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Executive Summary

The main objective of this document, ARCADE consolidated Roadmap 2019, is to bring together a consolidated multi-stakeholder view on the development of Connected Automated Driving (CAD) in Europe into three development paths, highlight ongoing activities and identifying challenges and key priorities extracted from the thematic areas.

This is the first-year version of the roadmap document. It will be updated annually. The purpose of the document is not to be exhaustive, due to the rapid development of the area and the number of ongoing projects and initiatives, but to serve as a consolidated view and a proposed way forward as described in the conclusions chapter.

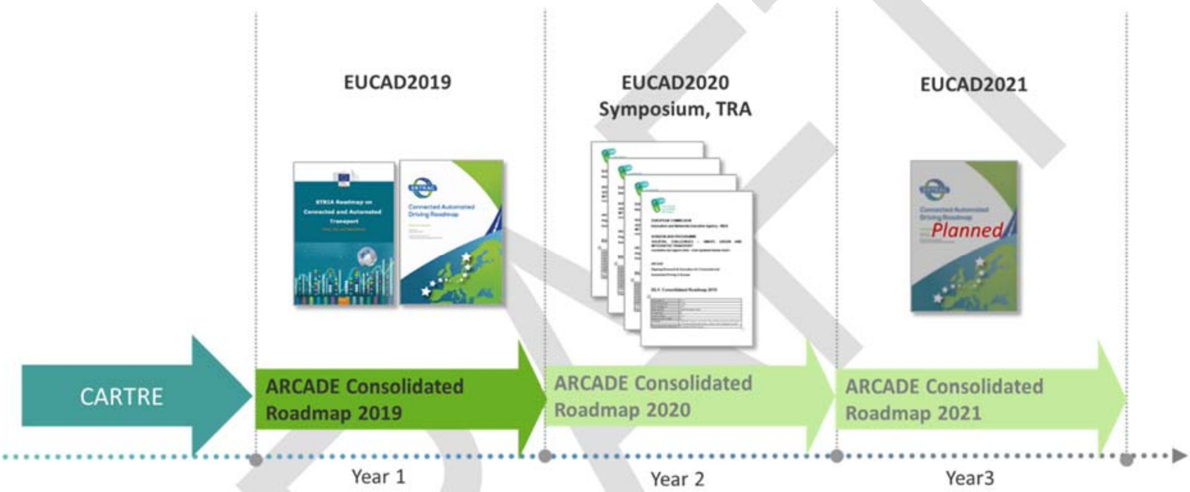

Figure 1 ARCADE consolidated roadmap evolution, annual updates and main deliveries

The ARCADE consolidated roadmap has during year 1 provided key input to the *ERTRAC CAD roadmap 2019*[1], the *STRIA CAT 2.0*[2]. The STRIA actions have been considered and is also integrated into this roadmap in section 4 consolidated key priorities.

The consolidated key priorities have also been used related to the draft scoping paper for WG1 in the *CCAM Single Platform*[3]. The development of this roadmap has been done in an iterative process involving the ARCADE stakeholder network (WP2), thematic areas (WP3) and inputs from projects.

The ARCADE consolidated roadmap consolidates the work from its thematic areas (WP3), knowledge base (WP4), related projects and initiatives (WP2).

The Roadmap also provides common basic definitions of automation levels and systems and identifies the challenges for the implementation of higher levels of automated driving functions.

[1] https://www.ertrac.org/uploads/documentsearch/id57/ERTRAC-CAD-Roadmap-2019.pdf

[2] https://ec.europa.eu/research/transport/pdf/stria/stria-roadmap_on_connected_and_automated_transport2019-TRIMIS_website.pdf

[3] https://connectedautomateddriving.eu/mediaroom/european-commission-launches-ccam-single-platform/

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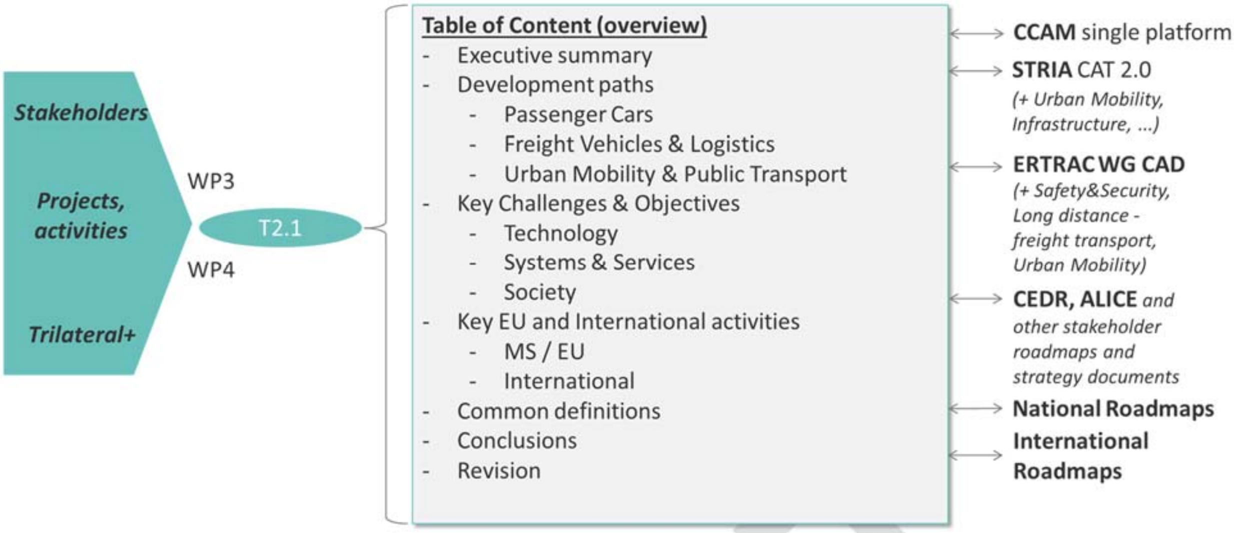

Figure 2 Relationship with ARCADE WPs and EU, national and international strategic documents

The roadmap also provides development paths for three different categories of vehicles, fully in-line with the ERTRAC CAD roadmap, to show the *indicative* development paths to reach TRL (Technology Readiness Level) 7 until 9 in some cases:

- Automated Passenger Cars
- Automated Freight Vehicles
- Automated Urban Mobility Vehicles

The focus for the development paths are towards high automation (L4) where research and innovation needs will be required. The development paths also support the consolidated view on R&I priorities as presented in the concluding section in this document.

This consolidated roadmap covers a broad section of main initiatives and projects from a national, European and International (incl. trilateral US-JP-EU) perspective.

The consolidated roadmap then continues with the key challenges identified to guide required efforts of pre-competitive collaboration research and development among European industry and research providers. The roadmap also highlights the key role of public authorities for policy, regulatory needs and support to deployment, with the objective of European harmonisation.

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1. Introduction

1.1. About ARCADE

ARCADE is an EC-funded Action that supports the commitment of the European Commission, European Member States and the industry (cf. the Amsterdam Declaration, GEAR 2030 final report, EC Communication on automated mobility[4], High-Level Structural Dialogue on connected and automated driving) to develop a common approach to development, testing, and validation of Cooperative and Automated Driving (CAD) in Europe and beyond.

The mission of ARCADE is to coordinate consensus-building across CAD stakeholders to develop this common approach. ARCADE involves 70 consortium and associated partners (to date) from 22 countries within and outside EU, who form the backbone of the Joint CAD Network of experts and stakeholders. This Network is composed of organisations from the public, industry and research sectors, stakeholder associations or individual experts, and was first established by the CARTRE Support Action (2016-2018).

In an annual cycle, ARCADE positions the Joint CAD Network (WP2) and Thematic Areas (WP3) centrally. The Network brings together the CAD stakeholder community at national, European and international levels while thematic areas work on content creation leading to consensus-based positions, needs and scenarios. The Knowledge Base (WP4) consolidates the CAD knowhow baseline and serves as a one-stop shop overview of CAD-related information. These main activities are depicted in **Figure *3***.

The main expected results of ARCADE are:

- Knowledge Base including CAD European, national and international R&I projects, roadmaps, regulations, standards, testing methodologies, etc.;
- Better understanding of challenges, enablers and research gaps on 12 thematic areas related to CAD, and recommendations for next steps and actions;
- Exchanges and harmonisation of R&I approaches across EU, US, Japan and other countries outside Europe;
- Awareness raising and promotion of national, European and international CAD R&I activities and results.

ARCADE capitalizes on CARTRE legacy, including tools developed by the project such as the https://connectedautomateddriving.eu website, the work done in the thematic areas and of course, the Joint Stakeholder Network, which ARCADE will leverage and further grow.

[4] COM(2018) 283

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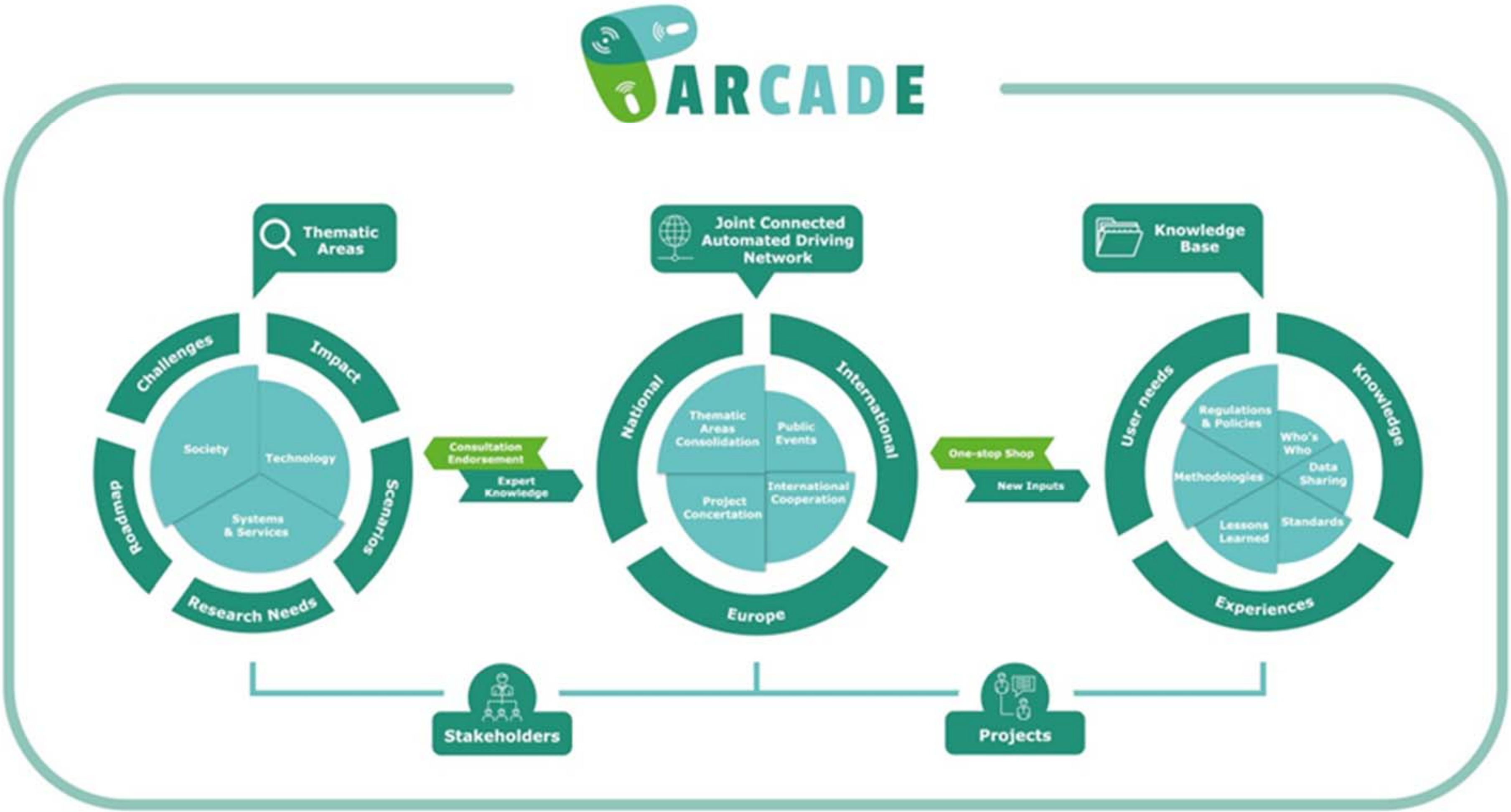

Figure 3: ARCADE main activities

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1.2.Purpose of the document

The main objective of this document, ARCADE consolidated Roadmap 2019, is to bring together a consolidated multi-stakeholder view on the development of Connected Automated Driving (CAD) in Europe into three development paths, highlight ongoing activities and identifying challenges and key priorities extracted from the thematic areas.

This is the first year version of the roadmap. It will be updated annually 2020 and 2021 according to the GA. The purpose of the document is not to be exhaustive due to the rapid development of the area and the number of ongoing projects and initiatives, but to serve as a consolidated view and a proposed way forward as described in the conclusions chapter.

1.3.Intended audience

The ARCADE consolidated Roadmap 2019 is addressed to the European Commission, the Joint stakeholder community and the project Beneficiaries to ensure a constructive dialogue based on current state of development.

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2. Why Connected Automated Driving?

Connected Automated Driving is 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. In addition, smoother traffic will help to decrease the energy consumption and emissions of the vehicles.
- **Comfort:** Enable user's freedom for other activities when automated systems are active.
- **Social inclusion**: Ensure mobility for all, including elderly and impaired users.
- **Accessibility**: Facilitate access to city centres.

Connected Automated Driving must therefore take a key role in the European Transport policy, since it can support several of its objectives and societal challenges, such as road safety, congestion, decarbonisation, social inclusiveness, etc. The overall efficiency of the transport system can be much increased thanks to automation. Traffic safety is of key importance for connected automated driving: to ensure safe interaction with all road-users in mixed traffic environments, in particular with vulnerable road users (VRU) and motorcycles, see 2019 ERTRAC roadmap for "Safe Road Transport"[5].

