secure connectivity integrate public and private transport, especially with regard to data exchange and access and related business models? New design concepts that stem from digitalized traffic infrastructure in simulation (flexibilization and individualization of lanes, traffic rules, traffic information required only for CAD) will be analyzed. How and to what degree will joint concepts by automotive sector, fleet and road operators will improve traffic management establishing dynamic traffic regulations even across borders. A focus will be on special interest areas like crossings, road-work zones, tunnels, urban environments, special events and natural disasters. How will this depend on connectivity to reach performance regarding safety, security, efficiency and service requirements, especially in hybrid communication environments from an end-to-end perspective, Therefore, methodologies as requirements for end-to-end security of transmitting sensor data and control data, beyond the communication interfaces need to be understood and methods (cyber security by design) to protect hacking of CAD will be explored. Additionally, the categorization of infrastructure support need to be standardized based on the ISAD levels, which provide additional information for on-board decisions of CAVs and enable a better end-user acceptance.

What are the roles and responsibilities of the different stakeholders of PDI for CAD? Who owns the data and who operates the services? Should the vehicle cope with any road infrastructure, and if not, what demands can be set to adapt the existing PDI? How to ensure continuity between those different environments?

Which tools (e.g. micro- and macroscopic transport modelling, impact assessment) can enable cities to assess the impact of automated vehicles on their physical road infrastructure and balance the needs of automated vehicles against the needs of existing modes (conventional vehicles, public transport, pedestrians and cyclists).

How to ensure resilient and robust communication in all environments? How to ensure functional safety (ISO26262) of CAD systems? How to ensure data privacy? How to handle the cyber security challenge?

5.9. In-vehicle technology enablers

Vehicle technologies are crucial to enable CAD. In-vehicle systems must be designed in such a way that they are:

- Scalable to cover the wide variety of vehicle platforms, models and markets,
- Robust enough to meet very high safety requirements, including improved redundancy to support fail-safe operation,
- Secured against cyber attacks to ensure system integrity.

The CAD in-vehicle system need to handle the diversity of systems of systems needed for various vehicle concepts and a spectrum of use cases in their respective ODDs. The system need to cover the complete functional chain from environment perception over decision making to actuation.

Complex perception systems are required to extract the information for real-time driving decision-making from the environment. Sharing very high amount of information within the vehicle system and processed by distributed embedded AI algorithms implies very high demand of the in-vehicle und networked system.

New hardware concepts for sensors and for computing units are key enablers to reach the computing power needed to detect correctly very complex driving situations and at the same time keep affordable energy consumption and integration costs.

Vehicle localization is one 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 need to cover detailed dynamic road infrastructure information and real-time traffic information.

These challenges will lead to increased complexity of the systems involved, their integration in the vehicle, integration to the connected and cooperative system. There is a need to handle remote software updates and increased maintenance/aftermarket requirements.

There is a close connection between the capabilities of vehicle technology with safety validation and technical monitoring. Suitable module-based vehicle architectures are crucial.

5.10. Deployment

The overall ambition is "to make Europe a world leader for the deployment of connected and automated mobility making a step-change in Europe in reducing road fatalities, reducing harmful emissions from transport and reducing congestion". Successful deployment of automated vehicles and mobility services is the result of the combined efforts of the thematic areas all together, addressing a number of challenges;

- Establishment an European stakeholder platform to coordinate open road testing
- Large scale tests and pilots towards deployment in the different application domains:
    - Deployment of connected automated passenger vehicles in mixed traffic conditions for improved safety and efficient road transport
    - Deployment of connected automated heavy commercial freight vehicles in mixed traffic for improved safety and efficient road transport
    - Deployment of electric, connected and automated urban mobility vehicles in mixed traffic for improved safety and efficient road transport
- Alignment with the deployment of C-ITS in balance with 5G deployment. Connectivity and cooperative systems is an important enabler for higher level of automation.
- Transformation of the automotive sector into a software driven industry complexity, functional growth, continuous software online updates and cyber-security.
- Efficient calibration and re-calibration of complex connected systems of systems.
- New diagnostic concepts, methods and standards.
- New support field-support, re-programing in the field, fleet-monitoring concepts.
- Develop the vehicle maintenance concepts of very complex systems
- Production end-of-line tests and methodologies to ensure product reliability
- Quality assurance tests and certificates
- After-market sector and after-market products and services
- Ensure maintenance considering vehicle life-time
- Second-hand sector development
- Long-term impact of connected automated driving on the automotive sector
- Speed up "time to market" to enable early market deployment of new solutions

6. ANNEX: DEFINITIONS OF SYSTEMS – LEVELS 0 TO 2 + PARKING

Systems beyond human capability to act

There are several systems on the market today that intervene when it is beyond the human capability to act, like ABS (Anti-Lock System), ESC (Electronic Stability Control) and emergency braking. These systems are only mentioned and not covered in detail here, but they are active safety systems that will be building blocks for high levels of automation and will facilitate deployment. Future versions of these systems will include emergency evasion and emergency stopping.

