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 Risto Kulmala (Finnish Transport Agency). The first "Automated Driving Roadmap" of ERTRAC was issued in July 2015 and requested a complete update to cope with the many developments that happened since then. This new 2017 version presents updated definitions and development paths, an updated list of EU and international activities, and an extended list of R&D challenges. The following European projects, funded by Horizon 2020, have provided extensive support for the realisation of this roadmap:

FUTURE-RADAR (coordinated by AVL)
SCOUT (coordinated by VDI/VDE-IT)
CARTRE (coordinated by ERTICO ITS Europe)

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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 Automated Driving in Europe. The Roadmap starts from common definitions and a listing of available technologies, and then identifies the challenges for the implementation of higher levels of automated driving functions. Development paths are provided for the 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, 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 Automated Driving?

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.

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.**

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 Automated Driving therefore contributes to the long-term vision of ERTRAC for the transport system. **In one sentence: in 2050, vehicles should be electrified, automated and shared.**

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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 September 2016, as accessible on: http://standards.sae.org/j3016_201609/ 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.

SAE level	Name	Narrative Definition	Sustained lateral and longitudinal vehicle motion control	Object and event detection and response (OEDR)	Dynamic driving task fallback (DDT fallback)	Operational design domain (ODD)
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Limited
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Limited
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Fallback-ready user (becomes the driver during fallback)	Limited
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Limited
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**Unlimited**

Figure 1: SAE Levels of Driving Automation for On-Road Vehicles (September 2016, copyright SAE)

Note: the definition of the level 5 of automation is still the object of confusion and different interpretations, in particular in the media and in public institutions. In respect of the SAE definition, the level 5 requires the automated driving system to be able to manage all roadway and all environmental conditions. In consequence, any system having limitations of its operational domains cannot pretend being at level 5. The confusion comes often from the use of the "full automation" wording being associated with the absence of driver e.g. in PRT systems: the limited speed and operation in confined area call, however, to classify such systems as Level 4. ERTRAC calls for a strict use of the SAE definitions in order to avoid this confusion.

2.2. Road definitions

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. Current systems – Levels 0 and 1

Similar than in the 2015 Roadmap. This chapter is available in the Annex.

2.4. Systems for Automated Passenger Cars

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 offboard and can be distinguished by parking and driving use cases.

2.4.1. Automated Parking Assistance

2.4.1.1. 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.

2.4.1.2. 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.

2.4.1.3. 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.

2.4.2. Automated Driving Assistance

2.4.2.1. 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).

2.4.2.2. 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.

2.4.2.3. 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.

2.4.2.4. 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 on defined road segments, in all traffic conditions. The driver can at all time override or switch off the system.

2.4.2.5. Highway Autopilot including Highway Convoy (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). Depending on the deployment of cooperative systems, ad-hoc convoys could also be created if V2V communication is available.

2.4.3. 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.

2.5. Systems for Automated Freight Vehicles

This path focuses on automation of commercial vehicles primarily for long-distance freight transport. Automated commercial vehicles operate mainly on open roads but also in restricted roads/lanes and confined areas should be considered where the automation level can be applied.

2.5.1. Platooning

Platooning will be deployed in steps balancing capabilities and needs from fleets, drivers and authorities:

- In scenarios where there are strong combined incentives through fuel savings, safety, traffic flow and road utilization improvements
- From short mono-fleet platoons in high density truck on selected roads to multi-brand/multi-fleet platoons on open roads in mixed traffic
- From low level platoons with driver involvement to high-level platoons without driver involvement, in line with safety and traffic regulation
- From platooning services for dedicated fleets to pan-European platooning services provided by independent platooning services providers

2.5.1.1. C-ACC Platooning (Level 1)

Partially automated truck platooning, in which trucks are coupled by Cooperative ACC (C-ACC), through speed control keeping a short but safe distance to the lead vehicle, while the drivers remain responsible for all other driving functions.

2.5.1.2. Automated Truck Platooning (Level 2)

This function enables platooning in both dedicated lane/road and on open roads in mixed traffic. The vehicle should be able to keep its position in the platoon with a safe distance between the vehicles. The driving behaviour of the leading vehicle is transmitted by V2V communication to the following vehicle taking vehicle characteristics into consideration, such as braking capacity, load. The function will also handle platooning management of forming, merging and dissolving platoons together with interaction with other road users and road infrastructure requirements.

2.5.1.3. Highway Pilot platooning (Level 4)

Automated Driving on motorways or highways from entrance to exit, on all lanes, incl. 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-time override or switch off the system. There is no request from the system to the driver to take over when the system is in normal operation area (i.e. on the motorway).

2.5.2. Confined areas and dedicated roads

These applications cover usage of automated freight transport vehicles in confined areas and on dedicated lanes/roads. Vehicles could be designed without cab for drivers.

2.5.2.1. Highly automated freight vehicles in confined areas (Level4)

Automated freight transport carriers in confined areas (e.g. harbour, mining and work-site) for potentially un-manned freight transport. Vehicles can be designed without cab for driver.

2.5.2.2. Highly automated freight vehicles in dedicated lanes/roads/areas (Level4)

Automated freight transport carriers on dedicated and controlled lanes/roads/areas and for potentially un-manned freight transport. Vehicles can be designed without cab for driver. Operation could be done during night in lower speed to safe fuel.

2.5.2.3. Highly automated freight vehicles on open roads (Level4)

Automated freight transport carriers on public roads and for un-manned freight transport. Vehicles can be designed without cab for driver. Operation could be done during night in lower speed to safe fuel

2.5.3. Highway applications

2.5.3.1. Traffic Jam Assist (Level 2)

The function controls the vehicle longitudinal and lateral to follow the traffic flow in low speeds (<30km/h). The system can be seen as an extension of the ACC with Stop&Go functionality without lane change support.

2.5.3.2. Traffic Jam Chauffeur (Level 3)

Conditional automated driving in traffic jam up to 60 km/h on motorways and highways. The system can be activated in case of a traffic jam scenario exists. It detects slow driving vehicles in front and then handles the vehicle both longitudinal and lateral. Later versions of this functionality could include lane change functionality. Driver must deliberately activate the system, but does not have to monitor the system constantly. Driver can at all times override of switch off the system. Note: There is no take over request to the driver from the system.

2.5.3.3. Highway Chauffeur (Level 3)

Conditional Automated Driving up to 90 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-time override or switch off the system. The system can request the driver to take over within a specific time, if automation gets to its system limits. Later versions of this functionality might include lane change and overtaking functionality.

2.5.3.4. Highly Automated Trucks on Open Roads (Level 4)

High automated trucks for automated operation on public roads in mixed traffic handling all typical scenarios without driver intervention on planned freight transport operations hub-to-hub on approved roads according to planned routes. Remote fleet and transport management and monitoring are required.

2.5.3.5. Fully automated freight vehicles (Level 5)

The fully automated vehicle should be able to handle all driving from point A to B, without any input from the driver or passenger in all operation environments.

2.6. Urban Mobility Vehicles

This path covers 'Low Speed 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. There are foreseen new types of urban mobility vehicles dedicated for urban use such as; cybercars, robotaxis, advanced city cars, dual-mode vehicles, urban shuttles and city buses. For this roadmap only 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.

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.

2.6.1. Urban driving assist and chauffeur applications

2.6.1.1. Parking Assistance (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.

2.6.1.2. Traffic Jam Assist (Level 2)

The function controls the vehicle longitudinal and lateral to follow the traffic flow in low speeds (<30km/h). The system can be seen as an extension of the ACC with Stop&Go functionality without lane change support.

2.6.1.3. Urban Bus Assist (Level 2)

Automated assist functions for city-buses to increase productivity and safety for city bus operation such as; bus-stop manoeuvring, short-distance follows and narrow-lane manoeuvring.

2.6.1.4. Automated Bus Chauffeur (Level 3)

Conditional automated driving in traffic jam up to 60 km/h on motorways and highways. The system can be activated in case of a traffic jam scenario exists. It detects slow driving vehicles in front and then handles the vehicle both longitudinal and lateral. Later versions of this functionality could include lane change functionality. Driver must deliberately activate the system, but does not have to monitor the system constantly. Driver can at all times override of switch off the system.

2.6.2. Highly automated urban applications

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

The automated PRT/Shuttle drives in designated lanes / dedicated infrastructure, with a maximum speed of 40km/h. This may be combined with automated functions for enhanced safety, traffic flow and network utilization.

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

The automated PRT/Shuttle drives in mixed traffic in same speed as other traffic.

2.6.2.3. Automated Buses on dedicated lane (Level 4)

The 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.

2.6.2.4. Automated Buses in Mixed Traffic (Level 4)

The automated bus operates in mixed traffic on open roads together in normal city traffic speed. Functions may include bus-trains, following and bus-stop automation for enhanced productivity, safety, traffic flow and network utilization.

2.6.3. Fully automated urban vehicles

2.6.3.1. Fully Automated Urban Vehicles (Level 5)

Fully automated vehicles that driverless can bring passengers to any destination as “robotaxis”, “cybercars” or as fully automated shuttles and city buses.

3. DEVELOPMENT PATHS

Warning, support systems and advanced driver assistance systems (ADAS) are already available on the market today as the base for increasing passenger car, freight-vehicles and bus automation. Another path is for urban mobility vehicles where high automation is already being tested in some areas in Europe in low speed and/or in dedicated infrastructure aiming for full automation. Yet the evolution is similar in all cases: a progressive step-wise increase of automation level during the upcoming decade. These main development paths for the different automation levels are shown in Figure 2.