Moreover, automated driving should be understood as a process taking place in parallel and possibly in integration with other important evolution of road transport: the electrification of the powertrains, and the multiplication of mobility offers, especially shared mobility concepts. This roadmap for Connected Automated Driving therefore contributes to the long-term vision of the ARCADE joint stakeholder network.

[5] https://www.ertrac.org/uploads/documentsearch/id58/ERTRAC-Road-Safety-Roadmap-2019.pdf

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3. Development paths

Stakeholders involved in the ARCADE network share the vision of a progressive stepwise increase of automation levels during the upcoming decade. The main development paths for the different automation levels are shown in the Figure 3 below.

Major collaborative projects funded by the EU are currently looking at the first levels of automation and organizing testing in order to prepare their roll-out in Europe: the L3Pilot[6] project for automated passenger cars, and the ENSEMBLE[7] project for multi-brand truck platooning.

The ARCADE stakeholder network has clearly indicated the need to focus on use-cases related to high-level automation, L4. The development paths indicate the timeframe to reach levels of TRL 7-9, to be understood as ready from a technology perspective. We refer to the TRL levels definition used within the Horizon 2020 programme[8]:

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

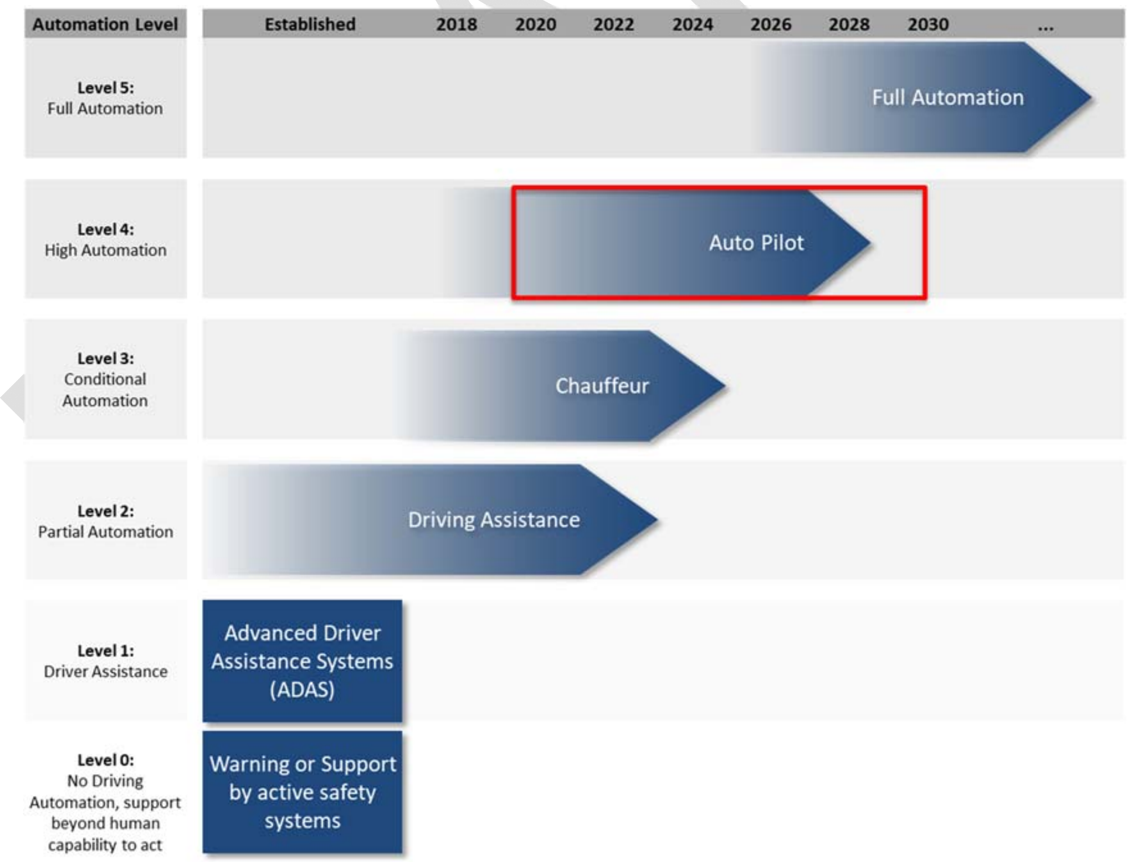

Figure 4: The generic vehicle automation development path along the SAE levels of automation

[6] https://www.l3pilot.eu

[7] https://platooningensemble.eu

[8] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

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

3.1. Automated Passenger Cars Path

Passenger cars are the main driver of the development towards automated driving, as with their high volume in the market, they can afford to develop the necessary technologies. They evolve level by level with more sensors, connectivity and computing power on- and off-board and can be distinguished by parking and driving use cases.

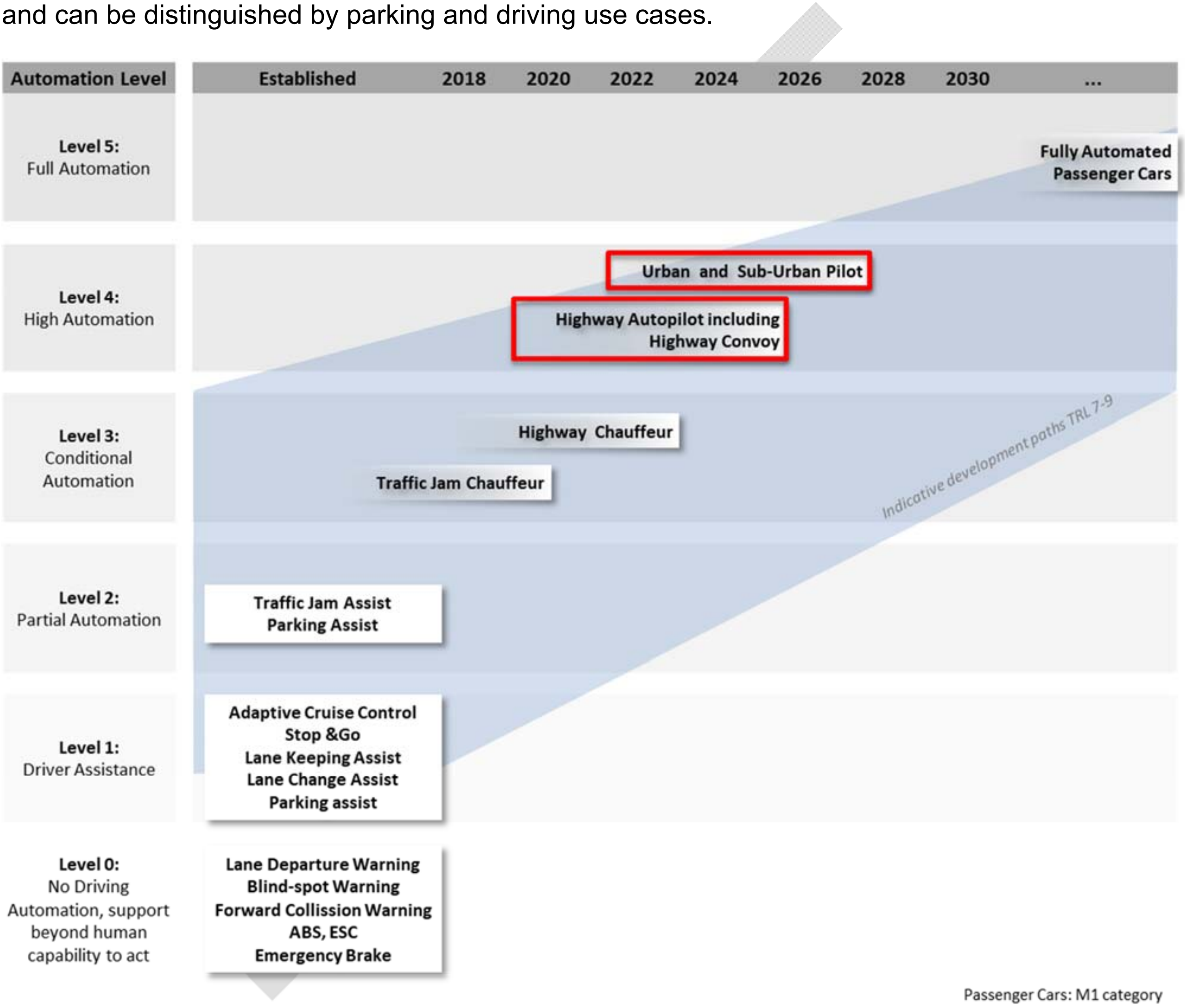

Figure 5: The Automated Driving development path for passenger cars

3.1.1. Traffic Jam Chauffeur (Level 3)

Conditional automated driving in traffic jam up to 60 km/h on motorways and motorway similar roads. The system can be activated in case of a traffic jam scenario. It detects slow driving vehicle in front and then handles the vehicle’s both longitudinal and lateral. Later version of this functionality might include lane change functionality. The driver must deliberately activate the system but does not have to monitor the system constantly. The driver can at all times

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override or switch off the system. In case of a takeover request to the driver from the system, the driver has sufficient time reserve to orientate himself and take over the driving task. In case the driver does not take over, the system will go to a reduced risk condition, i.e. bring the vehicle to a safe stop.

3.1.2. Highway Chauffeur (Level 3)

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

3.1.3. Urban and Suburban Pilot (Level 4)

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

3.1.4. Highway Autopilot (Level 4)

Highly Automated Driving up to 130 km/h on motorways or motorway similar roads from entrance to exit, on all lanes, including overtaking and lane change. The driver must deliberately activate the system but does not have to monitor the system constantly. The driver can at all times override or switch off the system. There 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), so sleeping is allowed. In case a situation occurs, when average human driver would try to end the journey or simply stop at the motorway (e.g. extreme weather) and the driver does not take over, the system has the capability to leave the motorway and park the vehicle safely.

3.1.5. Highway Convoy (Level 4)

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

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

The fully automated vehicle to handle all driving from point A to B, without any input from the passenger. The driver can at all-time override or switch off the system. Note: only a rough time

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estimation can be given for this system at the moment. The technology approach as well as map availability to handle country road conditions (narrow lanes without road markings, diverse road users etc.) is not yet foreseeable.

3.2. Automated Freight Vehicles Path

This path focus on highly automated (Level4) commercial vehicles for operation in dedicated areas), Hub-to-hub, on Open Roads or in/through Urban areas. These vehicles could be either vehicles with driver-cabin for selective manually driven and automated operation or cab-less vehicles for unmanned operation with remote monitoring and control. In both cases, the integration with the freight logistics flow, road traffic network and operators is important to consider, see ERTRAC Roadmap for "Long Distance Freight Transport" for freight automation details[9].

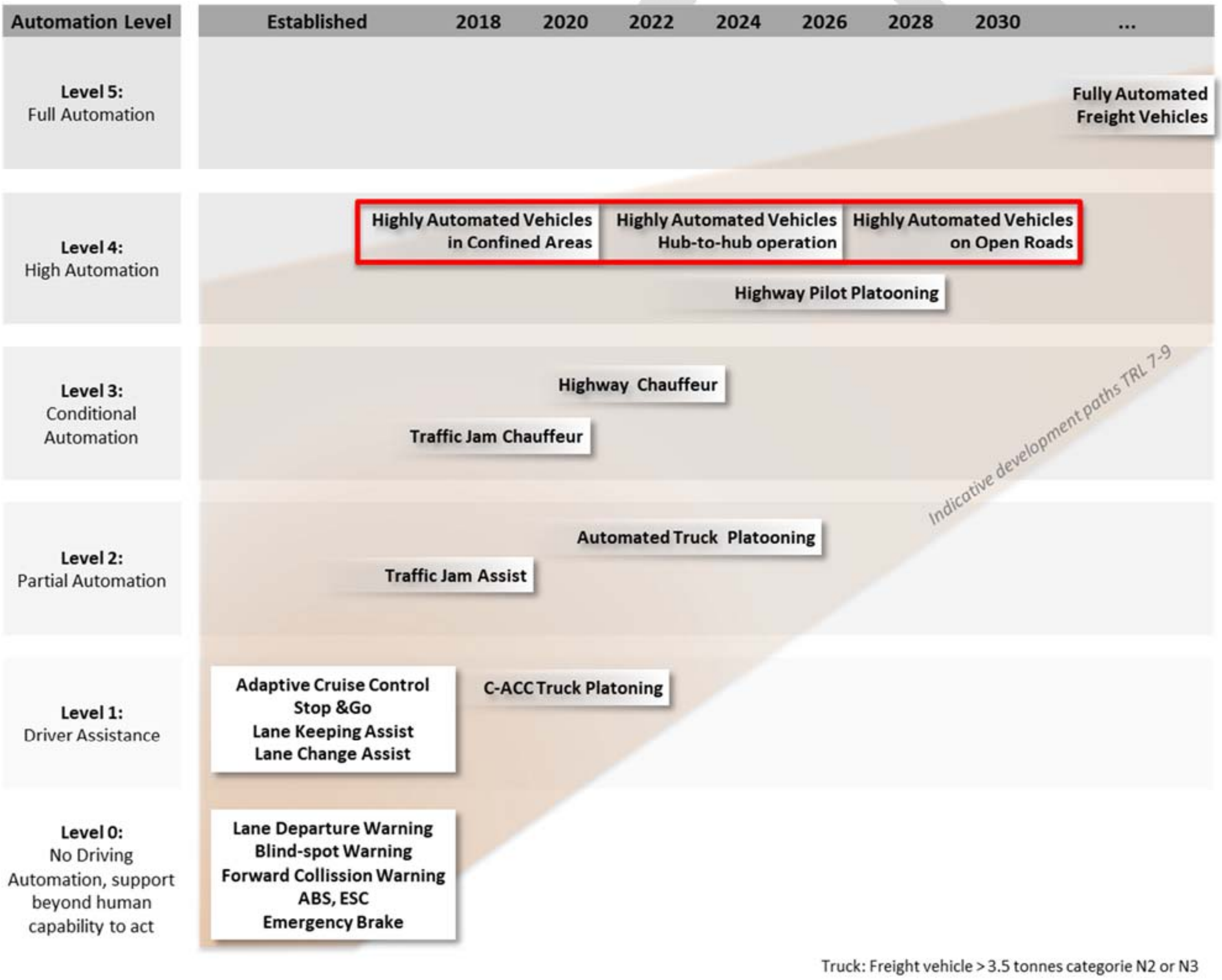

Figure 6: The Automated Driving development path for freight vehicles

[9] https://www.ertrac.org/uploads/documentsearch/id56/ERTRAC-Long-duty-Freight-Transport-Roadmap-2019.pdf