6.1. Current and future vehicle systems – Level 0

Currently on the market (both for trucks and passenger vehicles) there are several assist systems:

6.1.1. LCA: Lane Change Assist

The system monitors the areas to the left and right of the car, including the blind spot detection, and up to 50 metres behind it and warns you of a potentially hazardous situation by means of flashing warning lights in the exterior mirrors.

6.1.2. PDC: Park Distance Control

The Park Distance Control supports the driver to manoeuvre into tight spaces and reduce stress by informing him of the distance from obstacles by means of acoustic or, depending on vehicle, optical signals.

6.1.3. LDW: Lane Departure Warning

Lane Departure Warning helps to prevent accidents caused by unintentionally wandering out of lane, and represents a major safety gain on motorways and major trunk roads. If there is an indication that the vehicle is about to leave the lane unintentionally, the system alerts the driver visually and in some cases by means of a signal on the steering wheel.

6.1.4. FCW: Front Collision Warning

The Front Collision Warning monitoring system uses a radar sensor to detect situations where the distance to the vehicle in front is critical and helps to reduce the vehicle's stopping distance. In dangerous situations, the system alerts the driver by means of visual and acoustic signals and/or with a warning jolt of the brakes. Front Collision Warning operates independently of the ACC automatic distance control.

6.2. Current systems – Level 1

6.2.1. ACC: Adaptive Cruise Control

The cruise control system with "automatic distance control ACC" uses a distance sensor to measure the distance and speed relative to vehicles driving ahead.

The driver sets the speed and the required time gap with buttons on the multifunction steering wheel or with the steering column stalk (depending on model).

The target and actual distance from following traffic can be shown as a comparison in the multifunction display

6.2.2. PA: Park Assist

Park Assist automatically steers the car into parallel and bay parking spaces, and also out of parallel parking spaces. The system assists the driver by automatically carrying out the optimum steering movements in order to reverse-park on the ideal line. The measurement of the parking space, the allocation of the starting position and the steering movements are automatically undertaken by the Park Assist: all the driver has to do is to operate the accelerator and the brake. This means that the driver retains control of the car at all times.

6.2.3. ACC including Stop & Go

Adaptive cruise control with stop & go function includes automatic distance control (control range 0–250 km/h) and, within the limits of the system, detects a preceding vehicle. It maintains a safe distance by automatically applying the brakes and accelerating. In slow-moving traffic and congestion, it governs braking and acceleration.

6.2.4. LKA: Lane Keeping Assist

Lane Assist automatically becomes active from a specific speed (normally from 50 km/h) and upwards. The system detects the lane markings and works out the position of the vehicle. If the car starts to drift off lane, the LKA takes corrective action. If the maximum action it can take is not enough to stay in lane, or the speed falls below 50 km/h, the LKA function warns the driver (e.g. with a vibration of the steering wheel). Then it is up to the driver to take correcting action.

6.3. Automated Driving Assistance - Level 2

6.3.1. Traffic Jam Assist (Level 2)

The function controls the vehicle longitudinal and lateral to follow the traffic flow in low speeds (<60km/h). The system can be seen as an extension of the ACC with Stop&Go functionality. (i.e. no lane change support).

6.4. Automated Parking Assistance

6.4.1.1 Parking Assist (Level 2)

Partial Automated Parking into and out of a parking space, working on public parking area or in private garage. Via smartphone or key parking process is started, vehicle accomplishes parking manoeuver by itself. The driver can be located outside of the vehicle, but has to constantly monitor the system, and stops the parking manoeuver if required.

6.4.1.2 Parking Garage Pilot (Level 4)

Highly Automated parking including manoeuvring to and from parking place. In parking garage the driver does not have to monitor the system constantly and may leave once the system is active. E.g. via smartphone or key, parking manoeuvre and return of the vehicle is initiated. The parking garage may take over part of the functionality, so that early introduction is supported.

6.4.1.3 Automated Valet Parking (Level 4)

Highly Automated parking including manoeuvring in a limited area with limited speed to and from most parking spaces. The driver can leave the vehicle and initiates the manoeuvring to the parking space and the parking itself by e.g. smartphone or key. He does not have to monitor the system constantly and may initiate the parking-out manoeuvre the same way when coming back.

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