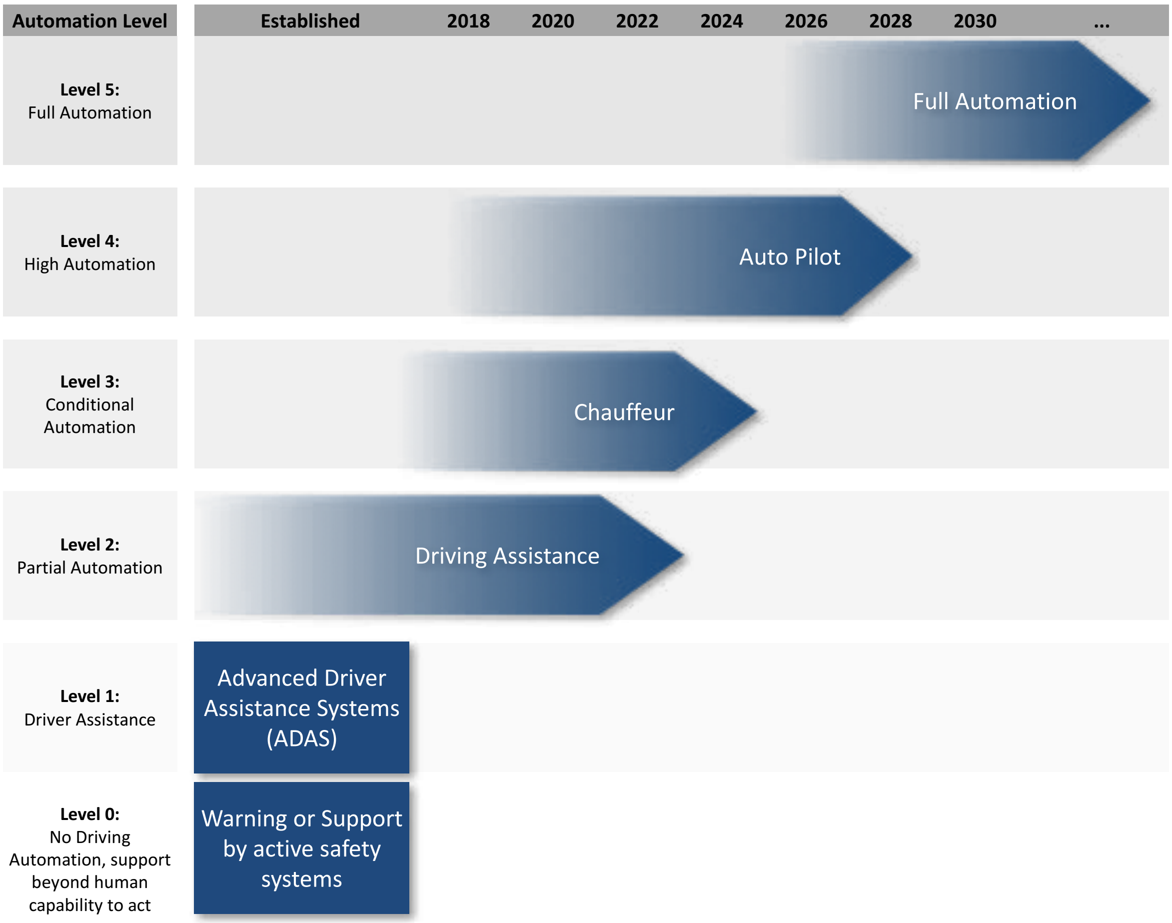

Figure 2: The vehicle automation development paths

3.1. Automated Passenger Cars Path

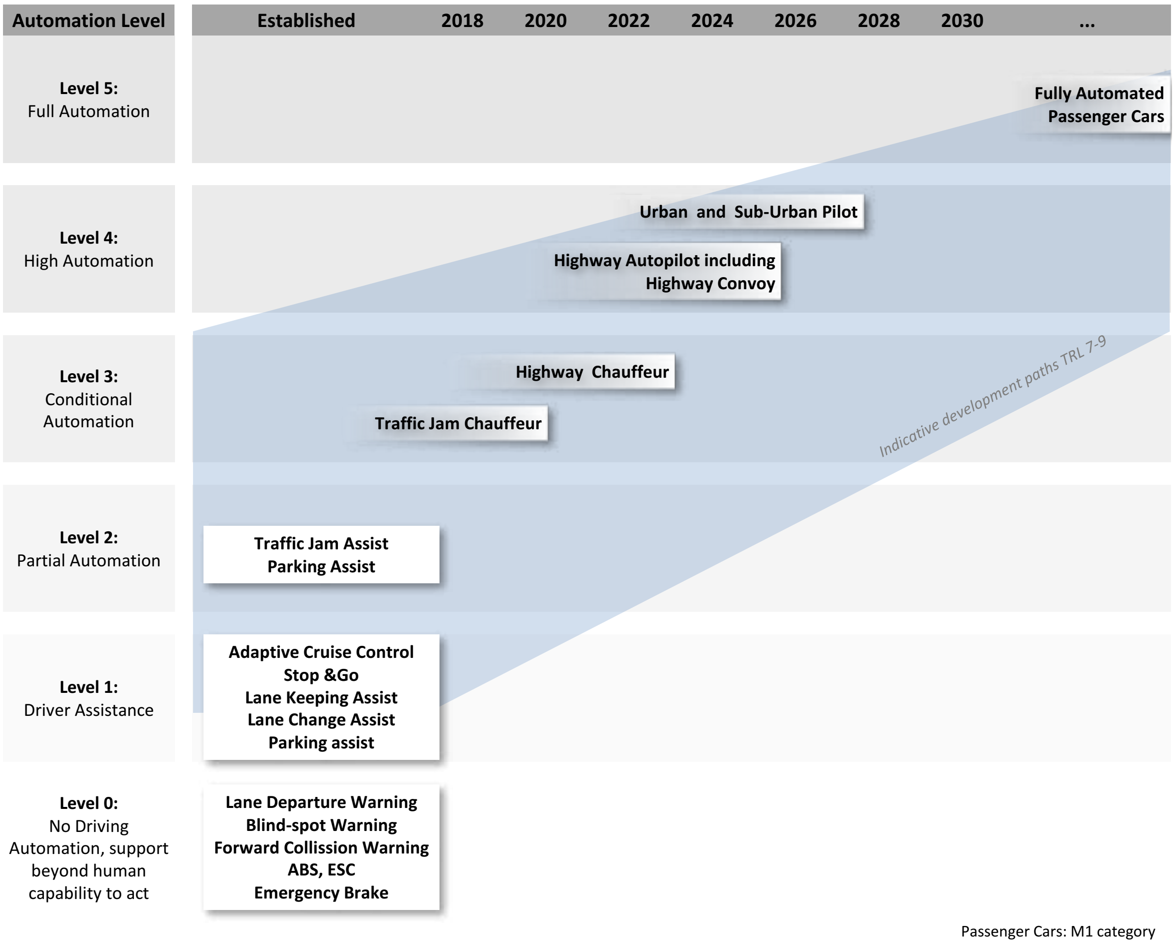

Figure 3: The Automated Driving development path for passenger cars

3.2. Automated Freight Vehicles Path

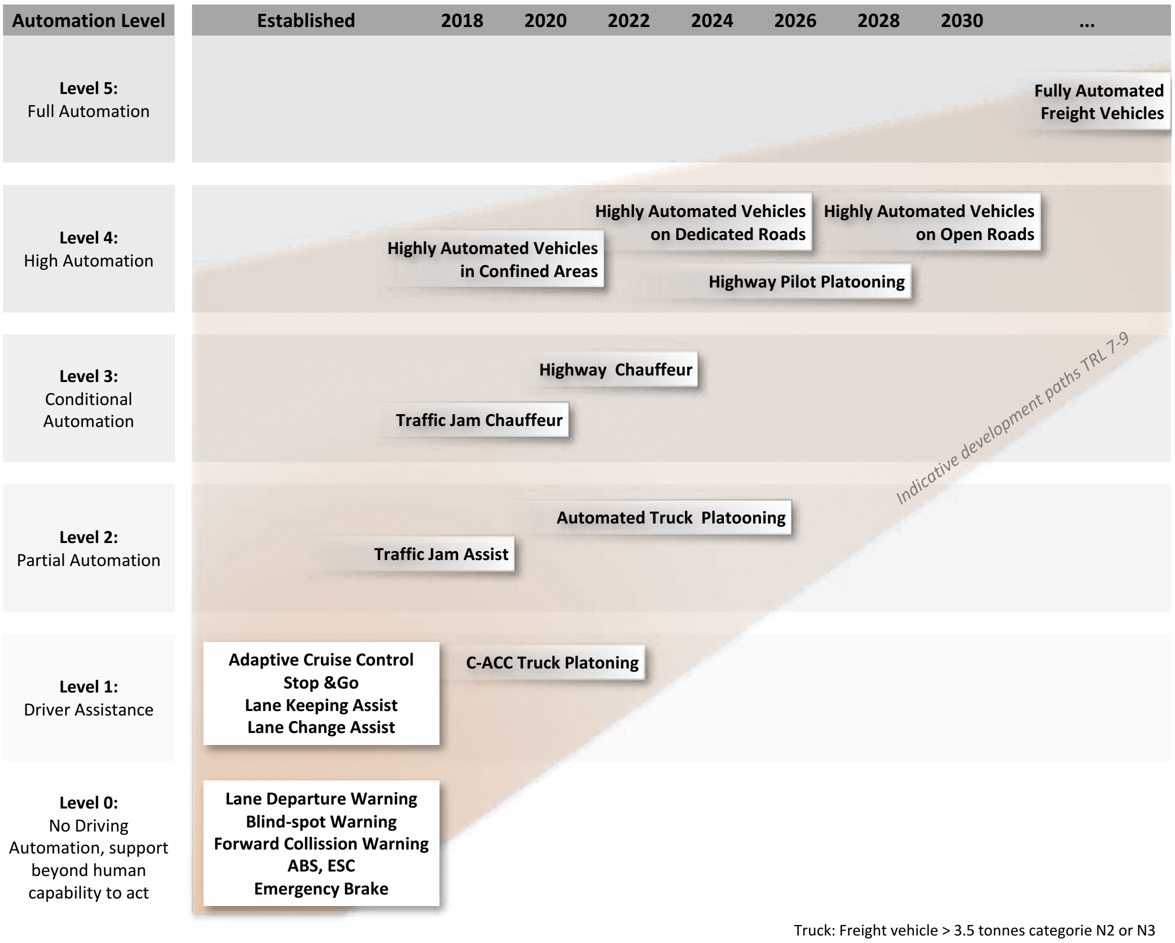

Figure 4: The Automated Driving development path for freight vehicles

3.3. Urban Mobility Vehicles

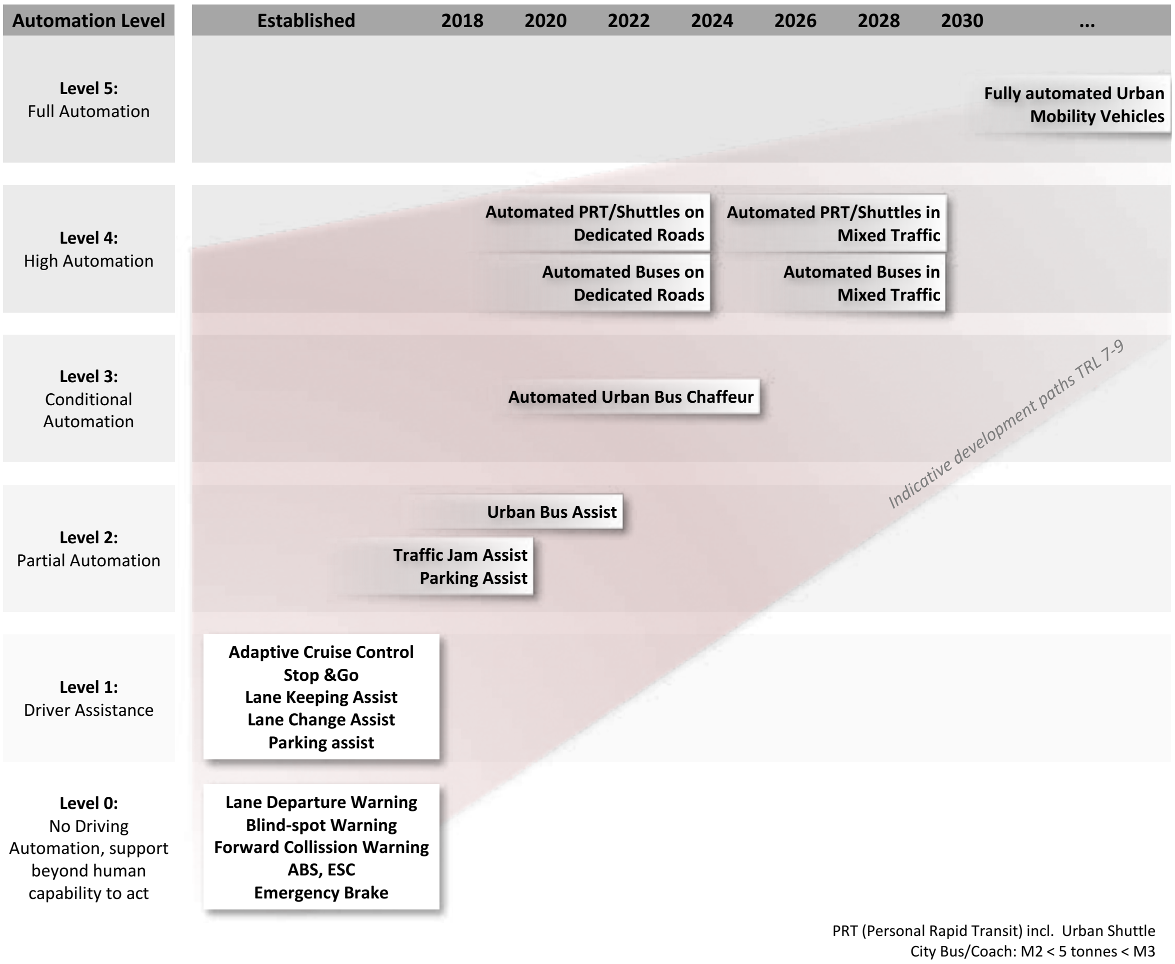

Figure 5: The Automated Driving deployment path for urban mobility vehicles

4. EU AND INTERNATIONAL INITIATIVES

4.1. European research projects

The European Union has already a strong history of funding collaborative research contributing to automated driving, as shown by the picture below, which provides an overview of the 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 in 2016 the launch within the Transport Programme of a specific call on "Automated Road Transport", with a dedicated budget of € 114 Mn for the years 2016-2017, addressing seven topics[1]. This "ART" call is expected to continue in the following years of the Horizon 2020 Programme, and this Roadmap aims to provide recommendations on the next topics to be addressed. Note that projects funded by the 2016 call are not yet included in the picture below, since projects are in the starting phase and full information was not yet available when drafting this document.

The picture gathers the projects in four research fields: Networking and Challenges, Connectivity and Communication, Driver Assistance Systems and Highly automated urban transport systems. A complete list of these projects is available in the Annex at the end of this document, containing additional information on duration, significant results and focus of the research work.