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

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

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

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

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

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

3.3. Urban Mobility Vehicles

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

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

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

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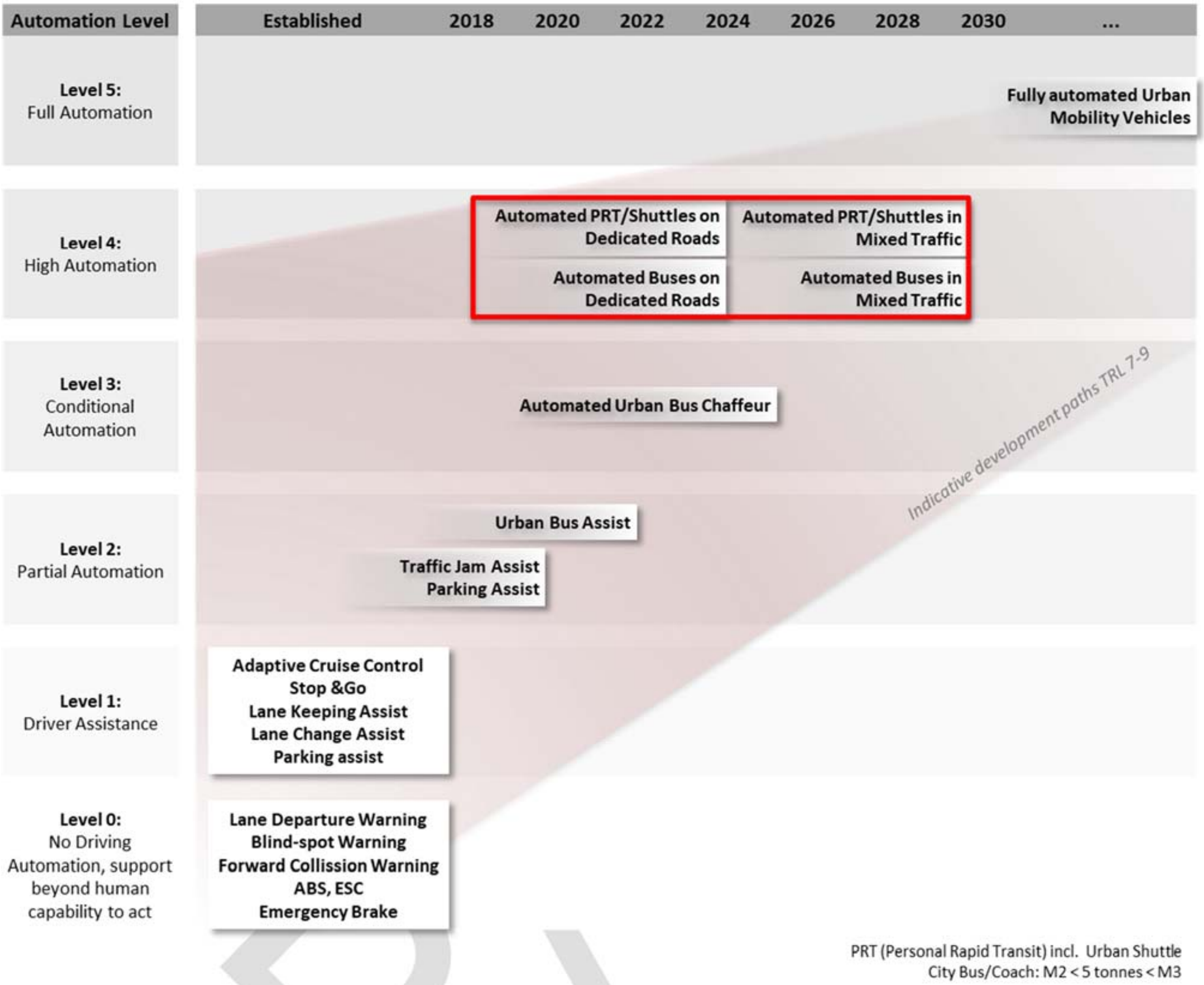

Figure 7: The Automated Driving development path for urban mobility vehicles

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

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

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

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

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

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

Level 4 automated PRTs or shuttle fleet solutions will need specific backend structures like control centres and data cloud support. Control centres will provide services and functions for remote control of vehicles that become necessary in emergencies, maintenance or authorities' intervention. Cloud functionalities will provide additional information for automated driving functions, cooperative environment and traffic data.

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

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

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

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

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4. Key Challenges, Objectives, Enablers and Actions

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

4.1. ARCADE Thematic Areas

In the ARCADE project the following twelve thematic areas have been identified and position papers is available in the CAD Knowledge Base[10] that is under continuous development.

In ARCADE the thematic areas *Connectivity* and *Freight and Logistics* are handled separately. (In the key challenge areas of ERTRAC they are included in in-vehicle enablers and the development path Automated Freight, respectively.).

Figure 8: ARCADE Thematic areas

[10] https://knowledge-base.connectedautomateddriving.eu/thematic-areas/

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In ARCADE, three task areas reflected in three separate deliverables D3.1, D3.4 and D3.7 that have been consolidated into this section in this document.

Each thematic area is mapped against the three development paths for automated vehicles; Passenger Cars, Freight Vehicles and Urban Mobility Vehicles.

4.2. Consolidated Challenges and Key Priorities

In this deliverable a first consolidation of conclusions from the deliverables from W3; D3.1, D3.4 and D3.7 has been made. The consolidated key priorities were identified at the consolidation workshop taking place with the ARCADE consortium and WP3 task and thematic area leaders in September 1-3, 2019. The final result is available in the ARCADE consolidated roadmap 2019, as announced in *Figure 1 ARCADE consolidated roadmap evolution, annual updates and main deliveries*.

This deliverable aims to be the first step to aggregate the key priorities from the WP3 into an overview to provide the bases for continued work within ARCADE. This will require further stakeholder workshops, to elaborate and identify recommendations. It is also of key importance to bring in results from ongoing projects as identified in the CAD Knowledge Base. It is also important to ensure input from various strategies and roadmaps.

Five key priorities have been identified for the different thematic areas, together with application specific priorities. The reason for this is to identify what areas are of most importance for further elaboration in the coming yearly updates of the ARCADE consolidated roadmaps 2020 and 2021. The key priorities will also to be scrutinized and further developed within the ARCADE stakeholder network.

The approach taken in this section follows the WP3 deliverables conclusions in the following three thematic task areas below. An integration across the scenarios analysis has also been achieved.

Technical thematic areas (refer to D3.1)

- Human Factors
- Connectivity
- Deployment
- In -vehicle technology enablers

Systems and Services thematic areas (refer to D3.4)

- New mobility services, shared economy and business models
- Freight & Logistics
- Big data, artificial intelligence and their applications
- Digital and physical infrastructure, including connectivity

Society thematic areas (refer to D3.7)

- User awareness, users and societal acceptance and ethics, driver training
- Safety validation and roadworthiness testing
- Policy and regulatory needs, European harmonization
- Socio-economic assessment and sustainability

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Consolidated Key Priorities per Use-Case vs Thematic area

		D3.7 Society Challenges & Scenarios				D3.4 Systems and Services Challenges & Scenarios			D3.1 Technical Challenges & Scenarios			
		User awareness, users and societal acceptance and ethics, driver training	Safety validation and roadworthiness testing	Policy and regulatory needs, European harmonisation	Socio-economic assessment and sustainability	New mobility services, shared economy and business models	Big data, artificial intelligence and their applications	Digital and physical infrastructure	Human Factors	Connectivity	Deployment	In -vehicle technology enablers
Development Paths / Use Cases	Generic	Societal Needs Analysis from user and society perspectives	Alignment of vehicle regulation (and type approval) and corresponding assessment tools & procedures	Working for flexible AD regulation, enabling different solutions, within the boundaries of safety.	Impact assessment needs both pilots (low TRL) and FOTs (high TRL)	Foster the development of new ecosystems, new types of partnerships, new business models in the fields of services	Develop 'standard' model for sharing data that ensure data privacy and security	Define common EU standards for the interaction of PDI and AVs (e.g. ISAD, ODD)	Integrated Safety (passive, active, seating positions, crash impact, etc)	Definition of connectivity requirements for AD functions (performance, QoS, resilience, etc.)	Living labs to support tests and demonstration by including end users earlier	Harmonize definition of ODDs and functionalities needed for given ODDs
	Generic	Positive Risk analysis	Determine proper combinations of virtual testing, closed test track and open road testing of AVs	Learn from adaptation of regulation, work towards common approach	Development of EU-level databases to allow more reliable scaling up (data on accidents, mileage, etc. including ODD aspects, with sufficient details and granularity)	Pilots and FOTs to validate business case, operational models and specifications	Harmonisation, alignment needed for development and validation of AI functionalities for AV	Define Classifications of PDI	Interaction with external road users (mixed traffic)	Specification of Day 2 and Day 3 C-ITS services	L4 Pilots including cross-border applications	Define, develop, and validate robust and scalable perception systems and sensor sets
	Generic	Ethics evaluation based on technology understanding	Share and harmonise driving/traffic scenarios and best practices	Build common CAD framework	Development of commonly available (validated) AV simulation and other evaluation tools	Define the involvement of public authorities in the early stage of deployment to create trust among stakeholders	Standards and solutions (HW/SW) for data management and data quality (e.g. L3Pilot)	AV-ready road planning and self-explaining roads. (e.g traffic signs and lane marking for Avs)	New role of remote operators (sustain attention, control environments, etc)	Standardisation and further deployment of V2X technologies	L3 FOT including cross-border applications	Develop technologies supporting vehicle's own understanding of ODDs and cooperation between AD vehicles. (incl. maps, localization,..)
	Generic	Impact on driver/users and operator training	Consensus building with respect to validation of methodologies, including Data-labeling standards	Make cross-border testing easy	Commitment to use common impact assessment methodologies (like FESTA, Trilateral framework)	Integration of new services with existing services (e.g. public transport) from start	Develop new AI-concepts for cyber-physical road traffic systems	Investigate the use of common definitions (e.g. ISAD). Create Living lab with PDI	Behavioral change. Social inclusion	(Cyber)secure and safe communications respecting privacy and various levels of trust	Promote deployment through simulations of scenarios, road transport & traffic management	Maintain system integrity and well-functioning once in the field, monitor for updates
	Generic	Secure privacy for mobility users	Develop procedures to manage validation of vehicle updates monitoring during the whole lifecycle of the vehicle	Harmonisation of the interpretation of traffic rules, digitalization of traffic sign information	Research on the long-term indirect impacts of automation, equity etc.	Further develop urban delivery AD solutions	Harmonisation of AI investments development	Define the involvement of public authorities in the early stage of deployment to create trust among stakeholders	Learning, education	Interoperability of communication technologies / Hybrid connectivity solutions	Customer pilots with non-homologated vehicles	Reach efficient integration of overall system in fail-operational architectures (costs, energy, redundancy)
	Passenger Cars	(no specific)	Homologation framework and simulations, self-certification	(no specific)	Impacts on safety and travel behaviour	Peer-to-peer sharing	New robust AI-passenger-car solutions	(no specific)	(no specific)	(no specific)	(no specific)	(no specific)
	Freight Vehicles	New fleet operation schemes for AV	Homologation framework Hub-to-hub, semi-confined ODDs	Business case for platooning need to be clarified depending on regulation scenario	Impacts on transport network efficiency and environment	Logistics services Business need for AD (TCO)	New AI freight and logistics solutions	Hub-to-hub corridors Freight traffic management. Truck parking safe-zones for AD trucks	The role of professional truck drivers	Correctness and latency for multi-brand configuration	Commercial operational pilots	Superstructure, e.g. trailer)
	Urban Mobility Vehicles	City authority Perspectives	VRU scenarios for unmanned buses and shuttles	Support early introduction through exemptions	Impacts on transport mode choice and social inclusion	New infrastructure business models and financing tools	New AI urban mobility solutions	Traffic management complementing public transport	The role of professional bus drivers	Specific requirements for remote operation "control-tower"	Identify needs.	Low-speed, low-tech AVs

Figure 9: Consolidated Key Priorities per Use-Case vs Thematic Area

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4.3.Technical Challenges & Key Priorities

The thematic areas of vehicles and technologies are defined in ARCADE as: In-vehicle technology enablers, human factors, connectivity and deployment.

4.3.1. In -vehicle technology enablers

In-Vehicle Enablers: the driving functions from sensing to driving, environment models and driving strategies, technologies like AI but also localization, components like sensors and actuators but also for communication, EE Architectures, Safety and security concepts, Monitoring and Data recording concept, Maintenance and technologies for updates in the field are the building blocks for all AD vehicles and applications.

4.3.1.1. Challenges

Vehicle technologies are essential to enable CAD. Design of in-vehicle systems in such a way that they are scalable to cover the wide variety of vehicle platforms, models and markets; robust enough to meet very high security requirements, including improved redundancy to support fail-safe operation; secured against cyber-attacks to ensure system integrity.

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

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

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

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

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

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

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4.3.1.2. Key priorities: In-vehicle technology enablers

Key Priority	***Description***
Harmonize definition of ODDs and functionalities needed for given ODDs Specific use-case priorities	Operational Design Domains (ODD) defines the functionality of the automated vehicle in each ODD. There is a need to establish a harmonised definition of ODDs (i.e. type of road, traffic situation, weather, etc.) that will be the basis for how the vehicles will operate in various situations. There will potentially also be different use-case specific definitions for different vehicles and for specific situations and use-cases.
Define, develop, and validate robust and scalable perception systems and sensor sets	Robust and accurate environment perception is essential for highly automated vehicles. To date systems are ready for partially automated driving in standard situations but not for complex driving conditions and demanding Operational Design Domains (ODDs). This will imply the need for: increased performance of perception systems (sensors), enhanced cognition using machine learning (AI), more powerful embedded in-vehicle systems, integration with infrastructure-based perception systems to complete data fusion where internal systems are out of reach, and highly accurate and dependable localization systems. An incremental progress for highly automated driving in agreed ODDs to achieve minimal number of false detections for improved driver comfort and trust from all road users of CAD.
Develop technologies supporting vehicle's own understanding of ODDs and cooperation between AD vehicles (including; maps, localization etc.)	Based on the ODD (traffic situation, type of road, weather etc.), the vehicles perception system, high accuracy localization, high-definition digital maps and cooperation with other vehicles and the infrastructure (e.g. C-ITS) the automated vehicle will build and understanding of the current situation that will be a further base for decision and action. The demand on the Automated vehicles in-vehicle technologies are very high to ensure speed (real-time), accuracy (centimeters), dependability, handling very large amounts of data, connectivity etc.
Maintain system integrity and well-functioning once in the field, monitor for updates	Ensuring system integrity of vehicles in operation is essential. Since connected automated vehicles needs to be well-operating over time there will be need to regular/continuous monitoring of systems to ensure overall safety and functionality. There will be new ways to monitor systems and provide system updates in accordance to functional safety requirements also considering cyber-security. Remote monitoring and access are areas of concerns from both technology and operational aspects. System integrity over time is a prerequisite for user and society trust.
Reach efficient integration of overall system in fail-operational architectures (costs, energy, redundancy	Integrating the different systems (perception, situation awareness, understanding etc.) into is of key importance for meeting market demands of affordability, robustness and security. Since in-vehicle systems must make decisions and take actions in real-time (milliseconds) the demand is very high on the integration of the complete system. There are considerable demands on cost, affordability, dependability,

	robustness, security, power consumption and functional safety.
Freight development path: Superstructure, e.g. trailer and load carriers	For the freight vehicles use-case, the load carrier and trailer superstructures will also be connected and automated. This opens new possibilities in automated complete vehicle operation (including load carriers and trailer) in the ODDs. For confined areas, it will be possible of highly automated vehicles for unmanned operations. This will open for improved efficiency and safety in for example logistics hub operation. For open-road operation there will be possibilities of innovative complete vehicle cooperative automation. There are also considerable challenges to ensure functional safety integrating flexible complete vehicles combinations. Trailers and load carriers may be arranged differently and will also have various properties, braking capacity, overall weight and weight distribution etc.
Urban mobility development path: Low-speed, low-tech AVs	For the urban-mobility vehicle use case, there will be new low-speed connected automated vehicles for dedicated applications. This could be shuttles and personal mobility vehicles, integrated into the public transport system or independent. Since the ODD and speed is limited, these vehicles can be comparably "low-tech" with limited capability for early deployment. Yet low-tech in-vehicles technology will include a completely integrated connected automated system also interacting with the infrastructure and operational monitoring and control.

4.3.2. Human Factors

Human Factors is the study of human behaviour in relation to particular environments, products, software, hardware as well as services and an important field for all introduction scenarios of different types of automated vehicles. Human Factors include among other things human behavioural models, harmonized interaction design and Human Factors related test procedures.

4.3.2.1. Challenges

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

- Find design solutions and standards for human factor challenges such as unintended use, skill degradation, level of trust and acceptance, motion sickness and controllability in transitions.
- Adapt vehicle automation to different user needs and group.
- How to design the safe, intuitive interaction of automated vehicles with other road users?

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- How to ensure driver is in the loop for L2 and below? How to ensure driver is able to transfer back into the loop for L3 and higher? How to ensure a safe transition phase without startling effects, low situational awareness and a smooth stabilisation phase.
- How to ensure appropriate driver state (e.g. not asleep or intoxicated).
- How to derive interaction design concepts for the automated vehicles so that both the human driver and other humans in the surrounding sufficiently understand the capabilities and limitations of the vehicle?
- What part of the Human-Machine Interaction (HMI) design should be standardised and what needs to be left open for novel solutions?
- Should the Human-Machine Interaction (HMI) design should be standardised or open for disruptive solutions?

4.3.2.2. Key priorities: Human Factors

Key Priority	***Description***
Integrated Safety (passive, active, seating positions, crash impact, etc.)	Active safety functions will be adapted and advanced so that automated vehicles safely navigate in both, expected and un-expected scenarios. Therefore, systems need to be developed that aim to anticipate and minimize risks, avoiding collisions where possible and reducing the consequences of unavoidable crashes. Advanced passive safety systems protecting passengers in new, non-traditional seating positions will be a focal point of research. The development of automated driving functions will lead to new interior concepts that can significantly increase the comfort of the occupants and transform driving time into leisure or work time. As automated driving evolves, we can assume that crashes will continue to occur. Consistent methods and assessment tools are required to fully understand the safety impact of automated vehicles in mixed traffic and to derive safety requirements. Progress in accidentology based on naturalistic driving data will be used to gain new insights on vehicle interaction with and for the protection of vulnerable road users
Interaction with external road users (mixed traffic)	Connected automated vehicles will interact with other road users with various automation levels. Connectivity will enable interaction between different vehicle systems connected automated vehicles. The mixed traffic environment is important to consider how to ensure unambiguous, safe and secure interaction between manually operated vehicles and VRUs. Different technology solutions, including concepts such as external HMI (human machine interaction). It will also be important to address how to make automated vehicle understand human interaction, such as recognition of hand signal (e.g. policeman) and eye-signals.

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New role of remote operators (sustain attention, control environments, etc.)	Even if automated vehicles will be able to operate autonomously, there will be need for remote monitoring and operation. This means that the role of remote operators needs to be taken into consideration. This will include understanding how to design systems to secure that operators will sustain attention over time. Initially the focus is on controlled environments where remote monitoring and surveillance is required. Remote control might be required to ensure operational demands. For automated vehicles in mixed traffic, this will be a new challenge to consider. This could be an extension to traffic management.
Behavioral change. Social inclusion	Connected automated vehicles will enable new means of using the mobility system. This will induce users' behavioral change to take advantage of these new possibilities. Study this behavioral change to understand how to develop systems and services using real-world studies and field operational trials and naturalistic studies. Automated vehicles will also be used to increase social inclusion to enhance mobility of elderly, disabled and children. For human factors, these insights provide new requirements for inclusive design.
Learning, education	Using automated vehicles will change the behavior of the users. There is also an element of user learning to be understood. User education will be needed together with training of the different roles handling automated vehicles from basic passenger information to advanced training for professionals to ensure safety. Also, rental cars and car sharing may lead to frequent switching between automation levels and different automation interfaces depending on vehicle brand.
Freight vehicles and urban mobility development paths: The role of professional truck/bus drivers	Automated vehicles will open up for a radical change of the driver role. The driver cost stands for a large portion of the overall fleet operational costs which provide considerable incentives for introduction of AD for professional operation. When the vehicle provides increased driving assistance or even takes over the driving task, there is also room for the driver to perform other tasks, such as loading, unloading, refueling, recharging, customs declarations etc. There is generally a lack of drivers of professional drivers. AD might improve the driver role and make the job more attractive. For professional drivers this needs to be done in accordance to driver regulation. Monetary incentives for drivers might also be considered, e.g. driving time salary versus resting time salary.

4.3.3. Connectivity

Connectivity between vehicles with other vehicles and/or the infrastructure is considered as an important factor enhancing further the benefits of automated driving in terms of safety, traffic efficiency and comfort.

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4.3.3.1. Challenges

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

4.3.3.2. Key Priorities: Connectivity

Key Priority	Description
Definition of connectivity requirements for AD functions (performance, Quality of Service, resilience, etc.)	For higher levels of automation connectivity and cooperative systems will be needed to fulfill the automated driving in more complicated ODDs. A common definition of connectivity requirements will hence be a base for AD functionality to ensure system performance. Connectivity could imply vehicle-to-vehicle interaction and vehicle-to-infrastructure interaction to gather information to enhance perception, decision and action of the automated vehicles. It will also be important to exchange information about quality of service. For connected systems, resilience against antagonistic threats needs to be defined.

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Specification of Day 2 and Day 3 C-ITS services	The C-ITS services needs further development and there will be a need to define and agree on Day 2 and Day 3 services, following the Day 1 and Day 1.5 services. This will form the basis for further investments in vehicle communication technology and required infrastructure to ensure deployment of automated vehicles in Europe.
Standardisation and further deployment of V2X technologies	To ensure (global) interoperability and capture the economy of scale specifications and definition will be standardized in appropriate bodies. The link between Automated Driving standardization and V2X will be further developed to secure a well-integrated and organized approach for the benefit of all actors.
(Cyber)secure and safe communications respecting privacy and various levels of trust	System resilience and functional safety is of key importance to ensure safe connected automated driving. The communication technology needs appropriate cybersecurity protection on different levels. In addition, user privacy and trust need to be ensured.
Interoperability of communication technologies / Hybrid connectivity solutions	Communication technologies are under constant evolution and the mobile network will continuously evolve, as new generations of system will be available. 5G mobile technologies will be deployed. In parallel ITS-G5 short-range peer-to-peer communication will be needed to ensure low latency, safe and secure connectivity for V2V and V2I to enable cooperative systems. Connected automated vehicles will use several communication technologies to obtain information to ensure environmental perception, decision and take action. Hence a hybrid communication approach will be applied using and several available communication channels. This will put requirements on antennas and frequency band allocation to eliminate interference. There will be communication chipsets available to handle hybrid solutions.
Freight vehicles development path: Correctness and latency for multi-brand configuration	In mixed traffic there will always be a need of multi-brand vehicle communication to ensure correct exchange of information. The latency needs to be low to ensure safe and real-time decisions require resilient millisecond level exchange of information. Common communication specifications and standardization will be required for multi-brand exchange.
Urban mobility development path: Specific requirements for remote operation “control-tower”	For freight and Urban mobility vehicles: For unmanned high-level automated vehicles there will be need for remote surveillance and remote operation. This to take over control when operation so require. A “control-tower” approach will be used to guide and take-over of so require.

4.3.4. Deployment

4.3.4.1. Challenges

Deployment is the crucial kick-off-phase of bringing technology to the users and the society, thus facing the innovation lifecycle, fears and expectations, but also the phase-in aspects to ensure a smooth transition from current mobility to the new mobility of Connected and Autonomous Vehicles.

4.3.4.2. Key priorities: Deployment

Key Priority	***Description***
Living labs to support tests and demonstration by including end users earlier	Living labs, tests and demonstration activities is of key importance to understand and develop connected automated vehicle solutions. These activities need to be done together with the various stakeholders, users, authorities, fleet operators, etc. to ensure broad and deep understanding of issues and opportunities. Cross-border tests will be done to ensure interoperability and harmonization of functionalities and to ensure safe uninterrupted operation. In addition, the transition between different ODD levels needs to be ensured. This means that cross boarder also can be seen between regions, city-boundaries in various operational domains.
L4 Pilots including cross boarder applications	Pilots together with real users will be done to ensure highly automated (L4) vehicles in various ODDs. Building on results and experiences from earlier test and demonstration activities. Pilots required that automated technologies reach high technology readiness levels of TRL 8-9 which is a challenge. This will require approval from authorities depending on the operational domain for each pilot. In particular pan-European pilots will be a challenge. Includes cross boarder applications,
L3 FOT, field operational tests, including cross boarder applications	Field Operational Tests (FOT) can be done when automated vehicles are available for real users (customers). FOT will follow pilots (e.g. L3Pilot) and will be done according to established methodologies (e.g. FESTA). It is today not clear when highly automated vehicles (L4) will be available for real users and customers. Includes cross boarder applications,
Promote deployment through simulations of scenarios, road transport & traffic management	Simulations is an important tool for promoting various deployment scenarios. This would provide knowledge about the effects of deployment of automated vehicles from a system perspective. This will be useful for transport and traffic management to plan for introduction and potential regulation to handle different scenarios of automated vehicles.
Customer pilots with non-homologated vehicles	To further explore the consequences and benefits of automated vehicles pilots is needed. It will be needed to ensure how to perform customer pilots with non-homologated automated vehicles in open roads. Multi-national and pan-European pilots are of particular concern

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	when several national/regional traffic regulations are concerned. A common European approach will be needed to balance the need for safety and expectations of rapid introduction of automated vehicles.
Freight vehicle development path: Commercial operational pilots	For automated freight vehicles, it will be important to use commercial operational pilots to also understand how the business model in automated fleet operation will evolve. There is a need to perform R&I and pre-deployment in an operational manner in real logistics operation to identify the pros & cons of connected automated freight vehicles. This needs to be done through pre-competitive R&I addressing common topics yet in a very competitive logistics environment – which is a challenge.
Urban mobility development path: Identify needs	For automated Urban Mobility vehicles, there is a need to identify the needs from both users and society. The integration with existing public transport and introduction of personal mobility vehicles will be addressed. The operational challenges from a fleet and transport operation perspective need to be analysed. Transport and traffic authorities needs to be involved. In addition, there will be new actor needs to identify the opportunities for innovative mobility services providers (e.g. MaaS).