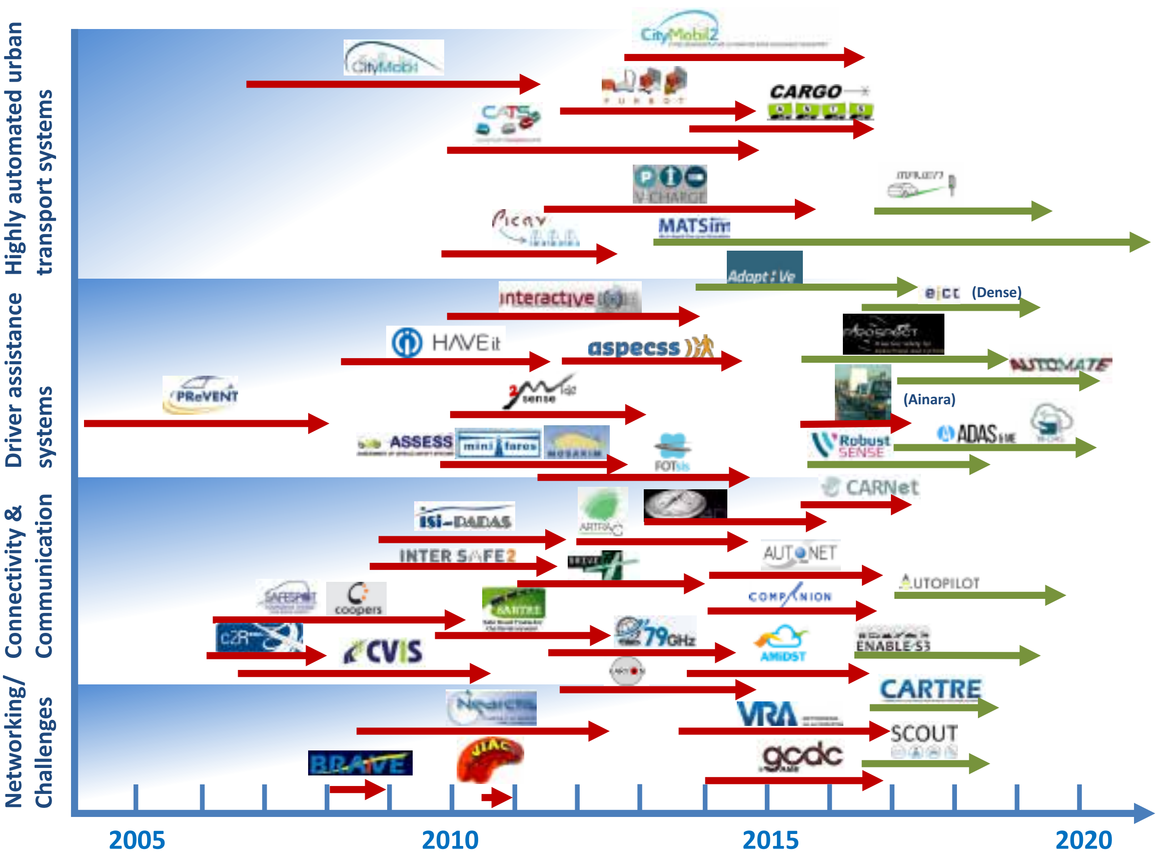

Figure 6: Overview of the EU funded projects that support development of automated driving. Red arrows indicate completed projects. Green arrows indicate projects still running in 2017

[1] 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. CARTRE and SCOUT Coordination and Support Actions

CARTRE is a Coordination and Support Action (CSA) funded by the Horizon 2020 programme. Started in October 2016 for a duration of two years, its goal is to support the development of clearer and more consistent policies for EU Member States, in collaboration with industry players, 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 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. It also includes support to international cooperation at global level, in particular with the US and Japan.

SCOUT (“Safe and Connected Automation in Road Transport”) is another CSA funded by Horizon 2020: it focuses on technology objectives and socio-economic benefits of Connected and Automated Driving, ranging from reduction of road accidents to an increase of productivity, improvements of social inclusion, and gains in energy efficiency, and also looking at the competitiveness of Europe by comparing EU activities with other regions of the world. The project therefore includes the assessment of use cases, societal goals and challenges; analyses gaps and risks for the take-up of C&AD; and identify sustainable business models. It includes a monitoring of international trends to detect opportunities and threats. And it gathers information and results from European funded research projects. SCOUT also aims to promote a common roadmap of the automotive and the telecommunication and digital sectors.

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.

A single website has been developed to gather and share information:

http://connectedautomateddriving.eu

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

4.2.2. Alliance of Automotive and Telecom Industries

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[2]. EATA comprises six sectorial associations: ACEA, CLEPA, ETNO, ECTA, GSMA and GSA as well as 38 leading European companies, including telecom operators, vendors, automobile manufacturers and automotive suppliers, all giving their commitment to support and contribute[3]. The main goal of the Alliance is to facilitate and accelerate the EU-wide deployment of connected and automated driving, with the following objectives:

[2] http://www.acea.be/press-releases/article/37-leading-companies-join-forces-in-european-automotive-telecom-alliance
[3] http://clepa.eu/wp-content/uploads/2017/02/20170227-Connected-and-automated-driving.pdf

- Removal of potential roadblocks and highlighting of required technical and regulatory measures.
- Identification of underlying business models for connected and automated driving, and stimulating public investment for innovation and deployment of connected and automated driving.
- Supporting to make Europe a global leader in this field.
- Providing a platform for knowledge-sharing between the automotive and telecommunications sectors to develop a 'common language'.

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[4].

As shown by the EATA roadmap below, the Alliance focuses on short-term deployment:

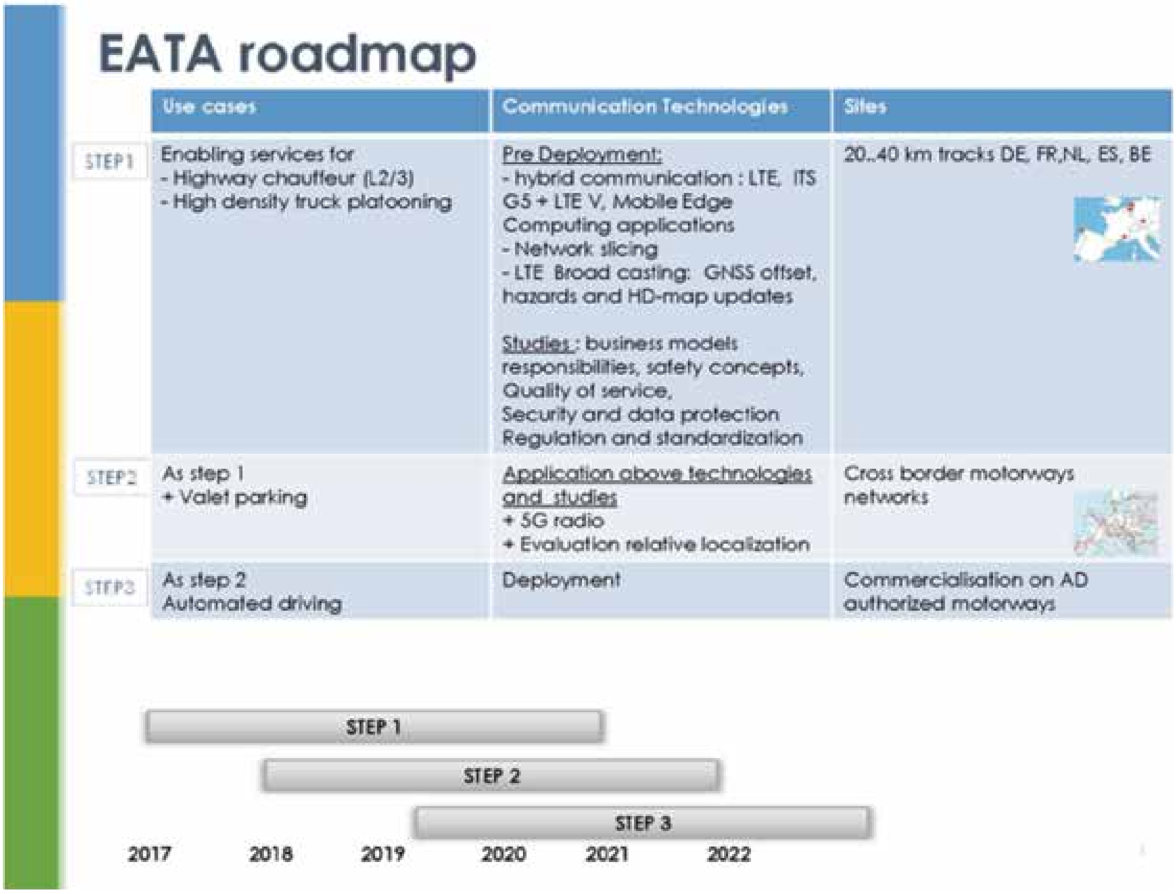

Figure 7: EATA roadmap: Within three steps the expansion of deploying connected and automated driving regarding use cases, technologies and sites will be realized

[4] https://ec.europa.eu/digital-single-market/en/news/eu-and-eea-member-states-sign-cross-border-experiments-cooperative-connected-and-automated

4.2.3. 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[5].

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 will deliver final recommendations by October 2017. These recommendations will be taken over by the Commission as part of its strategy for clean, connected and automated vehicles.

4.2.4. Cooperative Intelligent Transport Systems

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. It is considered important to increase the safety 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.

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

The European Commission created in 2014 a C-ITS Deployment Platform including national authorities, C-ITS stakeholders and the EC. It worked on building consensus amongst a wide stakeholder community on policy recommendations, a deployment strategy, and identifying potential solutions to critical cross-cutting issues.[6] In that frame of supporting the deployment of C-ITS on European roads, there are several C-ITS pilot projects funded under TEN-T and CEF programmes. Following the 2015 CEF call, the C-ROADS platform[7] was created to bring all these deployment initiatives together (currently 12 EU countries are associated) and develop joint technical specifications and ensure interoperability, through cross-site testing across Europe. The platform focusses on the deployment of the so-called Day 1 services using a hybrid communication approach (mature technologies currently include existing cellular networks and ITS-G5 for direct short range communication).

This is in line with the European Strategy on C-ITS[8], which the European Commission adopted in 2016 to facilitate the convergence of investments and regulatory frameworks across the EU, and enable the deployment of C-ITS services by 2019. It includes the adoption of the appropriate legal framework at EU level by 2018 to ensure legal certainty for investors, the availability of EU funding for projects, as well as international cooperation.

4.2.5. 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.

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 is available on the ECSEL website.[9] Here are some examples of research activities planned in ECSEL that can support the development of automated driving:

[6] https://ec.europa.eu/transport/sites/transport/files/themes/its/doc/c-its-platform-final-report-january-2016.pdf
[7] https://www.c-roads.eu/platform.html
[8] https://ec.europa.eu/transport/sites/transport/files/com20160766_en.pdf
[9] http://www.ecsel-ju.eu/web/publications/brochures.php

- 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

The 5G-Infrastructure PPP 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 challenges also include low latency, high reliability, and energy saving.[10] The target timeline for the deployment and commercialisation have been published in the Commission 5G Action Plan: 2020 for commercial roll-out and 2025 for continuous coverage over all 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: services based on vehicle-to-vehicle and vehicle-to-infrastructure connectivity are targeted, with a specific reference to automation. In October 2015, the 5G PPP together with ERTICO ITS Europe issued a white paper on “5G Automotive Vision”[11]. The document addresses how 5G is an enabler for innovation in the automotive industry, listing use cases among which automated driving is the first. Work is ongoing to integrate the specific technical requirements from the automotive industry towards future networks to be used for vehicles automation (in particular in the 5GCAR project). Standardisation and regulatory work for 5G are ongoing, and business models are still under assessment. This is why support to research and development activities is important at this stage: through the PPP, the EU will fund in the coming years R&D on the applicability of 5G connectivity to Connected and Automated Driving. It will be in line with the Letter of Intent[12] signed by Member States in Rome on 23 March 2017 and with the EATA Roadmap.

Cyber-Security

As part of the EU cybersecurity strategy, 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. The EU announced to invest €450 million in this partnership, under the research and innovation programme Horizon 2020.

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. Thus, it is essential for industry stakeholders with interest in automated driving to contribute to the definition of the upcoming cybersecurity regulation in order to ensure that interests and particularities are appropriately taken into account.

In essence, the following core activities are proposed by automotive companies:

[10] https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf
[11] https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-White-Paper-on-Automotive-Vertical-Sectors.pdf
[12] Digital Day in Rome – Signature of Letter of Intent by 29 Ministers – https://ec.europa.eu/digital-single-market/en/news/eu-and-eea-member-states-sign-cross-border-experiments-cooperative-connected-and-automated

- 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
- If cybersecurity regulation is unavoidable, it shall be restricted to cases of clear market failure and address processes and people before technology.

4.3. EU Member States initiatives

4.3.1. The Netherlands / Declaration of Amsterdam

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 is now also working on an '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 places 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. Learning by doing and making it happen 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 "Real-life cases Truck Platooning" and "Last mile solutions" in the Metropolitan area of Rotterdam – The Hague. 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 will be 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.