4.4. Systems and Services Challenges & Key Priorities

4.4.1. New mobility services, shared economy and business models

New mobility services are services based on connected and automated vehicles operated on demand or in a scheduled way, integrated in the city transport network and MaaS platforms, accessible via public transport or private operators' platforms or apps.

4.4.1.1. Challenges

The first focus will be to solve safety issues (safety demonstration) and have enough AV fleet available for services. Safety specifications are unclear, costs are still a problem, and interoperability of buses will have to be fixed. Another focus should be made on the users' behavior, acceptance and trust. Later, will come the need to integrate CAD services with existing transport networks and MaaS platforms. It will be necessary to establish reasonable trust among partners. Finally, new type of operators (meta operators) will be needed. The integration in the cities' planning process will have to be achieved.

4.4.1.2. Enablers

Actions should focus on large scale pilots and FOTS, to gain delivery and commercial speed. It will also be necessary to maintain the service on long period to evaluate the evolution of acceptance and behavior in time. Service, systems and operation conditions will have to be defined by/together with the authorities, which are the main transport organizers. This will also guarantee the immediate integration within the public transport grid.

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4.4.1.3. Key priorities: New mobility services, shared economy and business models

Key Priority	***Description***
Foster the development of new ecosystems, new types of partnerships, new business models in the fields of services	There is a catch-22 element in automated vehicle fleet development. In order to proof viability this will only be possible when automated fleets are available, at the same time investments of automated vehicle fleets will not happen before viability has been proven. Hence it is important to foster the development of new ecosystems, new types of partnerships, new business models in the fields of services.
Pilots and FOTs to validate business case, operational models and specifications	It is needed to perform pilots and FOTs to fully understand the benefits and consequences of automated fleets. Validation of business cases and operational models will pave the way for introductions. Specifications needs to be validated and be brought into standardization.
Define the involvement of public authorities in the early stage of deployment to create trust among stakeholders	Automated vehicle fleets are expected to provide considerable benefits for the end user. In addition, there are benefits for the fleet and transport operators. Yet the awareness at authorities needs to be raised in order to fully understand the benefits and consequences of automated vehicle fleets. There are various levels that needs to be considered; new services, system and technologies, integration with other vehicles and transport modes and the consequences for fleet operation.
Integration of new services with existing services (e.g. public transport) from start	Automated vehicles will contribute to a more efficient and smooth transport system for the end user, from door-to-door. This will require integration of new services with existing transport and mobility systems, such as the public transport system and early involvement of public transport operators and authorities from start.
Further develop urban delivery AD solutions	Transport services from last-mile delivery of goods in urban environment is an area that greatly can benefit from automated vehicles. Further development of new delivery solutions will be done together with transport operators. City involvement is of key importance. Automated delivery solutions will optimize current solutions. Radical new solutions may also be developed such as unmanned delivery vehicles and delivery services.
Passenger Cars development path: Peer-to-peer sharing	For personal cars, peer-to-peer sharing services will be further developed where the owner of

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	cars provides sharing of cars to other users in a direct manner. This could also include car sharing vehicle fleets operators. Automated vehicles may operate on parts of the trip or may provide highly automated driving for the whole journey.
Freight vehicles development path: Logistics services, Business need for AD (TCO)	For automated freight vehicles, opportunities will open up for innovative freight transport solutions. Highly automated logistics hubs and multimodal consolidation centers. Highly automated hub-to-hub transport over both short and long distance with dedicated lane and mixed traffic. New last-mile distribution services. Innovative garbage collection and unmanned waste management services. For commercial freight transportation the Total Cost of Operation/Ownership (TCO) is of key importance for market introductions. The business requirements may not only cover low costs, there will also be other operational aspects that needs to be fully understood to build concepts such as Transport-as-a-Services (TaaS).
Urban mobility development path: New infrastructure business models and financing tools	Urban mobility vehicles will require remote control, equipped infrastructure, supervision centres, and interoperability of the vehicles will be required. Developing, deploying and maintaining the infrastructure (physical infrastructure design, equipment, technical features) will be a new challenge for the cities and road operators and a key enabler for deployment

4.4.2. Big data, artificial intelligence and their applications

The utilization of Big Data and Artificial Intelligence (AI) techniques is essential for the developments of CAD systems and CAD related services, however it introduces several challenges in various domains.

4.4.2.1. Challenges

The challenges related to data and IA are mainly involving data problems such as:

- Data Sharing: (1) commercial exchange exist but not R&D, (2) there is no established model for data sharing, (3) companies remain protective
- Privacy: (1) there is a big challenge linked to the utilization of cameras (human faces+ license plates), (2) there is a need to establish best practice + legal precedence
- Security: ensuring integrity and the right receiver of data, which might have a direct influence on (see D3.7)

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- Validation of AI-based functionality: (1) require huge amounts of data (2) no common procedure
- Limitation of existing AI techniques: (1) existing methods are lacking modularity, traceability and transparency and (2) they are poorly handle new situations that were not observed before (i.e. not contained someway in the training data set)

Other challenges will be linked to Data management and quality, the development of AI techniques (AI functions need real-world data sets for validation, which are not available from OEM/tiers), the safety validation of AI bottlenecks (harmonization, alignment in investment and validation.)

4.4.2.2. Enablers and actions

Enablers and actions will be to define the data sharing model (n:n or 1:1) and the frameworks for privacy, security, trust, respect of legal constraints, and payment. It is recommended to start from the success cases, business models and use cases.

4.4.2.3. Key priorities: Big data, artificial intelligence and their applications

Key Priority	***Description***
Develop 'standard' model for sharing data that ensure data privacy and security	A data exchange framework and a common evaluation methodology to improve cooperation and make better use of the results of testing activities in Europe. Key objectives will be to ensure provision of high quality and well-documented datasets, co-operate on a technical reference platform with other data sharing initiatives, encourage data re-use and establish win-win situations and keep the balance between privacy, IPR and availability.
Harmonisation, alignment needed for development and validation of AI functionalities for AV	Training and Validation of AI is a bottleneck. Develop concepts, techniques and models of Artificial Intelligence (AI) will require huge amounts of in-vehicle and infrastructure-based sensor data together with other data sources to 'train' AI algorithms. This will be accelerated and supported through harmonization, availability, quality assurance, interoperability and exploitation of relevant data. Validation of AI is a bottleneck. Industrialization provides considerable challenges; requirement-based development and continuous improvement of trained modules for application in safety critical domains.
Standards and solutions (HW/SW) for data management and data quality	Building on results from projects (e.g. L3 Pilot) to establish standards and solutions for data management to ensure data quality. The consolidated data-sharing framework will be the base to enable and enhance data management and data quality standards.
Develop new AI-concepts for cyber-physical road traffic systems	The cyber-security and Artificial Intelligence (AI) domains are under rapid development. New concepts such as cyber-physical system road system will open for new ways to address AI and cyber-security. In cyber-physical, road traffic

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	systems connected automated vehicles and their users are intertwined through the digital infrastructure to the internet.
Harmonisation of AI investments developments	Currently, massive parallel investments are made in machine learning and AI technologies which result in a broad scattered range of developed techniques. This situation has a negative impact on the citizens' trust in AI technologies and in the decisions made based on AI. Making policies and sharing investment will accelerate AI-based developments and naturally leads towards harmonization which an essential step forward towards users trust and acceptance.
Passenger car development path: New robust AI-passenger-car solutions	Further research and innovation will be done to address the opportunities and challenges for applying AI towards the connected automated passenger cars use cases. Highly automated solutions will be addressed in different levels, vehicle, services and traffic system.
Freight vehicle and Urban mobility development paths: New AI-freight and logistics and urban mobility solutions	Further research and innovation will be done to address the opportunities and challenges for applying AI towards the connected automated freight, logistics and urban mobility use cases. Highly automated solutions will be addressed in different levels, vehicle, services, transport, logistics and traffic system.
New AI-urban mobility solutions	Further research and innovation will be done to address the opportunities and challenges for applying AI towards the connected automated urban mobility solutions use cases. Highly automated solutions will be addressed in different levels, vehicle, services, mobility and traffic system.

4.4.3. Digital and physical infrastructure

The adaptation of physical infrastructure and its link with the digital infrastructure is becoming a key factor for the deployment of connected and automated vehicles of higher levels of automation. A common understanding of the PDI role for CAD, specifications of required infrastructure and its interfaces as well as piloting the interaction between vehicles and infrastructure are required to fulfill the requirements of connected and automated driving in 2035. Physical and digital infrastructure can support in a broad variety of use cases, from the support of vehicles (e.g. in lane merging) to advanced traffic management measures (e.g. interactions with vehicles on strategic or tactical level). The requirements towards the physical and digital infrastructure are strongly dependent on the specific use case. A harmonized approach of how to describe scenarios and use cases is also required in order to put road operators in the position to install appropriate sensors and to supply the communication channels with the needed data and its quality.

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4.4.3.1. Challenges

There is a need to develop a common view, and to harmonize the EU architectures. As a priority, it is necessary to collect evidence on the relation between ISAD levels and AD functions, to involve operational safety in ISAD-AV interactions, clarify the reliability, to make the PDA easier to specify, and to standardize the road signs at a European level (in particular the lane markings). ISAD description makes the support to automation explicit.

4.4.3.2. Actions

Actions need to be taken in the field of:

- Simulations and assessment of PDI supported automation effects on traffic efficiency and safety and its effects on new traffic management concepts
- Development of (automated) PDI-quality on road network in terms of maintenance of road infrastructure (regarding ISAD levels)
- Studies and concepts regarding business models in order to assess and stimulate PDI investments and operation of services

4.4.3.3. Key priorities: Digital and physical infrastructure

Key Priority	***Description***
Need for definitions, standardisation if the interaction of PDI and AVs (e.g. ISAD, ODD)	Prepare for common definitions and standardization to support the interaction between the Physical Digital Infrastructure (PDI) and Automated Vehicles (AV). Explore and leverage on projects results (e.g. INFRAMIX, Mantra). Develop definitions towards standardization of Operational Design Domain (ODD) to enable common European harmonized approach on further development and pre-deployment of automated vehicles. Needed for vehicle validation and road-worthiness testing and even real-time control of vehicles.
Define Classifications of PDI	Based on the common PDI definitions, perform classification of the PDI support level as a base for further development, test, pilots and pre-deployment of Automated Vehicles. This will enable sharing of data and compare results from test, pilots and pre-deployment activities in the EU.
Prepare PDI for AV-ready road planning and self- explaining roads	Prepare the physical infrastructure (markings, road signs, layout, etc.) and digital infrastructure (digitized spatial network and regulations, communication technology, roadside sensors, etc.) to support connected automated vehicles.
Investigate the use of common definitions (e.g. ISAD). Create Living lab with PDI	Further investigate the behaviour and benefits of common definitions to ensure how the transition towards automated vehicles can be made in the most efficient and cost-effective manner. Demonstration pilots to test the use of PDI through living lab concepts with mixed traffic, users and multi-stakeholder involvement.

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Define the involvement of public authorities in the early stage of deployment to create trust among stakeholders	Research on business and financing models and ways to increase (legal) powers and resources for road authorities (and/or operators) to ensure, that the physical and digital infrastructure remains fit for purpose. Achieve common understanding of the role of PDI for connected automated vehicles and specifications of required infrastructure.
Freight vehicle development path: Hub-to-hub corridors, Freight traffic management, Truck parking safe-zones for AD trucks	Develop and prepare for hub-to-hub transport corridors for tests, pilots and pre-deployment activities. Leverage on existing established corridors (green-corridors) and connect corridors to include cross-border and truck-parking safe-zones for automated trucks. Develop and traffic management for automated freight transport to ensure network utilization improvement, enhance traffic safety and integration with other transport modes (transshipment in hubs)
Urban mobility development path: Traffic management complementing public transport	Develop and integrated traffic management systems for urban mobility vehicles (e.g. shuttles, buses, personal transit vehicles) to complement public transport. This will include the different stakeholders for urban traffic management to ensure efficient and safe integration of the complete mobility systems. Integration with other transport modes to ensure smooth mode transition.

4.5. Society Challenges & Key Priorities

4.5.1. Challenges

Appropriately addressing the challenges highlighted by the society related thematic areas will have a considerable impact on the deployment of CAD. EU regulation will increasingly need to be adapted to take into account technological advances. It is the responsibility of EU (and national) R&I projects to gather evaluation data that can be used for decision making at policy level along various impact areas that include financial and operational ones. EU Member States should share best practices and learn from those that already updated their regulation. This will lead towards the establishment of a common framework.

To enable learning from the early phase prototype systems and services all the way to mature ones, a sequence of studies from technical pilots towards more and more extensive field tests with real users of all kind and in different environments are needed. The knowledge that can be gained through them on technical readiness of the technology, implications on different user types and on societal impacts and mechanisms behind them would enable decision making that supports the development of the transport system toward sustainable solutions.

To ensure validity of results, development work is still needed on research methods, especially on indirect long-term impacts of CAD. The use of common frameworks that enable harmonization of certain aspects like KPIs in different studies would support easy comparison and overlook over several evaluation activities.

From a safety validation and roadworthiness testing perspective, ensuring functional and operational safety will play a decisive role in convincing users that CAVs are safe. For validation, transitioning should take place from one-time type approval to continuous

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monitoring of the vehicle operation (e.g. software updates). Putting in place measures against cyber-attacks is significantly important given the vast amount of data that the vehicle will produce. Furthermore, analysing the interaction between the driver, PDI and other road users should be included in the safety analysis. Actors such as road operators, OEMs, vehicle authorities and licence examiners should be involved.

Lastly, similarly to other TAs, user awareness and acceptance are currently being investigated across Europe. Public opinion is diverse and changing frequently, research projects should proactively inform users in order to gradually have CAVs featured more prominently on European roads. Privacy issues should be clarified and understood by users while at the same liability regimes should eliminate any legal uncertainty in case of an accident. In the coming years, an increasing number of CAVs on the road will be interacting with other vehicles and road users. For this reason, it will be challenging to identify the most suitable legal framework that ensures safety but at the same time fair compensation.

4.5.2. Key priorities User awareness, users and societal acceptance and ethics, driver training

Key Priority	***Description***
Societal Needs Analysis from user and society perspectives	There is a continuous need of societal needs analysis as automated vehicles will be more available and known to the users and society. Different user groups will be studies to ensure inclusiveness. Focused efforts towards different stakeholders through for example awareness campaigns.
Positive Risk analysis	Perform positive risk analyses to identify, assess and manage the potentially beneficial outcomes of connected automated driving for the users and society. This to balance the negative risk analyses of CAD dominating in the media. Scientific rigor should be maintained in such analysis to avoid bias.
Ethics evaluation based on technology understanding	Perform ethics evaluation as the understanding of connected automated driving technologies evolve and will be more available for the users and society. The ethics evaluation will be important as bases for further research, tests and pilots with automated vehicles on open roads in mixed traffic. AI and machine learning are areas of particular concern.
Impact on driver/users and operator training	Users will need training to know how to operate/use different types of vehicles working on different systems and how to drive in different modes of automation. The role of professional drivers will change to include remote controlling and dedicate more time to administrative tasks.
Secure privacy for mobility users	Privacy is of particular concern for mobility users. Research to understand privacy concerns and to develop solutions to mitigate and secure privacy. Applied GDPR for mobility users of automated vehicle solutions.
Freight vehicles development path: New fleet operation schemes for AV	Automated freight vehicles will open opportunities for new logistics operational schemes to further enhance transport efficiency and safety. Logistics stakeholder involvement is of key importance. New schemes will enable new actors and radical new ways of performing freight transport that will disrupt the logistics sector. This will affect users and the

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	professional roles will change (drivers, operators, fleet manager etc.).
Urban mobility development path: City authority Perspectives	The introduction of automated urban vehicles will drastically change the mobility system. City authorities' involvement is of key importance to understand and plan for how the future inclusive mobility system will be designed. New highly automated vehicles may have positive or negative effects. Regulatory measures need to be considered.

4.5.3. Key priorities: Safety validation and roadworthiness testing

Key Priority	***Description***
Alignment of vehicle regulation (and type approval) and corresponding assessment tools & procedures	The vehicle regulation and type approval framework needs alignment to enable deployment of automated vehicles (i.e. dealing with both the physical components, software and driving behavior). This needs to be done at least on a European level. This will also include development of corresponding assessment and type approval tools and procedures. The HEADSTART project addresses these topics.
Determine proper combinations of virtual testing, closed test track and open road testing of AVs	To fully test and validate automated vehicles, there is a need to combine different methods due to the complexity and vast number of use-cases in which AV will operate. There will be combinations of virtual testing using models and (scenario-based) simulations, closed test track and open road testing together with connectivity and cyber-security.
Share and harmonize driving/traffic scenarios and best practices	Driving and traffic scenarios need to be shared to ensure safety validation and roadworthiness of automated vehicles. Harmonizing shared best practices between different driving and traffic environments will secure that the experiences will be available for the benefit of safe introduction of automated vehicles. In particular, practices regarding cyber-security are important. Sharing scenarios and best practices can also significantly reduce costs at technical and organizational level.
Consensus building with respect to validation of methodologies, including data-labelling standards	There needs to be consensus between all stakeholders (associations, policy decision makers on mobility, road safety, urban planning, traffic control, etc.) to establish common validation methodologies. This will include data-labelling standards to ensure comparability.
Develop procedures to manage validation of vehicle updates monitoring during the whole lifecycle of the vehicle	Procedures for a common framework for harmonization, standardization and homologation of updates/upgrades need to be established on basis of a common understanding of the required safety, reliability and security of CAD. Developing procedures to manage validation of vehicle updates (e.g. over the air software updates) and monitoring during the whole lifecycle of the vehicle.
Passenger car development path: Homologation framework and simulations, self-certification	Higher levels of automation, in particular in mixed traffic situations require validation and verification from a traffic-centric point of view instead of vehicle-centric: considering

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	the interaction between the vehicle, the infrastructure, the human in the vehicle and other road users. Within this context, virtual, physical and hybrid approaches are needed to allow cost-effective, reproducible and interchangeable validation of individual components and software as well as of the vehicle automation functions, including the underlying safety concept. Common methodologies and tools are needed to define the validation and verification requirements as well as the orchestration of the required tests. In addition, new methodologies are needed to demonstrate that a highly automated vehicle behaves safely and predictably in real-life traffic situations, like human drivers do. A common framework for harmonization, standardization and homologation need to be established on basis of a common understanding of the required safety, reliability and security of CAD.
Freight vehicle development path: Hub-to-hub, semi-confined ODDs	For freight vehicle automation, the homologation framework will consider the dedicated ODDs related to freight transport. Hub-to-hub freight transport for long and short transport freight transport between freight consolidation centers, where specific freight vehicle regulation will apply. In addition, in confined and semi-confined areas, i.e. within restricted areas such as ports, where highly automated unmanned vehicles will operate with remote surveillance.
Urban mobility development path: VRU scenarios for unmanned buses and shuttles	Highly automated vehicles operating in urban areas, like unmanned buses and shuttles, will also interact with vulnerable road users, in particular cyclists and pedestrians. This may require specific safety validation and roadworthiness requirements for the corresponding ODDs and testing orchestrations.

4.5.4. Key priorities: Policy and regulatory needs, European harmonization

Key Priority	***Description***
Flexible AD regulation, enabling different solutions, within the boundaries of safety	A regulatory framework for automated driving is important, in particular for safety. The regulatory framework needs to be flexible to open for different technical solutions to meet the regulatory demands, yet within the boundaries to ensure safety. The possibility for different technical solutions will strengthen competition and open for innovative solutions, since the automotive domain is in full competition.
Learn from adaptation of regulation, work towards common approach	It will be of importance to learn from experiences from adaptation of the regulatory framework for connected automated vehicles. Sharing of best practices from the member-states to strive towards a common approach and framework.
Build common CAD framework	Based on the common approach, build a common framework from connected automated vehicles for the Europe. It will also be important to work towards a common global framework since the CAD market is global.

Make cross-border testing easy	One specific area of importance is cross-border testing. There will be more cross-border testing to secure that the regulatory framework is truly harmonized between different countries. Today cross border testing is difficult/costly due to different regulatory framework throughout Europe.
Harmonisation of the interpretation of traffic rules, digitalization of traffic sign information	The automated vehicle interpretation of traffic rules and traffic signs etc. is a necessity for safety. The variation of traffic rules on national, regional and even local level creates complexity for deployment. Harmonized digitalization of traffic signs would facilitate this.
Freight vehicles development path: Business case for platooning needs to be clarified depending on regulation scenario	For Freight vehicles, the business case for platooning is not clear. It strongly depends on the regulation for driving times while platooning. The benefits need to be further clarified in for example long-term pilots elaborating different scenarios. The benefits could be: improved safety and transport efficiency and traffic flow, but as of today the benefit is not fully understood.
Urban mobility development path: Support early introduction through exemptions	For urban mobility vehicles, there is a need to support early introductions to explore the benefits and consequences. There is a need to support with exemptions from regulations to continue deployment and build a harmonized regulatory framework through Europe.

4.5.5. Key priorities: Socio-economic assessment and sustainability

Key Priority	***Description***
Impact assessment needs both pilots (low TRL) and FOTs (high TRL)	Assess the short, medium- and long-term impacts, benefits and costs of connected, cooperative and highly automated driving systems (in all areas) considering the full range of impacts. Including, but not limited to, driver behavior, mobility behavior, accessibility, safety, traffic efficiency, emissions, energy consumption, use of resources, impact on employment, required skills, infrastructure wear and land use. Conduct comprehensive cost / benefit analyses and projections of the overall investment requirements, vehicle equipment costs, operating costs and environmental costs of large-scale deployment, in exchange for expected targets for road-safety, traffic efficiency, health and pollution, affordability for users, and inclusiveness, to direct development policies towards the most appropriate economic, social and environmental needs.
Development of EU-level databases to allow more reliable scaling up (data on accidents, mileage, etc. including ODD aspects, with sufficient details and granularity)	There should be Pan-European level databases for traffic and mobility. These databases need to include information about incidents, accidents, mileage, congestion, emissions, ODD aspects (i.e. conditions where e.g. mileage is driven or accidents happen) and sufficient data details and granularity. The databases are essential for reliably scaling up pilots on automated vehicles towards deployment.
Development of commonly available (validated) AV	Simulation and evaluation tools will further support development of automated vehicles and understanding the

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simulation and other evaluation tools	implications that they will have on societal goals. These tools will help simulate AVs in various traffic situations to evaluate the effects and impacts. Common availability of these tools will further support deployment and boost research and consequently knowledge in this domain.
Commitment to use common impact assessment methodologies (like FESTA, Trilateral framework)	Promote use of common impact assessment methodologies, such as FESTA (FESTA Handbook, 2018) and e.g. Trilateral Impact Assessment Framework for Automation in Road Transportation (Innamaa et al., 2018), being developed in EU–US–Japan cooperation. Harmonization of certain aspects of evaluation to enable comparability and understanding of results. In addition, several data and simulation tools should become available in the next 3–5 years.
Research on the long-term indirect impacts of automation, equity etc.	The long-term effects and impact on the society and transport sector of automation needs to be explored from various perspectives and methods to be developed for how will automated road transport provide benefits like safety, equity, etc. and how will land use policies affect those. Understanding these long-term impacts helps to support the positive development trends and, on the other hand, to mitigate risks and find counter measures for identified potential negative impacts. Knowledge on expected life-time costs of CAVs and related infrastructure up keeping is also needed.
Personal Cars development path: Impacts on safety and travel behavior	For automated personal cars, in particular the impact on traffic safety and travel behavior is important to study and understand. These impact areas are linked indirectly with many other impacts, like transport network efficiency, environmental impact of mobility, or health and wellbeing.
Freight vehicles development path: Impacts on transport network efficiency and environment	For automated freight vehicles, in particular the impact on network efficiency and transport environmental factors such as local emissions and energy efficiency. In addition, transport network utilization efficiency, load factor and transshipment efficiency. Safety is also important from both a traffic and work environment perspective.
Urban mobility development path: Impacts on transport mode choice and social inclusion	For automated urban vehicles, in particular the impact of transport mode of choice and social inclusion is important to study. Traveler behavior change, selection of public transport, personal cars or other means of automated urban mobility vehicles such as shuttles and personal mobility vehicles, e.g. pods. In addition, the social inclusion to study the effect on elderly, children and disabled access to automated urban mobility.

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5. EU and international initiatives

5.1. European research projects

The European Union has a strong history of funding collaborative research contributing to automated driving, as shown by the picture below, which provides an overview of the major recent and current European funded projects. EU funding for the domain started more than 10 years ago in the 6th Framework Programme and intensified in the 7th Framework Programme. It continued in the current Horizon 2020 Programme, with from 2016 the launch within the Transport Programme of a specific call on “Automated Road Transport”[11], which should provide about 300 Mn € of EU funding in the successive calls up to 2020. The first editions of this Roadmap provided recommendations on the topics to be addressed by this “ART” call for projects. Only the most prominent EU funded projects are included in the picture below: the reader should consult the online database for a complete and up-to-date list of all projects funded by the EU. The picture gathers the projects using acronyms in four research fields: Networking, Coordination & Support, Infrastructure, Connectivity and Cooperative Systems, Driver Assistance Systems and Partial Automation and Highly Automated Road Transport.

For a comprehensive list of projects see the ARCADE WP4, deliverable D4.2 describing the knowledge base. The figure below only provides a selection of the extensive project list. See https://knowledge-base.connectedautomateddriving.eu/projects/

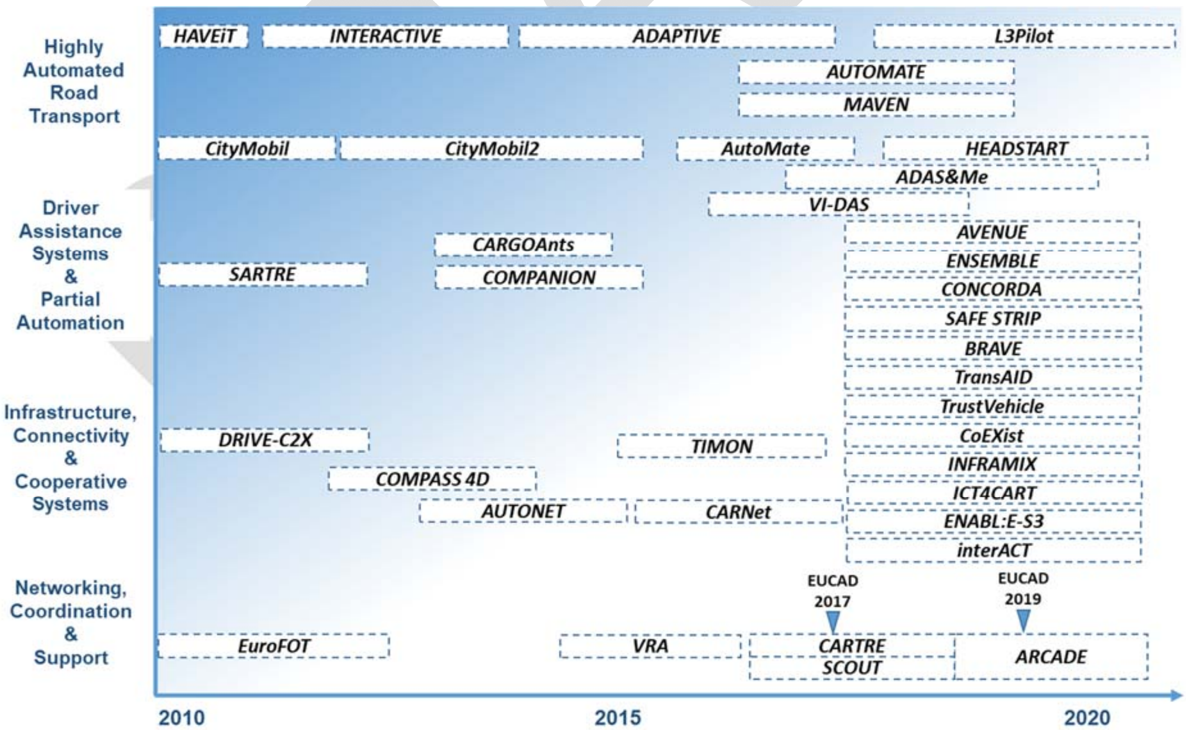

Figure 10: Overview of a subset of EU funded projects that support development of automated driving.