Declaration of Amsterdam

During the Dutch Presidency of the EU in 2016, at the Informal Transport and Environment Council in Amsterdam (14 April 2016), the **Declaration of Amsterdam**[13] was endorsed by Europe's Transport Ministers, the European Commission and the European Automobile Manufacturers' Association (ACEA). This was an important first step towards a common European strategy in the field of Connected and Automated driving and includes a joint agenda for further action to support the shared objectives. 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

[13] https://english.eu2016.nl/documents/publications/2016/04/14/declaration-of-amsterdam

development of connected and automated driving and to monitor progress. This will be done by having High Level Meetings twice a year, the first one took place in Amsterdam on February 15th 2017. In order to be ready for the deployment of connected and automated driving in 2019, the participating Member States, the European Commission and industry:

- agreed to continue the High Level Meeting on connected and automated driving;
- expressed support for a joint European approach;
- considered willingness to share vehicle data contributing to traffic safety and congestion reduction;
- set-up a public-private data;
- considered the need for cross border testing;
- emphasized the need for close cooperation in UN-ECE;
- agreed to work together on coherent national, international and European regulation;
- agreed to elaborate the working agenda, taking into account additional topics: impact on road operators, transport operators and traffic management; public awareness; cyber security; managed test environments.

4.3.2. France

The autonomous driving French national program, within New France Industry's initiative launched by the government, based on roadmaps from 2013 and 2015, has the objective to reach "affordable autonomous vehicles for all" from 2020. It focusses on three different applications and stakeholder groups: the industrial vehicle, the individual vehicle and public transport. The goal is to build the future of France equipped with autonomous vehicles that may revolutionize individual, collective and industrial transports. The development is built upon advanced driver assistance systems breakthrough and is strategic for both industry and jobs safeguarding. Automotive and transport industries, jointly with web and digital companies, create a competitive offer for components, sensors, software, control systems and services. The purpose of the national program is to put French automotive and road transport industry among the pioneers in designing mainstream autonomous vehicles. The action plan lists 4 objectives:

- Study the socio-economic impacts of such vehicles in depth
- Develop relevant technologies
- Create a regulatory and material environment that allows experimentation, in order to demonstrate safety
- Remove regulatory, social and material obstacles to commercialization

First results of the program have been achieved: a new legal framework for experimentation with automated driving is in place resulting in already 10.000 km of roads available, 28 test trials and more than 30 different projects. 14 working groups have been set up to realise this and progress towards the future on the topics of legal aspects, technical regulation, homologation, technologies, safety and security. The current focus is on large scale experimentation on open roads, to be started from 2018 onwards.

4.3.3. Germany

The "Round Table Automated Driving"[14] identified the different fields of action/challenges for implementing the strategy for Automated and Connected Driving set out by the German Federal Ministry of Transport and Digital Infrastructure[15]. To promote developments in these areas, the programme “Implementing the Automated and Connected Driving Strategy” was initiated by the State Secretaries of five different Ministries, defining five different working groups: Infrastructure, Legislation, Innovation, Interconnectivity, Cyber security and data protection and Societal dialogue. Each working group is connected to a Ministry and have defined their specific milestones. Research programmes/funding guidelines are available. A key project is PEGASUS, that is setup to deliver the standards for automated driving. Gaps in the field of testing will be concluded by the middle of 2019, up to the release of the highly-automated driving functions. The main goals are:

- Definition of a standardized procedure for the testing and experimenting of automated vehicle systems in simulation, on test stands and in real environments.
- Development of a continuous and flexible tool chain to safeguard the automated driving.
- Integration of the tests in the development processes at an early stage.
- Creation of a cross-manufacturer method for the safeguarding of highly automated driving functions.

With regard to the legal framework for automated driving on public roads, the national law has been adapted to incorporate the amendment to the 1968 Convention on Road Traffic (Vienna Convention), as well as the adaptation of legal regulations. A commission of inquiry has been established. The development of test fields in urban and suburban areas are financially supported. This way a sustainable interaction of motorway, rural and urban traffic should be established and insight into complex driving situations (traffic lights, crossings, roundabouts, identifying obstacles) are gained. First projects on digital test fields are currently implemented in Berlin, Braunschweig, Dresden, Düsseldorf, Hamburg, Ingolstadt, Munich. The Digital Motorway Test Bed (the A9 motorway in Bavaria) is also further worked on.

4.3.4. United Kingdom

Intelligent mobility is seen as a major opportunity by the UK government, especially the field of connected and autonomous vehicles and cooperative systems. This view is shared with the industry. The Transport Systems Catapult[16] has been created to accelerate innovation, funded by both government and industry, to speed deployment of new technologies and services. Examples of innovative products have already been encouraged within this environment, including the ULTRA driverless passenger transfer system at Heathrow Terminal 5.

In 2015, the UK Government created the Centre for Connected & Autonomous Vehicles (CCAV). The CCAV was set up to keep the UK at the forefront of connected and autonomous vehicle (CAV) technologies; to support that the research on CAV is effective and targeted at delivering value for the UK; and to ensure that vehicles are safe and secure by design and handle data appropriately. A Code of Practice for the testing of autonomous vehicles on public roads has been published.[17] No special permits or sureties are required for testing as long as the test vehicles are roadworthy; a trained driver or operator is ready, able and willing to take control; and there is an appropriate

[14] "Runder Tisch zum Autonomen Fahren", http://www.autonomes-fahren.de/runder-tisch-zum-autonomen-fahren/
[15] https://www.bmvi.de/SharedDocs/EN/publications/strategy-for-automated-and-connected-driving.pdf?__blob=publicationFile
[16] https://ts.catapult.org.uk
[17] https://www.gov.uk/government/publications/automated-vehicle-technologies-testing-code-of-practice

insurance. This facilitated three “driverless car” trials in Greenwich (GATEway), Bristol (Venturer), Coventry and Milton Keynes (UK Autodrive), which saw public demonstrations commence in 2016 and continue throughout 2017.

A £100 million Intelligent Mobility Fund (match-funded by industry) was announced with the aim of supporting collaborative R&D in “driverless” technologies. To date almost £50 million from the Intelligent Mobility Fund (and an additional £38m funding secured from the Industrial Strategy Challenge Fund) has been awarded to support almost 50 innovative collaborative research and development projects and feasibility studies.

The UK also recognises the potential to dramatically reduce the amount of fuel consumption in heavy-duty vehicles and is working closely with Highways England to demonstrate the benefits of platoons on the UK road network.

Finally, £100 million funding (matched by industry) has been made available to strengthen the UK’s testing ecosystem for connected and autonomous vehicles[18]. The test bed programme seeks to build upon the UK’s existing cluster of centres of excellence for physical testing, including the A2/M2 London to Dover Connected Corridor, and competitive advantage of being able to test anywhere in the UK. The programme will work closely with the UK’s 5G test bed, promoting the development of 5G technologies in the UK.

4.3.5. Sweden

The launch of the joint initiative "Drive Me - Self driving cars for sustainable mobility", endorsed by the Swedish Government and motivated by the vision of zero traffic fatalities, will enable research in different areas associated with self-driving cars on public roads. Beside Volvo Car Group, the Swedish Transport Administration, the Swedish Transport Agency, Lindholmen Science Park and the City of Gothenburg have been involved in this pilot project. Over approximately 50 kilometres of selected roads in and around the area of Gothenburg with 100 real customers in self-driving Volvo cars. An added value of the project lies in the fact that automated driving will be tested on typical commuter areas strained by congestion. The main objective of the project is, however, to conduct necessary research on how autonomous driving will affect road transport (both vehicle and infrastructure), considering worldwide challenges such as safety, energy efficiency and traffic flow. In addition, the project will also explore all accompanying factors such as infrastructure requirements, traffic situations, and surrounding interactions and social benefits of autonomous driving. The pilot is aimed to start in 2017 and similar pilots are planned for London and in China.

Scania and Volvo participated in the European Truck Platooning Challenge, and are now preparing for multi-brand platooning projects in Sweden as well as within Horizon 2020. Both are investing in the off-road (work yard) domain like mines, harbours, etc.

At Kista Mobility Week (April 2016), visitors got the opportunity to ride self-driving buses from CityMobil2 (EU project) for the first time in Sweden. The aim was to demonstrate how public transport services and ICT companies – with Urban ICT Arena’s platform as the foundation – could collaborate to create a smart and responsive city.

AstaZero, the world’s first full-scale test environment for future road safety, has now been in operation for around two years. And from 2016 is it the first test track in the world to have a dedicated 4G network on site at the facility, strengthening its position in the world.

[18] https://www.gov.uk/government/news/government-sets-out-next-steps-in-establishing-the-uk-as-global-leader-in-connected-and-autonomous-vehicles

On the legal side, in March 2016 a proposal for the regulation of trials with self-driving vehicles on public roads was submitted. Proposals for an introduction of fully or partially automated vehicles on the road are expected no later than November 28, 2017.

4.3.6. Spain

Spain is very active in the field of automated driving with a special focus on connected mobility. Sample projects and initiatives currently running are:

- Comobity: an app that allows drivers to be informed on the presence of other road participants like Vulnerable Road Users or a stopped vehicle so that they can adapt their behaviour to that and thus improve traffic safety.
- Collaboration with Mobileye on improving urban road safety.
- Mobility Map: providing real-time travel estimations for calculating the optimal trajectory of a journey.
- Supporting different automated driving testing through Europe like the PSA Vigo - Madrid tour and Cruise4U.
- During the Mobile World Congress 2016, Telefónica, ERICSSON, KTH and IDIADA organised a demo in which a vehicle in IDIADA proving ground was remotely driven from Barcelona (at a 70km distance) making use of 5G connectivity.
- Catalonia Living Lab: a Public Private Partnership lead by the Directorate-General of Traffic and with partners IDIADA, Polytechnic University of Catalonia, Cellnex, Urbis Up, RACC and the municipality of Barcelona. The goals are:
  - To create an ecosystem to develop urban self-driving initiatives taking in account all the involved agents,
  - To create the infrastructure to develop, to validate and test self-driving experiences
- AUTOPILOT: a European funded project to connect the Internet of Things to Connected Automated Driving. Amongst others a pilot test site for connected automated driving applications will be realised in Spain, i.e. further utilising SISCOGA, an initiative started by CTAG and DGT in 2010. It comprises a permanent cooperative corridor of more than 100 km created in order to carry out field operational tests on real roads towards cooperative safety and efficiency applications. This cooperative corridor includes interurban and urban scenarios (Vigo City).

Parallel to these initiatives and projects, the Directorate-General of Traffic (DGT) is working on an amendment to the General Regulations on Vehicles to allow the use of some urban and interurban roads to test autonomous vehicles. This now resulted in national traffic law ("Instruction 15/V-113: Authorization to conduct tests or research trials of automated vehicles on roads open to general Traffic") allowing for testing of automated vehicles in real traffic (and this is already used in the above described projects). The authorisation procedure is swift and flexible, and subscribes the foreseen transition from vehicle type approval to software certification for automated driving functionality, complying with the Annex I requirements. And it works under the "Mutual recognition" principle with other Member States.

4.3.7. Austria

The National Action Plan "Automated - Connected - Mobile" has set up the strategy towards automated driving in Austria in 2016 based on the expertise of more than 140 experts coordinated by AustriaTech as national focal point supporting its implementation and aligning activities. Specific use cases and applications are prioritised highlighting different criteria (e.g. traffic safety, increase of transport capacity, application in passenger, freight or off-road transport,...) The Austrian Ministry for Transport, Innovation and Technology (bmvit) sup-ports this process based on its responsibilities in planning and financing of road and ICT infra-structure, R&D funding programs, test facilities ("Learning Labs") as well as adapting legal framework conditions. A budget of more than 20 million Euro is provided for the years 2016 – 2018 for projects that comprise test facilities (Innovation Clusters), RDI Programs (Mobility, ICT, Security) and dedicated endowed professorships.

Like for many other European countries Austria has updated its type approval law to legalise testing. It comprises specific regulations for automated functions (up to SAE4+), delegated powers for the Minister to issue legal regulations, a Code of Practice (Part of the National Ac-tion Plan), international harmonisation and a standardised application form.

In 2016 and beginning of 2017, funding for more than 15 R&D projects as well as preparation studies for test facilities and projects for their implementation have been rewarded, covering different fields of technologies and applications. One test facility is under development in the surrounding and in the city of Graz, addressing the automation of light-duty vehicles. Another activity is the real-world mixed traffic experiment to be started in Vienna: a "European integrated automated driving test facility" shall be set up. Also in the Vienna region, a testing environment for automated vehicles is being organized, with a particular focus on freight transport and a multi-modal approach including a link to the airport and the port of Vienna. Another prov-ing ground called DigiTrans shall be developed in upper Austria, to serve as a test track for automation of vehicles.