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

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5.2. European initiatives

5.2.1. The European Union strategy on connected and automated mobility

The European Commission adopted in May 2018 the 3rd Mobility Package[12], including legislative and policy initiatives, among which a Communication entitled "On the road to automated mobility: an EU strategy for mobility of the future"[13]. The Strategy proposed a comprehensive series of measures to be implemented in the next years to: 1) develop the necessary technologies and infrastructure in Europe, 2) ensure that automated mobility is safe and 3) to cope with societal issues such as jobs, skills and ethics. As vehicle safety is key for consumer acceptance, the Commission proposed as part of the 3rd Mobility Package a legislative proposal to provide the legal framework for the approval of automated and connected vehicles (the so-called vehicle general safety regulation).

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

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

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

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

- New vehicle type-approval rules
- Proposal for new safety measures for driver assistance systems and autonomous driving

[12] https://ec.europa.eu/transport/modes/road/news/2018-05-17-europe-on-the-move-3_en

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

- Proposal for new safety requirements for roads to support automated vehicles
- Proposal for mandatory black box in automated vehicles
- Upcoming guidelines on the product liability framework
- Develop a balanced and fair framework for the sharing of vehicle data
- Adopt rules to ensure secured communication, data protection and interoperability
- Set recommendations on the use of spectrum for 5G large scale testing

Regarding societal and ethical aspect, the European Commission will:

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

5.2.2. GEAR 2030

The European Commission has launched in 2016 a new High Level Group for the automotive industry called GEAR 2030: it gathers industrial representatives and European associations with EU institutions and national ministries. The objective is to address the challenges faced by the automotive industry and anticipate the future needed regulatory frameworks. A special attention is given to position the European industry as a technology leader and ensure its competitiveness on world markets. By principle of transparency, working documents of the group are accessible on the European Commission website[14].

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

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

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the certification approach, liability issues, automotive data issues and societal issues like the impact of automation on public transport, jobs or skills.

GEAR 2030 adopted its final recommendations on 18 October 2017.

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

The EC Communication on Automated Mobility[15] proposes to develop a strategic planning of R&I actions and to better coordinate national and multinational funding programmes. The need for a coordinated approach and priority setting for funding research, demonstration and pre-deployment activities was also stated by the EU Member States in the 'Declaration of Amsterdam'[16] and in the recommendations of the GEAR 2030 High Level Group[17].

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

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

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

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

- In-vehicle enablers
- Vehicle Validation

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

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

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

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

The STRIA roadmap on CAT was published in spring 2019.

The identified STRIA roadmap actions have been integrated into the consolidated key priorities in section 4.

5.2.4. SCOUT Coordination and Support Actions

Beside the previous CARTRE and ongoing ARCADE projects, the SCOUT ("Safe and Connected Automation in Road Transport") was a Coordinated and Support Action funded by the European Commission under Horizon 2020 from 2016 to 2018.[18] The main outcome of the project is a comprehensive cross-sectorial roadmap describing the pathways for an accelerated proliferation of safe and secure high-level CAD by 2030 in Europe.[19] The roadmap, which has been developed in a co-creative manner with the involvement of a diverse group of stakeholders, is taking into account technical, economic, legal, societal and human factors. It highlights opportunities to leapfrog hurdles for innovation in SAE level 4/5 automated driving by a coordinated interplay of actions that are described for five specific use cases: automated on-demand shuttle, truck platooning, valet parking, delivery robot, and traffic-jam chauffeur. Eventually, advice for policies and regulatory frameworks is given. The topic is now being further elaborated in the framework of the follow-up project COSMOS ("Coherent Support for MObility.E Strategy") which is being funded in the framework of the ECSEL Joint Undertaking to support its Mobility.E lighthouse with an implementation plan that bridges white spots and funding gaps, particularly in the enabling technologies for CAD.

The SCOUT and CARTRE projects supported the European Commission in the organisation of the first European Conference on Connected and Automated Driving, which took place in Brussels on 3-4 April 2017. The results were incorporated into the CARTRE project and consequently also into ARCADE.

5.2.5. European Automotive-Telecom Alliance

[18] https://cordis.europa.eu/project/rcn/204978/brief/en?WT.mc_id=exp

[19] J. Dubbert et al., Roadmap for Accelerated Innovation in Level 4/5 Connected and Automated Driving. In: J. Dubbert, B. Müller, G. Meyer (Eds.), Advanced Microsystems for Automotive Applications 2018: Smart Systems for Clean, Safe and Shared Road Vehicles. Springer 2018.

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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[20]. EATA comprises six sectorial associations: ACEA, CLEPA, ETNO, ECTA, GSMA and GSA as well as 32 leading European companies, including telecom operators, vendors, automobile manufacturers and automotive suppliers, all giving their commitment to support and contribute[21]. The main goal of the Alliance is to facilitate and accelerate the EU-wide deployment of connected and automated driving, with the following objectives:

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

At the Digital Day in Rome on 23 March 2017, 29 European countries, Members of the European Union and of the European Economic Area, have signed a Letter of Intent to intensify cooperation on testing of automated road transport in cross border test sites. In this Letter of Intent, they express their regard and acknowledge to support reaching the goals formulated by EATA[22].

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

A core aim of CONCORDA is also to enhance interoperability of technologies, services and implementation in the EU (test sites are located in the Netherlands, Belgium, France,

[20] http://www.acea.be/press-releases/article/37-leading-companies-join-forces-in-european-automotive-telecom-alliance

[21] http://clepa.eu/wp-content/uploads/2017/02/20170227-Connected-and-automated-driving.pdf

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

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Germany, and Spain). By early 2020, the partners in CONCORDA will present the outcomes, including recommendations on regulations, policies and standardisation.[23]

5.2.6. Cooperative Intelligent Transport Systems & C-Roads

Cooperative Intelligent Transport Systems (C-ITS) connect vehicles with each other and with the road infrastructure, allowing road users and traffic managers to share information and use it to coordinate actions. This cooperative element is expected to bring significant benefits for road safety, traffic efficiency and driving comfort, as stated by the European Commission: "significantly improving road safety, traffic efficiency and comfort of driving by helping the driver to take the right decisions and adapt to the traffic situation". It is considered important to increase the safety of future automated vehicles and their integration in the overall transport system, in particular as these will be expected to negotiate increasingly complex traffic situations. The vision is that cooperative ITS, connectivity and automation are complementary technologies and shall reinforce each other and converge over time.

The C-Roads Platform[24] is a joint initiative of European Member States and road operators which are in the phase of installing C-ITS for the testing and operation of "C-ITS Day-1 services". In accordance with the C-ITS Platform recommendations, harmonised specifications are being developed and the first harmonised communication profile for C-ITS services is already finalised. All developed specifications will be publicly available and form the basis for pilot installations on the road network. In accordance to the European strategy on Cooperative Intelligent Transport Systems (COM(2016) 766) the C-Roads Platform supports the use of hybrid communication technologies. The starting point for pilot deployments will be the combination of ETSI ITS-G5 and existing cellular networks.

This first generation of services for Cooperative Intelligent Transport Systems (C-ITS) is ready for deployment. They are based on a set of standardized messages developed by ETSI[25] or CEN/ISO[26] which have been used to implement a first set of use cases to increase traffic safety in general, like e.g. road works warning, hazardous location notification, in-vehicle signage or intersection safety. Implementations and tests of such "Day 1" C-ITS services have taken place in several countries and/or C-ITS initiatives throughout Europe. To guarantee service interoperability, these services and messages have been harmonized in the C-ROADS initiative, providing common use descriptions and message profiles for infrastructure-based C-ITS messages. This C-ROADS "Infrastructure Profile" complements the CAR 2 CAR Communication Consortium's "Basic System Profile", which defines message profiles for vehicle-based C-ITS messages. Both these efforts are major contributions for the preparation of a Delegated Act on C-ITS, which, after publication (currently planned for early 2019) will be the guideline for harmonized "Day 1" C-ITS deployments in Europe.

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[23] http://erticonetwork.com/new-project-driving-automation-kick-off-brussels/

[24] https://www.c-roads.eu/platform.html

[25] ETSI (2013). Cooperative ITS (C-ITS); Release 1. TR 101 607 V1.1.1 Available online: http://www.etsi.org/deliver/etsi_tr/101600_101699/101607/01.01.01_60/tr_101607v010101p.pdf

[26] CEN/TC278 ITS Standardization, Available online: https://www.itsstandards.eu/cits

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5.2.7. Related Public-Private Partnerships

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

A reorganisation of this landscape of Partnerships is expected, with some being continued, some merged, and some newly created, during the preparations for the next EU Framework Programme Horizon Europe.

5.2.8. ECSEL

ECSEL is a Joint Undertaking formed by the European Union (through the European Commission), EU Member States and three associations: EPoSS, AENEAS and ARTEMIS-IA, representing the actors from smart integrated systems, micro- and nano-electronics, and embedded/cyber-physical systems. Electronic components and systems are Enabling Technology at the core of many industrial branches, including transport and automotive: they play a key role in digitalisation and connectivity, and are necessary components for automated driving systems. The objective of ECSEL is to ensure the availability of innovative electronic components and systems for key markets and for addressing societal challenges. The mission of the PPP is to bridge the gap between research and exploitation, align national strategies, and promote an increase in European and national investments. Within its multi-annual strategic plan, “Smart Mobility” is one of the key applications, and automation of vehicles has been set as an objective. Information on the PPP and its projects are available on the ECSEL website[27], including its latest Strategic Research Agenda (SRA) on Electronic Components and Systems published in 2019[28]. Here are some examples of research activities planned in ECSEL that can support the development of automated driving:

- Functional safety development for test procedure, and test systems including sensor fusion
- Improvement of sensor accuracy, as well as miniaturization
- Improvements of the architecture for vehicle electronic systems (Hardware and Software)

[27] https://www.ecsel.eu

[28] https://www.ecsel.eu/sites/default/files/2019-02/ECS-SRA%202019%20FINAL.pdf

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- 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)

The project “Coherent Support for Mobility.E Strategy” (COSMOS) aims at supporting the ECSEL Lighthouse Initiative Mobility.E in its endeavour to accelerate the deployment of clean and automated road mobility solutions and the realisation of the associated socio-economic benefits. For this purpose, the COSMOS project will assist the Lighthouse Initiative Advisory Service (LIASE) in the continuous identification and prioritisation of research topics and the subsequent translation into an action plan to support roadmap implementation.

5.2.9. 5G

5G is family of mobile communication standards building upon the great success of 4G/LTE. The 5G New Radio promises advanced native features such as mobile broadband, reliable low latency and massive IoT. The 5G- PPP[29] is an initiative between the ICT industry and the European Commission to prepare the next generation of communication networks and services, with the objective of “ubiquitous super-fast connectivity and seamless service delivery in all circumstances”. The Commission’s 5G Action Plan[30] published in 2016 laid down the deployment timeline: 2020 for early roll-out in at least on major city in each member state, and, 2025 for uninterrupted coverage over all urban areas and major transport paths. Transport and vehicles are mentioned as a major field of opportunity to develop new services based on those new capacities. So-called “mission critical services” will become feasible thanks to the higher performances achievable by 5G: advanced services based on cloud, edge computing, vehicle-to-vehicle and vehicle-to-infrastructure connectivity are targeted, with a specific reference to automation. In February 2018, the 5G PPP issued “A study on 5G V2X Deployment”31. This white paper is the outcome of the 5G-PPP Automotive working group and provides insights into the deployment costs for 5G V2X and revenue analysis for financially and socially beneficial commercialization. Work is ongoing to integrate the specific technical requirements from the automotive industry towards future networks to be used for vehicles automation (in particular in the 5GCAR project). Together with the 5G Automotive Association (5GAA), standardisation, spectrum and regulatory work for 5G are ongoing, and business models are proposed. Through the PPP, the EU recently launched three Connected and Automated Driving cross-border innovation actions (5GCroCo, 5G-Mobix, 5G-Carmen). These activities are in line with international plans to exploit the potential of 5G for connected and automated driving. However, Europe tends to be slower to pick up the new opportunities offered by such breakthroughs. NGMN has recently published a full white paper on the potential of V2X[32] around the world.

[29] https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf

[30] https://ec.europa.eu/digital-single-market/en/5g-europe-action-plan

[31] https://5g-ppp.eu/wp-content/uploads/2018/02/5G-PPP-Automotive-WG-White-Paper_Feb.2018.pdf

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

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5.2.10. Cyber-Security

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

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

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

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

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

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

5.3. EU Member States initiatives

5.3.1. Declaration of Amsterdam and High Level Dialogue

On 14 April 2016 at the Informal Transport and Environment Council in Amsterdam, 28 EU Ministers of Transport endorsed the “Declaration of Amsterdam” to work towards a more coordinated approach enabling the introduction of connected and automated driving. Close cooperation between Member States, the European Commission and industry partners is seen as an important prerequisite for the widespread introduction of innovative and

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interoperable connected and automated driving technologies and services in Europe. The Declaration of Amsterdam on Connected and Automated Driving was an important first step towards a common European strategy in this field and includes a joint agenda for further action to support the shared objectives. Key action points for Member States mainly involve the need to address legal and practical barriers to the testing and deployment of connected and automated vehicles. The Declaration of Amsterdam also called for the establishment of a high level structural dialogue for Member States to exchange views and best practices regarding the development of connected and automated driving and to monitor progress.