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

A 75 km Aurora test section with a specifically equipped 10 km instrumented section along E8 in Northern Finland is in active use 2017-2019. The Arctic Challenge launched in the Aurora test section in January 2017 provides technical and financial support to stakeholders investigating the performance of automated vehicle technologies and the use of different solutions for automated driving also in harsh arctic conditions with snow and ice.

Automated public transport shuttles and buses as well as MaaS solutions are being tested in several Finnish cities to assess their technical performance, impacts, benefits and costs.

Truck platooning trials are being planned in Southern Finland, as well as road works machinery automation in Oulu region. Passenger car automation in urban environments is being tested in the Tampere region.

4.3.9. Greece

Greece has decided to allow the circulation of fully automated driverless vehicles in urban areas and on public roads. 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.

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 high-priority areas for conducting collaborative research have been identified as of now:

- Standards Harmonization
- Evaluation Tools and Methods
- Automation in Road Transport
- 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 is to:

1. Exchange regional information so that all parties stay up to date with one another's research programs and policy developments
2. Address vehicle and road transport automation issues that apply to the public authorities in relation to all stakeholders
3. Develop and disseminate proceedings or reports that advance understanding of the impact, policy, and operational issues of increasingly automated vehicles
4. Identify needs for harmonization and standardization in order to support international developments and deployment.

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

To date, eight areas of shared interest have been agreed upon as candidates for ART WG cooperation. Topics are taken up for bilateral or trilateral work within the ART WG according to the interests and resources of the parties.

- Digital infrastructure: to identify the role of digital maps for automation
- Human factors: to identify solutions for driver and other road user interactions
- Roadworthiness Testing: to define the necessary or appropriate tests required to allow the safe and reliable operation of automated vehicles on public roads
- Evaluation of Impact – Impact assessment: to establish a unified list of potential direct and indirect socio economic impacts, and jointly try to quantify them
- Accessible transport: to identify transformative automated transportation solutions for all people, including those with disabilities, and demonstrate operational solutions.
- Connectivity
- System Reliability and Security (including cybersecurity)
- Legal Issues (ad hoc): to monitor the activities in the different regions

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 tracks:

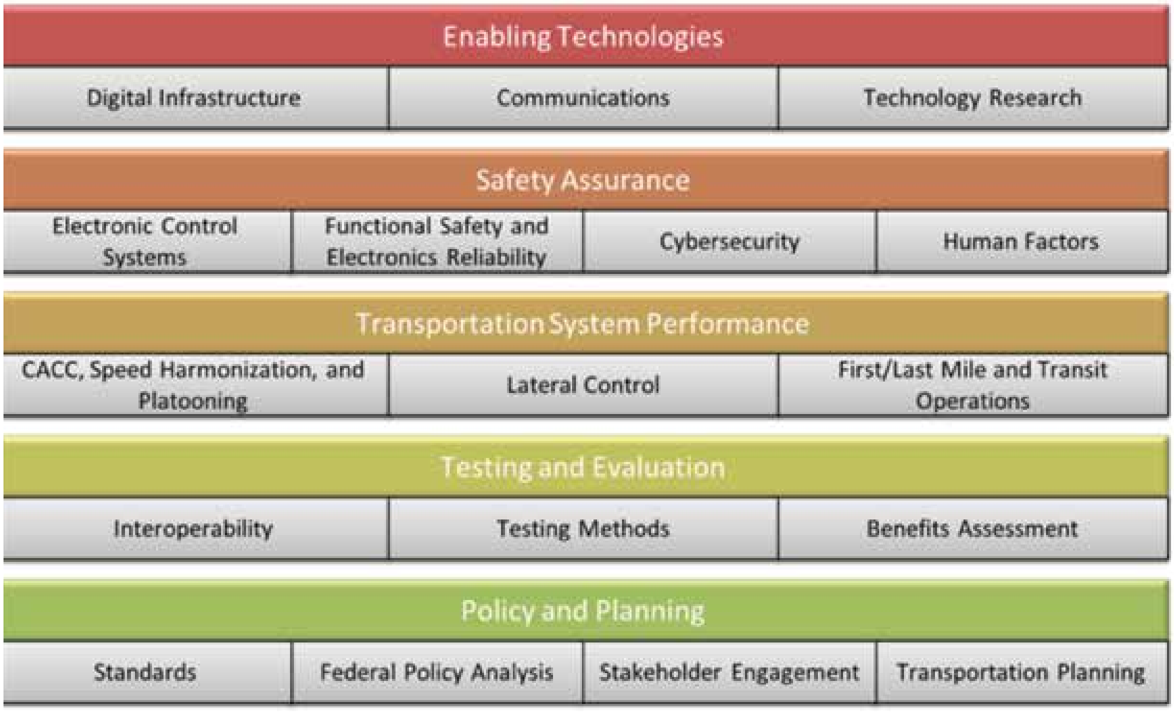

Figure 8: US DoT ITS JPO Automation Program research tracks

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. Deployment experience is gathered efficient and quick, as all new models delivering a Level 2 system have to deliver the 15 vehicle safety performance criteria.

The ITS JPO together with VOLPE has recently worked on a harmonised framework to impact assessment of ART, which is now further developed with the EU and Japanese experts. The framework takes a broad look at the impact of AV introduction combining a large set of influencing factors such as safety, mobility, energy, emissions, network efficiencies, land use, etc.

FHWA continues to conduct exploratory research to understand the impacts of automated vehicle technologies on the nation's roadway system: technical research leading to commercialization on connected Level 1 automation applications (e.g. CACC and light vehicle platooning) – with CAMP; CACC-Enabled Eco-Approach/Departure Small Scale Test – with CAMP; Exploratory research on truck platooning applications including truck manufacturers and suppliers; Evaluating the transportation planning process and policies for automated vehicles.

FHWA is funding demonstration projects: developing and testing Cooperative Adaptive Cruise Control (CACC) for Heavy Trucks in Los Angeles, and, Advanced Transportation and Congestion Management Technologies Deployment in San Francisco. FHWA also runs a programme addressing accessible transport named ATTRI.

NHTSA has extended the funding for the Level 2 AD naturalistic driving study in order to gather data for longer exposure. The agency has also granted a project on driver expectation impairing the ability of drivers to take over control of the vehicle. An additional project is funded on communication and interaction of AVs with other road users.

FTA is finalizing a plan for transit automation research; it will address automated buses of different types including low-speed low-capacity last-mile public transport.

As part of another initiative, the US DoT has awarded the smart city challenge to the city of Columbus, Ohio. The scope of the project is very large including first-last-mile solutions and truck platooning.

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

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) includes a new research and development plan called Innovation of Automated Driving for Universal Services (adus) as one of ten priority policy issues. The plan was initiated in May 2014 and includes 2.45 billion yen per year. Targets include Level 2 systems in 2017, level 3 in the early 2020s, and Level 4 sometime thereafter.

There are three working groups which include both public and private members: system implementation, international cooperation, and next generation urban transportation. Only pre-competitive issues are addressed leaving the rest of the research to the competition to the industry.

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.

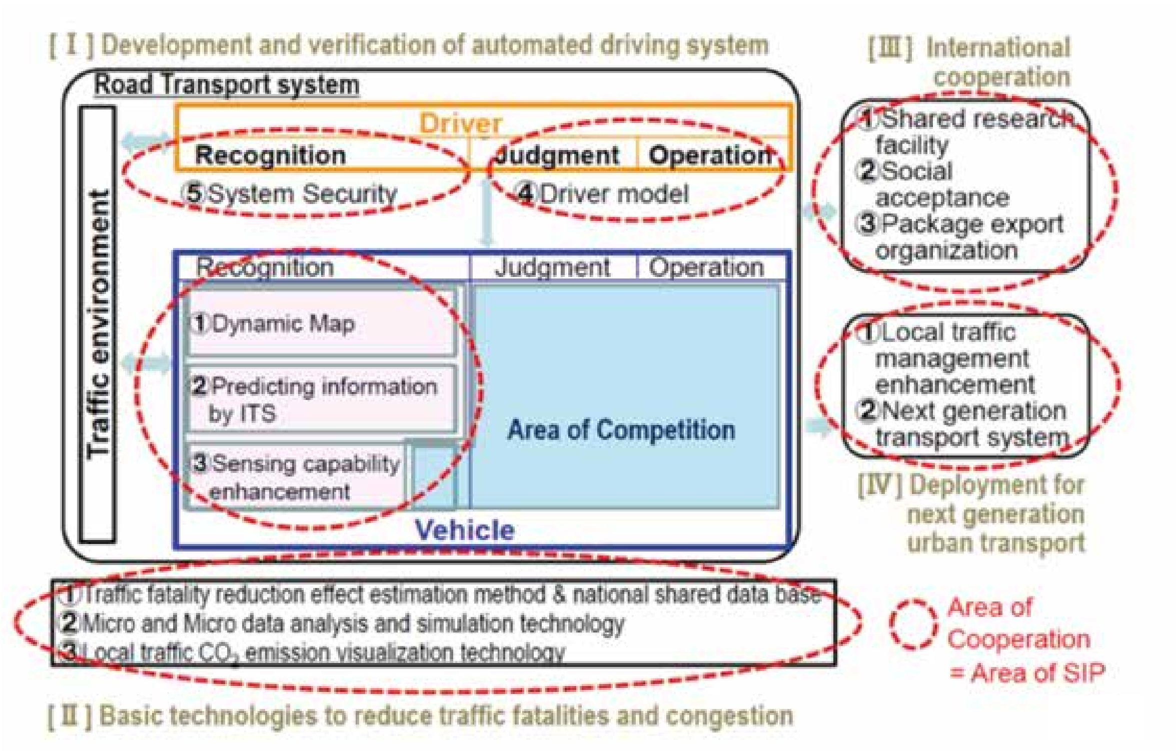

Figure 9: Japan Cross-Ministerial Strategic Innovation Promotion Program (SIP) Automated Driving System Research themes

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.

After two years of research, SIP-adus is planning to make a series of field tests with the wide participation of the Japanese automotive industry. Public road testing will start from September 2017 for a period up to 3 years. Different test sites are planned: Arterial roads around the Olympic games area in Tokyo, the Express way around Tokyo and the JARI testing facilities.

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 a total of 320 km designated routes on five national highways, including Suwon, Hwaseong and Yongin and a 41-kilometer section on the Gyeongbu Expressway from Seoul to Busan as well as the Incheon-Gangneung expressways. Therefore, the Ministry provides temporary licence plates to OEMs, universities and research laboratories.

Furthermore, the Seoul National University has introduced a demonstration project called Snuber (SNU + Uber) at the Seoul National University campus testing different technologies in its autonomous vehicle prototype.

Besides that, the main research activities in South Korea are evolving from the car manufacturers themselves. 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.

4.4.5. China

In October 2016, China's "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. Furthermore, 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 set up 3 national test sites for connected and self-driving cars in Shanghai, Beijing and Chongqing, which aim to facilitate R&D, standard studies and policy formulation, as well as to test and certify connected car technologies. The government plans to expand the number of testing programs to 100 by late 2017. From 2018-2019, 5,000 automated vehicles will be deployed in an expanding testing area of 100 square kilometres. And then in 2020, China plans to launch a self-driving vehicle demonstration city near Shanghai.

The China Automotive Technology and Research Centre (CATARC), a centralized technical organization of the auto industry and the technical supporting body to the relevant national government departments, assists the authorities and enterprises regarding research on industry policy and stakeholder involvement also in the area of connected and automated driving. In this regard, CATARC has signed a cooperation agreement with the Japanese company Nissan Motor Co., addressing the adaptation of safety features to adjust its work and production to China's driving habits and road conditions.

The OEM Great Wall Motor Co. is investing in R&D activities as well as in cooperation with other nations. This also includes the construction of research and development centres in India, North America and Europe in order to intensify the business relations in the area of automated and connected vehicles.

There were several research centres, related to automated driving, opened by Chinese OEMs overseas. Chongqing Changan Automobile Co. has an autonomous driving program and additionally invested in new research facilities in the U.S., Japan, Britain and Italy. Zhejiang Geely Holding Group Co. and Volvo car unit created a research centre in Sweden (Gothenburg). There is also the China-Sweden Centre for Traffic Safety (CTS) as the bilateral Sweden-China centre where AD is an important area for research. Furthermore, Baidu Inc. launched its Autonomous Driving Unit (ADU) to develop vehicles capable of sensing and navigating without human input. Based in Beijing and in Silicon Valley, ADU is part of Baidu's Intelligent Driving Group (IDG). Also Bosch announced a new cooperation with the leading Chinese high-precision map providers Amap, Baidu und Navinfo: the objective is to provide improved maps for automated driving in China based on Bosch radar and video sensors.

4.4.6. Singapore

The Singapore Autonomous Vehicle Initiative (SAVI) is a joint partnership between the Land Transport Authority of Singapore (LTA) and the Agency for Science, Technology and Research (A*STAR) to provide a technical platform for industry partners and stakeholders to conduct R&D and test-bedding of AV technology, applications and solutions and support the committee for Autonomous Road Transport for Singapore. One of the focus areas under SAVI is to prepare technical and statutory requirements for future deployment of AVs in Singapore.

The Massachusetts Institute of Technology (MIT) established the Singapore-MIT Alliance for Research and Technology (SMART) in collaboration with the National Research Foundation of Singapore (NRF). One of the interdisciplinary research groups within this alliance is addressing the topic "Future Urban Mobility" in and beyond Singapore.

To achieve a future mobility vision of a new systems of self-driving shared mobility-on-demand services, LTA recently signed a separate partnership agreements with Delphi Automotive Systems (International Tier 1 supplier of vehicle technology) and nuTonomy (self-driving vehicle technology start-up) to test their different self-driving transportation concepts in the one-north test-bed.

Since the collaboration of Singapore with the two automotive companies Delphi and nuTonomy, Singapore's Land Transport Authority has launched a new autonomous vehicle research and development centre, the new Centre of Excellence for Testing and Research of Autonomous Vehicles, which is supported by the LTA and the Nanyang Technological University of Singapore.

Further international research project as for example TUM CREATE, a joint project between the Nanyang Technological University in Singapore and the Technical University Munich, was funded by the national research foundation of Singapore and investigates the Design for Autonomous Mobility amongst other.

Furthermore, the world's first self-driving taxis were recently launched in Singapore.

4.4.7. Australia

The Australian Transport and Infrastructure Council has reviewed its 'National Policy Framework For Land Transport Technology' in August 2016. The update to this Policy Framework provides policy principles and guidance on governance and actions to support AV deployment. The document outlines a full action plan for the introduction of new transport technologies. Key issues in deploying new transport technologies are Safety, Security and Privacy; Digital Infrastructure; Data; Standards and Interoperability; and Disruption and Change.

The National Transport Commission (NTC) has published its “regulatory reforms for automated road vehicles”. This policy paper sets out transport and infrastructure recommendations for policy and regulatory reforms to support automated road vehicles in Australia.

The VicRoads “Road Safety Action Plan” includes $10M action to trial connected and automated vehicle technologies. The VicRoads grants program is working with industry to undertake a range of trials and assessments to clarify the current and new infrastructure technology needed to optimise mobility and safety benefits from emerging technologies among them a trial of automated vehicles, including their integration with roadside infrastructure, has been announced. Also Bosch has been partnering on Highly Automated Driving Vehicle with Transport Accident Commission (TAC) and VicRoads.

In Queensland, the Cooperative and Automated Vehicle Initiative (CAVI) incorporates a smaller pilot of cooperative and highly automated vehicles driven on selected roads.

In Western Australia, Main Roads WA is partnering with industry to launch an Autonomous Heavy Vehicle Platooning Trial.

Finally, a series of driverless shuttles have been planned in different cities such as Melbourne, Perth, and university campuses.

5. KEY CHALLENGES AND OBJECTIVES

Automated driving is the opportunity to address several important societal challenges of road transport: **safety, energy efficiency, congestion, urban accessibility and social inclusion**. These societal needs match with the Vision and the Strategic Research Agenda of ERTRAC for the long-term evolution of the Transport System. Impacts should be assessed in the wide sense: not only from the introduction of new vehicle technologies but also considering new services enabled by automation and their likely societal impacts. So a System approach is necessary to have a good overview of what the deployment of Automated Driving can bring. Mobility offers could extend to more users including elderly and people with disabilities. And new solutions for shared mobility and public transport could be developed, which could have important impacts on our future urban and inter-urban environments. And these benefits can be applicable to both passenger and freight transport.

The following chapters list the main challenges and objectives on the path to higher levels of automation. Various types of actions are necessary, sometimes at local level, sometimes at European level, and sometimes also at the international level with other world regions. 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. But firstly, policy and societal aspects must be addressed, to ensure proper user information and acceptance, and trigger the necessary regulatory adaptations.

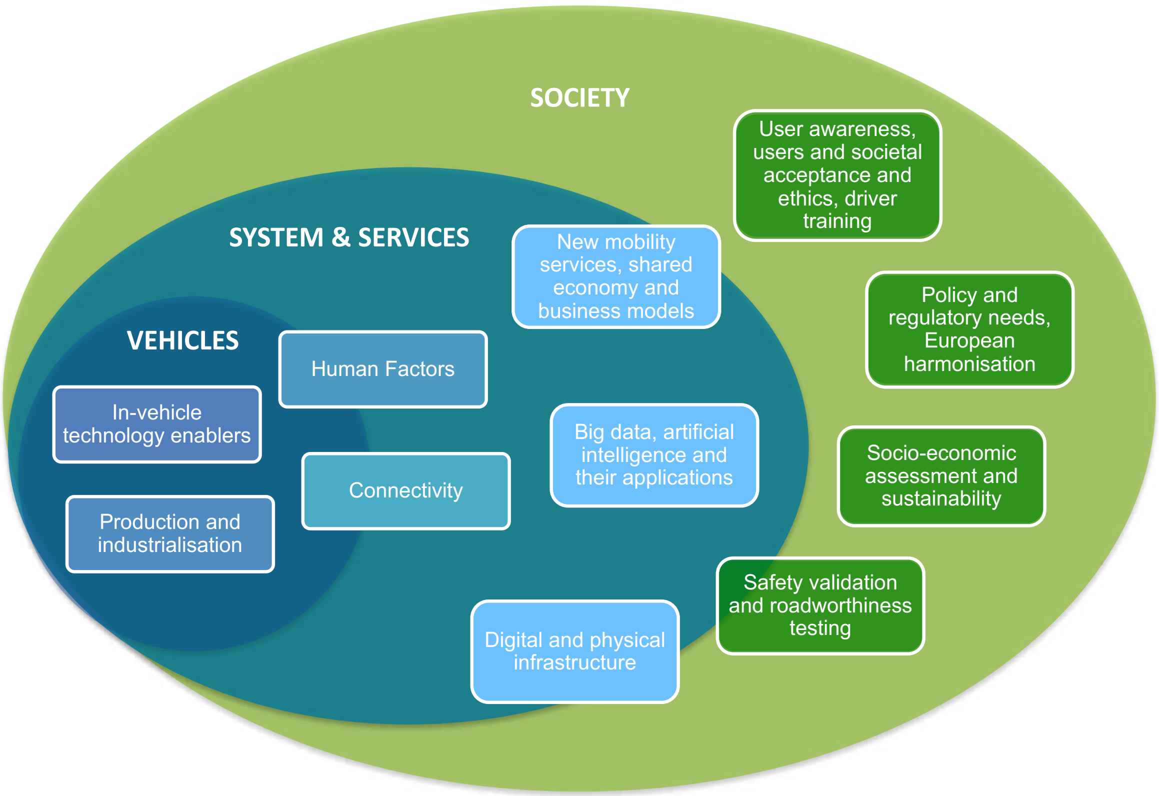

Figure 10: Thematic challenge areas

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

The classic questions in discussion since the earliest science fiction movies on robots are dominating public debate. Will ART take control from the users? Will it be accepted? How will this personality be reflected with automated vehicles?

More concrete are questions to be answered: In what setting could it be acceptable that ART takes the control from the users (against the background of autonomous shuttles on public roads with no actuators like pedals and steering wheel which force the driver to become the silent passenger)? How to handle socio-economic and age group differentiation with regards to automated vehicles? 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?

It is a big public and scientific discussion: in which situations will an automated car ever have to make an ethical decision? How can this be compared to today´s accident situations and driver decisions? – 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. Policy and regulatory needs, European harmonisation

Today, the discussions concentrate on research, testing and type approval. First activities on traffic rules are started in some countries. But which areas of policy and regulation are affected in total?

As technology is developing, research and testing comes to a phase where questions of standardisation start. How can European research and testing activities be bundled and coordinated to speed up and not loose worldwide competition?

On type approval regulation, Level 2 is in the process of being regulated in detail under UN-ECE WP29 with the update of UN-ECE R79. The detailed regulatory requirements on Level 3 are just starting, on Level 4 and 5 there is not yet a concept there on how to proceed. How can the type-approval approach evolve? How to set up regulation quick enough to be in place when technology will be ready? How to deal with software updates?

In some member states, there are first adaptions in progress or even in place (Germany´s new “Straßenverkehrsgesetz”). How and to which extent should traffic rules be harmonized for a quick introduction of higher automation levels?

Also liability is an area, where much is discussed, but no concepts show up, how to support a quick and controllable deployment. What liability framework needs to be in place to facilitate market penetration from a legal/liability perspective?

5.3. Socio-economic assessment and sustainability

How to come to a realistic und harmonized evaluation of socio-economic and sustainability impact of connected and automated driving?

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?

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?

5.4. 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 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 automated driving? To what extent should virtual tools support safety validation?

How to ensure modularity to cover different levels of the whole system: component level, vehicle level, system 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, infrastructure functional updates and vehicle lifecycle?

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?

5.5. New mobility services, shared economy and business models

How will the area of shared vehicle and shared ride services evolve?

How to handle and stimulate mobility services innovation?

How to handle management of professional driver services management such as driving/working/resting time operation?

What are the new business models for private, commercial and public users of automated vehicles?

What role should local governments play in facilitating Mobility as a Service (Maas)?

5.6. Big data, artificial intelligence and their applications

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 Artificial Intelligence (AI) techniques, such as machine learning including deep learning, play a major role in both data analytics and development of (AI) automated driving functions/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.

One main challenge is to evaluate the fields of application of Artificial Intelligence (AI) methods for automated driving. The data processing chain as a whole must be considered and the modules with the highest potential must be identified. In focus are understanding of scenarios, prediction of behavior and driving strategies. Answers to the questions which architectures are needed to integrate AI-methods and combine with classic algorithms are needed and what is the impact on component and safety requirements are needed.

Here are some specific challenging questions listed:

What ART data is most valuable to store and share and how to be acquired and converted and updated?

How can big driving data be used for human factors as well?

How to provide a reliable and privacy proof interfacing with big data repositories?

How to handle the reducing validity of big data over time, i.e. how to control validity of deep learning?

How is the format of the data sets to be standardized?

What are the criteria for data records for AI training and validation?

How are AI-algorithms integrated in an AD-system focusing on modularity and maintenance?

How is ground truth and functional safety and reliability of systems with AI content validated and verified effectively and with legal certainty? In this context It is important to distinguish between AI functions for perception, control, safety, comfort or for pure data analysis.

What are the requirements on the architectures of the underlying technological platforms?

5.7. Digital and physical infrastructure

What are the roles and responsibilities of the different stakeholders for physical and especially digital infrastructures for connected and automated vehicles? Who should pay and how for the implementation, maintenance and operation of the infrastructures?

Should the vehicle cope with any road infrastructure, and if not, what demands can be set to adapt the existing physical infrastructure – including planning, building, operation, maintenance while also considering the differences in operating environments ranging from rural roads in remote areas to busy interurban motorways and from residential areas to central business districts? How to ensure continuity between those different environments?

In which conditions should dedicated lanes/roads/areas be allocated to automated vehicles especially in the transition phase towards full automation?

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).

Where is digital infrastructure necessarily needed for different levels of automation?

What are the terms, conditions and roles for service provision, collection of, and access to data from especially automated vehicles?

How to ensure the security of the infrastructures?

How to manage and verify the changes made to the physical infrastructure, and guarantee the level of quality of the information? How to deal with failures? How to deal with extreme and adverse weather conditions (heavy rain, fog, snow, ice, sun reflection, etc.)?

5.8. In-vehicle technology enablers

In-vehicle technology systems, devices and components are an essential part and main enablers of the evolution towards CAD.

One leading challenge is to reduce costs down to an optimum balance to the benefits and master complexity for the strongly divergent solution space of functional and technological combinations.

The whole functional chain from perception over decision making to actuation must fulfil significantly enhanced redundancy and fail operational requirements. Facing a variety of vehicle concepts and use cases, this will only work with vehicle system architectures built upon modularity, scalability, standardization and maintenance. This includes in particular also software architectures.

For environmental perception robust, complementary and highly reliable sensor systems must be provided. These must satisfy reliability requirements by using redundant technologies for each area. Depending on the specific AD use case the affordable sensor configuration is to be evaluated.

Vehicle localization is one essential enabler for HAD. This leads to the need for an on-board available HD map which must be precise and up-to-date integrating several input data like video and radar road signature information. From vehicle perspective this must be supported by efficient communication networks.

Not to mention that there is a strong interference of in-vehicle technology enablers with safety validation and roadworthiness testing.

5.9. Production and industrialisation

Future vehicles, services and business models on the one hand and technical requirements on CAD functions on the other have impact on the needed enabling products and components. The leading main challenges on production and industrialization in this context may be characterized by the following questions:

How to speed up “time to market” to enable early market deployment of new solutions with?

How will the automotive industry handle the transformation into software driven industry and handle complex functional growth, continuous software online updates and cyber-security?

What production (End of Line) tests and methodologies will be necessary to ensure product reliability considering CAD?

What kind of quality assurance tests and certificates will be required?

How will the after-market industry be impacted? Which after-market products will be available? How will maintenance be assured considering vehicle life time?

What will be the overall impact of CAD on the automotive industry?

5.10. Human Factors

How to understand the interaction between humans and automated vehicles (in-vehicle and outside vehicle) at different levels of automation?

How to find design solutions and standards for human factor challenges such as misuse, skill degradation, level of trust and acceptance, motion sickness?

How to adapt the vehicle automation to different user needs and group?

How to design the safe, intuitive interaction of automated vehicles with other road users?

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?

Should the Human-Machine Interaction (HMI) design should be standardised or open for disruptive solutions?

What are the needs for changes in the traffic environment?

Will automation enable a much higher share for car sharing and ride sharing schemes?

How will human mobility change from individual driving towards mobility-as-a-service?

5.11. Connectivity

What are really the AD needs for connectivity? Will AD be a driver for V2X communication? Will multi-brand trucks-platooning be a driver for CAD? There is a strong demand for viable AD use-cases.

How to ensure ubiquitous connectivity of different communication technologies? How to ensure mass market adoption of V2X communication in accordance with spectrum availability? How to ensure interoperability of V2X connectivity between countries? How to ensure V2X communication protocols for automated driving?

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?

How to balance the fast evolution of and the demand for connectivity with the slower pace of vehicle and infrastructure development? How to deal with the growing demand for communication, bandwidth and data?

6. RECOMMENDATIONS FOR HORIZON 2020 WORK PROGRAMME 2018-2020

Recommendations have been prepared by the ERTRAC Working Group on “Connectivity and Automated Driving” and delivered to the European Commission services in December 2016. They call for activities at European level in the coming years, addressing the Transport Programme of the European Research and Innovation Programme “Horizon 2020”.

The mission of ERTRAC is only to provide recommendations upfront: the European Commission is responsible for the preparation and publication of the Horizon 2020 Work Programmes.

Efficient and safe Connected and Automated heavy-duty vehicles in real logistics operations

Specific Challenge: Implementing connected and automated driving in multi-brand/multi-fleet heavy-duty trucks freight transport operation has great potential to improve freight efficiency, safety and fuel efficiency in real logistics operation on roads in mixed traffic and in confined areas. There are a number of specific challenges that needs to be addressed: enhanced vehicle technologies for improved perception, control, connectivity, resilience and cost; harmonization and acceptance with other road users, infrastructure and logistics in mixed traffic on public roads; enhanced harmonized operation in port and terminals to optimize the complete logistic chain.

Scope and Content: The focus of this topic is to: investigate needs and opportunities; develop, test and demonstrate innovative, safe, efficient and resilient hub-to-hub long-distance connected and automated enhanced freight logistics operation on public roads in mixed traffic and at terminal logistics sites.

Expected Impacts: Improvement of overall freight transport efficiency, energy efficiency and safety.
RIA/IA, WP2020

Automated concepts for safe and efficient last-mile urban logistics

Specific Challenge: Connected and automation technologies open up for new possibilities to improve freight transport vehicles utilization, operation, loading and distribution. The challenges for urban freight transport are to handle the increased demands for urban freight transport in balance with the need to improve efficiency, safety, emissions and resource utilization of the overall urban logistics system.

Scope and Content: Research and innovation of end-to-end automated urban logistics solutions, waste collection, last-mile delivery, goods-on-vehicle consolidation and consolidation centres. This topic will address how automated low-speed solutions will complement the existing high-speed transport networks for goods. Modular building blocks (mechanical and electrical) for autonomous transportation units designed for scalability enabling maximum availability. Multi-stakeholder pilots in order to address the operational needs and opportunities to increase efficiency, flexibility and reduce travel time and costs. Investigate the potential of combining automated urban delivery and people transportation.

Expected Impact: Improvement of overall urban freight transport efficiency, operation efficiency, emission reductions and safety.
RIA

Automated Public Transport – from Today and into the Future!

Specific Challenges: The bus public transport system needs to evolve to meet and balance the increasing demands from the users, the operators and from the society of improved efficiency, safety and environmental impact. Improved utilization of existing urban road infrastructure, reduced travel time, increased accessibility for all users, convenience, safety, reduced time at bus stops and charging stations, operation at bus-depots are challenges that needs to be addressed. Implementation of connected and automated technologies in enhancing driver operated full size buses, highly automated public solutions. Introduction of innovative solutions for connected travellers and fleet operators of tomorrow.

Scope and Content: To speed up the introduction of CAD technologies this action will demonstrate how to implement automated solutions in the public transport system for increased mobility efficiency and safety. Urban bus-trains/BRT-evolution, bus depot automation, bus-stop automation, charging station automation and automated accessibility solutions for impaired and elderly users should be addressed. Multi-stakeholder involvement, research, concept development and demonstration and impact assessments in typical European urban and rural contexts.

Expected Impact: Transport efficiency, driver and operator aspects, enhance existing system, BRT, electrification.
RIA, WP2019

Short and long-term impact and socio economic assessment of connected and automated driving

Specific Challenge: We need to assess the short, medium and long term impacts, benefits and costs of the deployment of automated vehicles in order to make decisions related to investments on connected and automated driving. Higher levels of automated driving present a rupture in evolution of driver support and the whole driving task making the assessment of impacts of automated driving difficult and challenging as the changes in mobility itself (vehicle ownership and use, choice of residence, use of mobility services, use of travel time for different purposes, etc.) are likely substantial but hard to estimate ex-ante, and will affect all other impacts. The behavioural impacts will also be challenging due to need to get also sufficient empirical data on actual behaviour of automated vehicles in open traffic as results from simulators and models need empirical support for their transferability.

Scope and Content: A large research and innovation project comparing the impacts, benefits and costs of different scenarios of road vehicle automation deployment would enable European and national decision-makers to assess and promote the most promising scenarios. The scenarios assessed should contain all major location, road, condition and different user types as well as the related varieties of vehicle automation. Impacts on both mobility behaviour as well as driver behaviour, and thereby on safety, traffic efficiency, CO_2 and other environment should be included. Specific attention should also be paid to the transition phase towards higher levels of automation, where human- and machine operated vehicles are both present in varying penetration degrees, as well as the impacts on urban mobility.

Expected Impacts: Good knowledge basis for European and national decision makers to decide on which deployment scenarios to support and which to deploy, resulting in accelerated measures to facilitate large-scale deployment. Information on gaps related to assessment methods and their further development.
WP2018-19

Connected automated driving for the mobility of all

Specific Challenge: With higher levels of automation being deployed, development of easy access and use of automated vehicles, as a driver/rider also for the elderly, the children, and those with disabilities (movement, sight, hearing, cognitive, mental), will give many new possibilities of mobility to their lives and need to be understood and included in the development of the future road transport system.

Scope and Content: A large research and innovation project assessing the requirements of the afore-mentioned user groups to better understand which new possibilities in work, leisure and travel have their priority, and developing use cases, services and designs corresponding to the needs of these users. With these use cases, connected and automated vehicles and infrastructure work hand in hand with these new mobility solutions. In the assessment and development, also some more general well-being criteria and indicators such as participating in transport, access to new ICT solutions, access to physical and mental health services, personal safety, equality, cost of travel will be applied. The development can address possibilities to adapt the basic parameters for automation (headways, control takeover, safety margins, etc.), access (entry, exit) to automated vehicles, automated driving in adverse road and weather conditions, mobility of both people and goods, and use of public and shared transport. The different user needs in different regions and operating environments including both rural and urban conditions should be addressed, aiming at compatibility across EU member states.

Expected Impacts: Completely new solutions for the mobility of all will have impact on all stakeholders of the road transport system across Europe and give new opportunities to the elderly, children and persons with disabilities.
WP2020

Automated vehicle driver behaviour modelling and demands

Specific Challenge: The role of the driver will change dramatically when higher levels of automation are introduced into road transport. This is the start of a very long transition phase with coexistence of manually driven vehicles and automated vehicles. Drivers/operators must have a very clear understanding about the automation grade available in each situation.

Scope and Content: Research for upgrading the driver behaviour, monitoring and readiness models and impact and especially safety assessment methods based on these models is necessary due to new relationship between driver and vehicle (mutual cooperation or even handover rather than continuous control) as well as the use cases where an operator controls the vehicle remotely. This leads to virtual human modelling for driver/operator behaviour and readiness as well as impact evaluations considering also driver control handover, driver/operator state and impairment. Solutions for keeping the driver/operator in the loop and for ensuring a secure function (re-)allocation with reduced resources. A support action is needed to explore the impact on the new driver/operator roles and skill needs on regulations, driving tests, advanced driving courses, general public information, and safe driver education programmes, including both current and new drivers, and use of both automated and manually driven vehicles. [The focus is on levels 4-5 while building on ART4 for level 3].

Expected Impacts: A better common understanding and evaluation of driver/operator behaviour gives the framework for the deployment of higher automation levels. So behavioural risks in road traffic caused by drivers/operators being not aware of the performance and limits of the automation grade of their vehicle can be avoided. WP2018-19

Testing and Validation

Specific Challenge: Driver assistance functions require significant effort of testing and validation to be achieved by automotive industry already today. In highly automated and autonomous driving modes, the driver will be out the loop: this means a huge increase of scenarios, which have to be validated. This will not be feasible - not to mention affordable by individual approaches. So there is need to assess testing and validation processes for highly automated and autonomous driving. On such a basis, also completely new liability questions need to be addressed before products are on the market, to create a robust framework for business cases of all partner industries (transport, IT, telecom, insurance). Also, enforcement can be crucial to Member States when new approaches are necessary to be in place together with automated vehicles coming to the market.

Scope and Content: What should be covered by this project is the development of testing and validation processes of future systems. Detection of driver or user misbehaviour, misuse or abuse by utilizing data available through communication (in- vehicle or backend), and the interaction of automated vehicles with law enforcement officials or any other person in charge of regulating traffic should be considered. Specific focus should be on differences across the EU member states. The scope should imply to elaborate common criteria for model-based validation and simulation on vehicle and component sensor level as well. Both, on- and off-board validation should be considered. Target is to support harmonization and standardization of homologation processes.

Expected Impacts: In preparation of the deployment of higher levels of automation, transport, it, telecom and insurance industries work on common standards across Europe concerning testing, validation and so liability criteria. Impact is expected on new vehicles and on existing vehicles as well. Member States can harmonize requirements on interaction with enforcement of connected and automated road transport.

Physical and digital infrastructures for higher-level automation

Specific Challenge: Higher levels of road vehicle automation will set specific requirements and have specific consequences for both the digital and physical road and road-side infrastructure. Many of the physical infrastructure elements will have a life-span of several decades and thereby the infrastructures set up and deployed during the next ten years should already be adapted where and when possible, according to the requirements of higher levels of road vehicle automation. Higher level automation also needs in addition to on-board sensors, off-board data in order to operate in complex environments and specific traffic scenarios. There is so far no general agreement on the roles and responsibilities of different stakeholders in implementing, maintaining, operating and financing infrastructures for automated driving, threatening to delay investments in these.

Scope and Content: Research and Innovation and/or large scale FOT on especially the physical (road and roadside) infrastructure needs for and consequences of higher level automation. This relates to use and adaptation of exiting physical infrastructure (consequences to pavements, bearing capacity, utilisation of hard shoulders, roundabouts, new road monitoring/maintenance tools, allocation of special use lanes, forms of visual guidance, traffic management, connectivity solutions, electrification, need of standardized road infrastructures for automated driving) and for building up new physical infrastructure (city planning, road/ street planning and design). The transition phase needs to be specifically addressed. The interaction between road infrastructure and connected automated vehicles needs to facilitate functional safety in distributed functions for automated road transport.

With regard to digital and data-oriented infrastructure and especially off-board sensors, in urban environments new infrastructural sensing methods could overcome blind spots in vehicle surround sensing by aggregating data from multiple sources to cope with critical situations. Another approach could be to use large-scale heterogeneous vehicle fleet data for a backend-based collective perception resulting in a near-real-time map. In this case, the needs and the conditions for the use, reuse and sharing of data generated by connected and automated vehicles need to be assessed. To set up a suitable backend solution, integrated, efficient and dependable computing platforms and control strategies are required. Altogether, a scalable consolidation of large amounts of floating car data is needed while data reliability must be assured. New standards for the applied data interfaces are to be established.

Expected Impacts: City and road authorities/operators know what is expected from them and what is feasible for them to deliver with regard to the physical and digital backend infrastructure. The infrastructure operators and service providers will be able to commence actions to adapt their planning, building, maintenance and operation guidelines accordingly.

Development of security methods to protect automated driving

Specific Challenge: Already today, cyber-security and vehicle safety are strongly linked due to continuously increasing connectivity. Higher levels of vehicle automation even increase the need for secure electronics architectures significantly for two reasons. On one hand, vehicle control will be automated: the human driver will not be enabled to intervene immediately in case of a cyber-attack. On the other, in many automation use cases, off-board data will be used for immediate driving decisions. The used data channels are potential entrance gates for attacks. There is need for a holistic approach to protect the electronics architecture with specific reference to automation. To ensure accessibility and integrity of automated driving related data, these have to be constantly and reliably accessible and its integrity must be guaranteed.

Scope and Content: Examine a potential extension and combination of Functional Safety Standards with already existing security standards (Common Criteria). We need to identify and analyse large-scale cyber-security challenges and current weaknesses. To reach this goal, risks and threads of the whole chain of effects from infrastructure to the vehicle control have to be assessed and validated, and assets need to be identified. Suitable high automation use cases should be considered. (Remark: Privacy topics are not considered under this topic as long as there is no direct impact to safety).

Expected Impacts: A holistic approach to protect automated vehicles is described. Authorities know what to expect. Automotive knows what is expected. Deployment of connected automated driving is promoted.

Data architectures for automated driving enabling safe off-board and on-board inter-operability

Specific Challenge: Safety in backend and cloud computing, the connectivity technologies as well as on-board computing applied to automated road transport services need to be assessed across industries to fit to the requirements of a safe vehicle control functionality. To reach this goal, we need common cross-industries safety and security standards.

Scope and Content: Safe cooperative digital High Definition map corrections need to be developed and standardized. One major issue for that is the validity of live data, which can be reached e.g. by adding confidence in terms of trust values and digital signatures. The remote diagnosis interface is a critical asset to ensure the operation of the autonomous vehicle (e.g. cloud computation, navigation data updates, remote diagnosis) and to protect the safety of the operator. A standardized and protected "over the air" (remote) diagnosis interface will be required to protect the interface and to comply with legitimate needs of the aftermarket (3rd party service providers, insurance companies, free garages, automotive clubs etc.).
Along with the increase of number and complexity of use cases there is need to develop and assess data architectures for autonomous driving. One aspect is that sensor data need to be stored in a standardized way. We need to examine how these data can be "securely" stored in the vehicle and end-to-end protected transferred to a backend server (e.g. OEM or to public authorities). Technologies, methods and standards to handle the challenges to enable safe, secure and dependable V2X data communication for Automated Driving critical functions in all driving environments need to be developed.

Expected Impacts: Common standards across automotive, IT and telecom industries for a safe and secure input (from road infrastructure and vehicle sensors), connection (for v2i, i2v, v2v), algorithms and software systems (both offboard and onboard for operating systems like AUTOSAR, LINUX, middleware as well as application software).

7. ANNEX

7.1. Common Definitions: current systems – Levels 0 and 1

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.

Current and future vehicle systems – Level 0

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

7.1.1. 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.

7.1.2. 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.

7.1.3. 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.

7.1.4. 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.

Current systems – Level 1

7.1.5. 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

7.1.6. 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.

7.1.7. 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.

7.1.8. 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.

7.2. List of European funded projects addressing Connected and Automated driving

Category	Acronym	Name	Duration	Purpose / Keywords
Highly automated urban transport systems	**CityMobil**	Towards Advanced Road Transport for the Urban Environment	02/2004-01/2008	Safety applications and technologies: safe speed and safe following, lateral support, intersection safety, active 3D sensor technology for pre-crash and blind spot surveillance
	PICAV	Personal Intelligent City Accessible Vehicle	08/2009-07/2012	Passenger transport, urban traffic, car sharing, networking, assisted driving, vulnerable road users
	CATS	City Alternative Transport System	01/2010-12/2014	Robotic driverless electric vehicle, passenger transport, transport management, urban transport
	V-Charge	Automated Valet Parking and Charging for e-Mobility	06/2011-09/2015	Autonomous valet parking, EVs coordinated recharging, smart car system, autonomous driving, multi-camera system, multi-sensor systems
	FURBOT	Freight Urban RoBOTic vehicle	11/2011-10/2014	Fully electrical vehicle for freight transport in urban areas, robotics
	CityMobil2	Cities demonstrating automated road passenger transport	09/2012-08/2016	Automated road transport system, automated vehicle, driverless, urban transport, safety, infrastructure, legislation
	MATSim	The multi-agent transport simulation	since 2013	framework to implement large-scale agent-based transport simulations, it offers traffic flow simulation, re-planning, a controller to iteratively run simulations as well as methods to analyze the output generated by the modules
	CARGO	Cargo handling by Automated Next generation Transportation Systems for ports and terminals	09/2013-08/2016	Creation of smart Automated Guided Vehicles and Highly Automated Trucks that can co-operate in shared workspaces for efficient and safe freight transportation in main ports and freight terminals
	MAVEN	Managing automated vehicles enhances network	09/2016-8/2019	Adaptive Traffic Light, Platoon Organization, Negotiation Algorithms, Trajectory and Manoeuvre Planning
Driver assistance systems	**PReVENT**	Preventive and Active Safety Application	02/2004-01/2008	Development and demonstration of preventive safety applications and technologies (advanced sensor, communication and positioning technologies)
	HAVEit	Highly Automated Vehicles for Intelligent Transport	02/2008-07/2011	Automated assistance in congestion, temporary auto-pilot
	MiniFaros	Low-cost Miniature Laserscanner for Environment Perception	01/2010-12/2012	Develop and demonstrate innovative low-cost laserscanner
	MOSARIM	MOre Safety for All by Radar Interference Mitigation	01/2010-12/2012	Interference mitigation, automotive short-range radars
	2WideSense	WIDE spectral band & WIDE dynamics multifunctional imaging SENSor ENabling safer car transportation	01/2010-12/2012	Development and testing of next generation imaging sensors, new camera systems

Driver assistance systems	**interactIVe**	Accident avoidance by active intervention for intelligent vehicles	02/2010-06/2013	Development of safety systems supporting the driver (joint steering and braking actuators)
	AdaptIVe	Automated Driving Applications and Technologies for Intelligent Vehicles	01/2014-06/2017	Automated driving, cars, trucks, motorways, transport in cities, close-distance manoeuvres
	PROSPECT	PROactive Safety for Pedestrians and CyclisTs	05/2015-10/2018	Better understanding of relevant VRU scenarios. Improved VRU sensing and situational analysis. Advanced HMI and vehicle control strategies; iv. Four vehicle demonstrators, a mobile driving simulator and a realistic bicycle dummy demonstrator. Testing in realistic traffic scenarios and user acceptance study
	AINARA	Automation and Intelligence solutions for Automated Road Transport systems	05/2015-04/2017	software solutions for vehicle automation and fleet management, for passengers and goods transportation
	RobustSENS	Robust and reliable envornment sensing and situation predicition	06/2015-05/2018	introduces reliable, secure and trustable sensors and software by implementing self-diagnosis, adaptation and robustness; advanced methods for improved sensor technologies and sensor signal processing as well as innovative algorithms for sensor data fusion, scene understanding, behavioural planning, and trajectory planning
	DENSE	Adverse weather environmental sensing system	06/2016-05/2019	develop and validate an all-weather sensor suit for traffic services, driver assistance and automated driving
	ADAS&ME	Adaptive ADAS to support incapacitated drivers Mitigate Effectively risks through tailor made HMI under automation	09/2016-02/2020	adaptive ADAS, driver impairment, inattention, drowsiness, stress, impairing emotions, HMI under automation adaptive ADAS, driver impairment, inattention, drowsiness, stress, impairing emotions
	VI-DAS	Vision inspired driver assistance system	09/2016-08/2019	Driver behaviour modelling, risk quantification, ADAS, scene understanding, advanced mapping cartography, connectivity, cooperative ITS, accident analysis, cloud infrastructure
	AutoMate	Automation as accepted and trustful teammate to enhacen traffic safety and efficiency	09/2016-08/2019	Human-Machine Team, Driver and Situation Monitoring, Dynamic Driving Task distribution, Shared Understanding, Mutual Support, Safety

Connectivity & Communication	**COM2REACT**	Cooperative Communication System to Realise Enhanced Safety and Efficiency in European Road Transport	01/2006-12/2007	Road and in-car communication systems, cooperative system, involvement of two-way communication systems: V2V and V2I, contribution for standardization and harmonization throughout Europe
	SAFESPOT	Cooperative Systems for Road Safety	02/2006-01/2010	Implementation and demonstration of V2V-based technology, Local Dynamic Maps, multi-sensor data fusion
	COOPERS	Co-operative Networks for Intelligent Road Safety	02/2006-01/2010	Development of intelligent transport systems (ITS), I2V technology, co-operative traffic management
	CVIS	Cooperative Vehicle-Infrastructure Systems	07/2006-06/2010	Development of a technology platform that provides wide-ranging functionality for data collection, journey support, traffic and transport operations and driver information
	Intersafe2	Cooperative Intersection Safety	06/2008-05/2011	Development of a Cooperative Intersection Safety System (CISS) – detection of static and dynamic components of the traffic environment
	ISI-PADAS	Integrated Human Modelling and Simulation to Support Human Error Risk Analysis of Partially Autonomous Driver Assistance Systems	09/2008-08/2011	Joint Driver-Vehicle-Environment Simulation Platform, prediction of driver errors in realistic traffic scenarios, driver modelling, Human Error Risk Analysis
	SARTRE	Safe Road Trains for the Environment	09/2009-10/2012	Development of strategies and technologies allowing vehicle platoons to operate on public highways – introduction of the vehicle platoons concept
	DRIVE2X	DRIVing implementation and Evaluation of C2X communication technology in Europe	01/2011-12/2013	Creation of harmonized Europe-wide testing environment for cooperative systems, promotion of cooperative driving
	FOTsi	European Field Operational Test on Safe, Intelligent and Sustainable Road Operation	04/2011-09/2014	Intelligent transport systems, electronic stability control, cooperative I2V & V2I technologies, emergency management, safety incident management, intelligent congestion control, dynamic route planning, infrastructure safety assessment
	ARTRAC	Advanced Radar Tracking and Classification for Enhanced Road Safety	11/2011-10/2014	Generic detection system, detect low-friction road sections, automatic braking, VRU safety technologies, radar hardware, software and performance-related algorithms

	Karyon	Kernel-based architecture for safety-critical control	10/2011-12/2014	systems need to communicate and cooperate with other systems in their environment; robust cruising strategies for vehicles; small local safety kernel; fault detection concepts
	79GHz	International automotive 79 GHz frequency harmonization initiative and worldwide operating vehicular radar frequency standardization platform	07/2011-06/2014	Global harmonization, 79GHz band, automotive short-range radars
	Compass4D	Cooperative Mobility Pilot on Safety and Sustainability Services for Deployment	01/2013-12/2015	Forward collision warning (FCW), red light violation warning (RLVW), energy efficient intersection service (EEIS), cooperative system, standardization cooperation
	AMiDST	Analysis of Massive Data STreams	01/2014-12/2016	Big data, stream processing, software development, automotive
	COMPANION	Cooperative dynamic formation of platoons for safe and energy-optimized goods transportation	10/2013-09/2016	Application of platooning on heavy-duty vehicles; concepts development for platoon applications in daily transport operations (off- a on-board systems for coordinated platooning, multimodal user interfaces)
	AutoNet2030	Co-operative Systems in Support of Networked Automated Driving by 2030	11/2013-10/2016	Development and testing of a co-operative automated driving technology with a time-horizon between 2020 and 2030.
	CarNet	Rapid Data Communication Network for Connected Cars	04/2015-03/2017	support KDPOF to adjust, test and demonstrate the benefits of KDPOF's Giga technology to the Automotive market
	ENABLE-S3	European initiative to enable validation for highly-automated safe and secure systems	05/2015-04/2019	standardized validation procedures for highly automated systems

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