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

- The first High Level Meeting, organized by the Netherlands, was held in Amsterdam on 15 February 2017: https://www.government.nl/documents/leaflets/2017/05/18/on-our-way-towards-connected-and-automated-driving-in-europe
- The second High Level Meeting, organized by Germany, was held in Frankfurt on 15 September 2017: https://www.bmvi.de/SharedDocs/EN/Documents/DG/action-plan-automated-and-connected-driving.pdf?__blob=publicationFile
- The third High Level Meeting, organized by Sweden, was held in Gothenburg on 18/19 June 2018: https://www.government.se/articles/2018/06/third-high-level-meeting-on-connected-and-automated-vehicles-led-to-common-conclusions/
- The fourth High Level Meeting, organized by Austria, was held in Vienna on 28/29 November 2018: http://www.smart-mobility.at/hlm2018/

5.3.2. The Netherlands

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

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

2016 EU Truck Platooning Challenge. The goal is to bring truck platooning to the next phase of the innovation cycle by implementing platooning into real-life logistics operation for different use cases running at different participating companies.

5.3.3. France

In May 2018, Ms. Idrac, former Minister, Head of the National Strategy for the Development of Autonomous Vehicles, published[33] the strategic framework that will structure the French government's policy actions dedicated to the development of automated or driverless vehicles, covering the following areas: modes of use and local expectations, safety, acceptance, competitiveness and employment, and European and international cooperation.

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

The French automotive & mobility platform (PFA), with its "France Autonomous Vehicles" program, committed to the development of this ecosystem of autonomous vehicle with large scale experimentations. Several groups have been set by platforms addressing technologies and safety and security demonstrations.

First results of the National Strategy have already been achieved: a legal framework for experimentation with automated driving is in place, resulting in already 10.000 km of roads available, and more than 60 test trials. This framework is being adapted (draft law in Parliament) to higher levels of automation, with the possibility that the driver would not be in control of the vehicle during manoeuvres, and the corresponding liability provisions. The current focus is on large scale experimentation on open roads for safety demonstration and acceptance, for which a dedicated innovation program has been set up under the "Programme des Investissements d'Avenir". Corresponding experiments shall start from 2019 onwards. A draft law (Loi d'orientation des Mobilités) has been proposed to Parliament to enact the future regulatory framework for autonomous vehicles deployment in a permanent regime. France has proposed a revised version of the Vienna Convention and a new approach to safety validation at the UN-ECE level. Several working groups between regulatory authorities and the industry have been set up to assess challenges and propose adaptations on the topics of technical regulation, homologation, liability, driving rules, interaction with police forces, and acceptance. A focus will in 2019 be given to regulatory framework for automated public

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

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transport in dedicated areas or paths, and to setting a relevant framework for managing driving scenarios for validation purposes.

5.3.4. Germany

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

In September 2015, based on recommendations made by the Round Table, the Federal Government published its *Strategy for Automated and Connected Driving - Remain a lead provider, become a lead market, introduce regular operations*[34]. This document lays out objectives adopted by the government for exploiting the opportunities for growth and prosperity inherent in automated and connected driving.

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

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

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

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

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

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

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

5.3.5. United Kingdom

In 2015 the UK Government founded the Centre for Connected and Autonomous Vehicles (CCAV[35]) to secure the UK's position at the forefront of this change, focussing on the safe development, production, deployment and use of CAVs and their related technologies.

Regulation – The UK's flexible regulatory environment supports innovation and safety. The recently updated Code of Practice[36] for public trials of automated vehicle technology sets out that trials of any level of CAV technology are possible provided they comply with the law. This includes having a driver, in or out of the vehicle, who is ready, able, and willing to resume control of the vehicle; a roadworthy vehicle; and, appropriate insurance in place. It also presents plans to develop a process to support advanced trials, which will see truly self-driving trials on UK roads.

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

The UK also passed the Automated and Electric Vehicle Act 2018[37], which extends compulsory motor vehicle insurance to cover the driver when they are driving and when they have handed control to their self-driving vehicle. If the self-driving vehicle caused a collision, any victim would get quick and easy access to compensation. Building on this, CCAV has asked the Law Commission of England and Wales and the Scottish Law Commission to jointly undertake a three-year review of the UK's legal framework in the context of automated vehicles[38]. This review will report in 2021 and develop proposals to support the safe deployment of AV technologies and their use in new mobility services.

The UK worked with other countries at the UNECE on the recently adopted Resolution on the Deployment of Highly and Fully Automated Vehicles in Road Traffic[39]. This innovative resolution adapts the guiding principles of the 1949 and 1968 Conventions on Road Traffic to

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[35] https://www.gov.uk/government/organisations/centre-for-connected-and-autonomous-vehicles

[36] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/776511/code-of-practice-automated-vehicle-trialling.pdf

[37] https://services.parliament.uk/bills/2017-19/automatedandelectricvehicles.html

[38] https://www.lawcom.gov.uk/project/automated-vehicles/

[39] https://www.unece.org/info/media/presscurrent-press-h/transport/2018/unece-adopts-resolution-on-the-deployment-of-highly-and-fully-automated-vehicles-in-road-traffic/doc.html

today's environment, paving the way for the safe mobility of the future, for the benefit of all road users.

Research and Development – The 2014 Four Cities Trials showcased Autonomous Vehicles and their integration into real-world environments. CCAV has followed that with funding for innovative research and leading-edge trials working with more than 200 companies including Original Equipment Manufacturers and Small and Medium Enterprises, Academics and Charities and local authorities and regional transport authorities[40].

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

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

The first four infrastructure projects were launched in 2017, developing two controlled testbeds and two public, open roads, testbeds in the West Midlands and London to expand and compliment the substantial existing vehicle testing capability in the UK. The UK Government also founded Meridian Mobility[41] to facilitate partnerships, collaboration across sectors and to help secure global recognition of the UK's leadership in testing and development in this new arena.

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

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

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

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

[40] https://www.gov.uk/government/publications/connected-and-autonomous-vehicle-research-and-development-projects

[41] https://meridianmobility.tech

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See the UK Connected and Automated Mobility Roadmap to 2030 "ZENZIC"[42]

5.3.6. Sweden

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

The *FFI partnership program* is the main program for automotive research in Sweden funded by the innovation agency Vinnova, the Swedish Energy Agency, the Transport Administration and the main automotive stakeholders in Sweden. The FFI program covers several important areas for connected automated driving, such as "Road Safety and Automated Vehicles", "Electronics, Software and Communication", "Efficient and Connected Transport System", "Systems-of-systems", "Cyber-security for automotive" and Electro-mobility.

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

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

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

5.3.7. Spain

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

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

[42] https://zenzic.io/about/

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- SISCOGA^{4CAD} is a permanent European CAD corridor to test future CAD solutions. SISCOGA^{4CAD}, comprehends more than 150 km equipped with different connectivity technologies including ITS-G5 and cellular (3G/4G, MEC, PC5 and 5G).
- Madrid AUTOCITS A-6 Cooperative Corridor is located in the Northwest Madrid Urban Node access, a 16 km stretch of highway between the M30 and M40 the main urban and interurban nodes in Madrid, equipped with ITS-G5 continuous communications.
- C-ROADs Spain: Following the C-ROADS framework several corridors are being deployed in several locations in Spain: Madrid C-ROADS M-30 Cooperative; SISCOGA Extended (city of Vigo); Cantabrian corridor in the northern area of Spain; Mediterranean corridor (Catalonia and Andalusia).
- Catalonia Living Lab is a public-private framework for development and testing CAD technologies. Its primary goal is to cover international needs related to CAD development and testing through the comprehensive aggregation of Catalan public and industry infrastructures and services.

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

5.3.8. Austria

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

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In autumn 2018 the Action Programme on Automated Mobility[43] covering the period 2019 until 2022 was released. Additional 65 million Euro of public funding have been dedicated to follow-up actions on automated and connected mobility. It was developed by considering the perspectives of more than 300 stakeholders on national and international level and addressing all means of transport. The primary use cases ("New flexibility", "Security+ though an all-round view", and "Well supplied") from the first action plan in 2016 are still decisive for the alignment of testing and deployment activities regarding automated mobility in Austria. However, when it comes to better understanding technological and organisational matters as well as complex testing scenarios, even stronger efforts will be made addressing experimental frameworks ("sandboxing"). Among that, the current Action Programme Automated Mobility covers seven different thematic areas, such as transparent information, constant adaption of legal frameworks, public sector capacity, impact assessment, R&D, infrastructure as well as human-machine, i.e. user interactions.[44] Among these thematic areas more than 30 measures within the responsibility of different public and sector institutions are proposed.

5.3.9. Finland

Based on a national automation strategy for all transport modes in 2015, the Road Transport Automation Road Map and Action Plan 2016–2020 was published in early 2016. This document lists the transport administration actions in the domains of infrastructure, road superstructure and equipment, vehicle systems, services and functions, and driver. A major emphasis is on testing activities. In 2018, a national study investigated the impacts of highly automated driving on road operators and transport authorities in Finland by 2040. The existing Finnish legislation is liberal, allowing automated vehicle operation on open roads by a driver also outside the vehicle i.e. in remote control. The Finnish Transport and Communication Agency Traficom is issuing test plate certificates for stakeholders wishing to test & validate automated vehicles and driving functions on Finnish roads.

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

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

[43] National Contact Point Automated Mobility: http://austriatech.at/en/activities/point-of-contact-automated-driving

[44] For more details see figure 8 in the Austrian Action Plan on Automated Mobility, p.28

5.3.10. Greece

Greece has decided to allow the circulation of fully automated driverless vehicles in urban areas and on public roads for research/pilot implementations. The framework requires a thorough analysis of the proposed routes, a certification process for the vehicles, a proper training for the operators (remote or on-board), a supervision by appropriate specialized research or academic bodies and an active support by local authorities. These specific conditions were defined in detail in a ministerial decision that was published on June 13th 2015.

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

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

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

5.3.11. Hungary

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

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

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

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

5.3.12. Slovenia

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

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

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

5.4. Initiatives around the world

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

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

- Architecture and Standards Harmonization (US-EU bilateral)

- Human Factors

- Automation in Road Transport

- Deployment (including a Sub-Working Group on Probe Data)

The collaboration is structured in a three-layer manner: namely a Steering Group, a Coordinating Group and several Working Groups, including one on Automation in Road

Transport (the ART WG). The ART WG was established by approval of the Steering Group in October 2012 at the Vienna World Congress.

The mission of the ART WG can be summarised as follows:

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

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

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

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

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

- Next Generation of Transport: coordinate efforts to identify most promising shared and automated mobility services.
- Digital infrastructure: coordinate efforts to identify the static and/or dynamic digital representation of the physical world with which the automated vehicle will interact in order to operate;

5.4.1.1. USA

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

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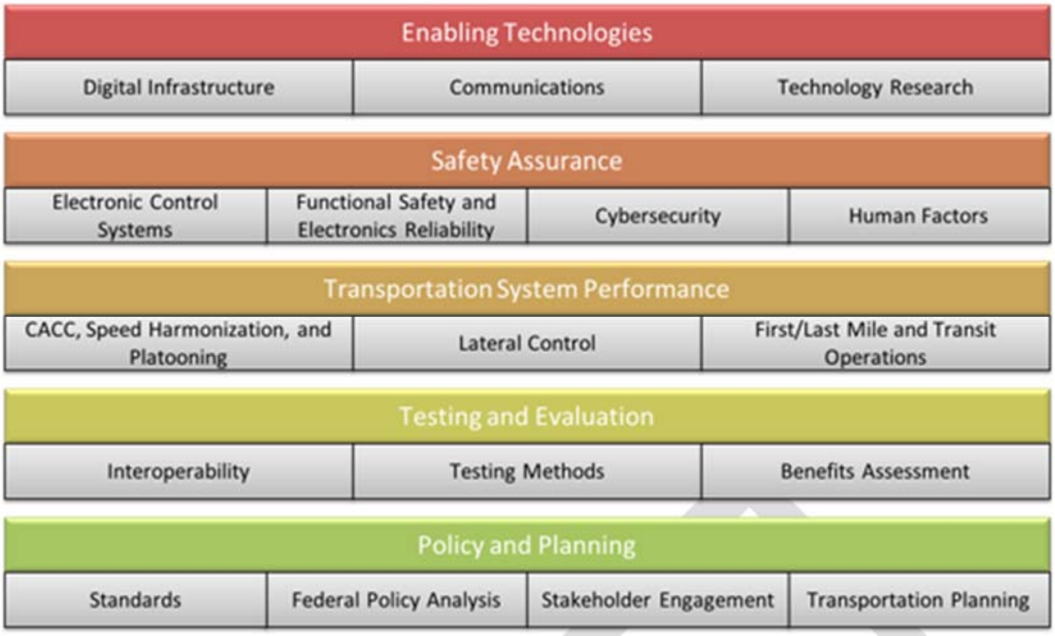

Figure 11: : US DoT ITS JPO Automation Program research tracks

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

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

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

The ITS JPO together with VOLPE has worked on a harmonised framework to impact assessment of ART, which has been further developed in the EU-US-Japan Trilateral Working Group on Automation. The framework takes a broad look at the impact of AV introduction with a classification in nine impact areas and mechanisms, including Safety,

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Mobility/energy/emissions, User response and Economic impacts. It is being used in a series of projects in US, Europe and Japan.

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

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

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

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

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

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

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

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

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5.4.1.2. Japan

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

There are three working groups which include both public and private members: system implementation, international cooperation, and next generation urban transportation. The System implementation working group included tasks on the development and verification of automated driving systems and on basic technologies to reduce traffic fatalities and congestion (see Figure 11). Only pre-competitive issues were addressed leaving the rest of the research to the competition to the industry.

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

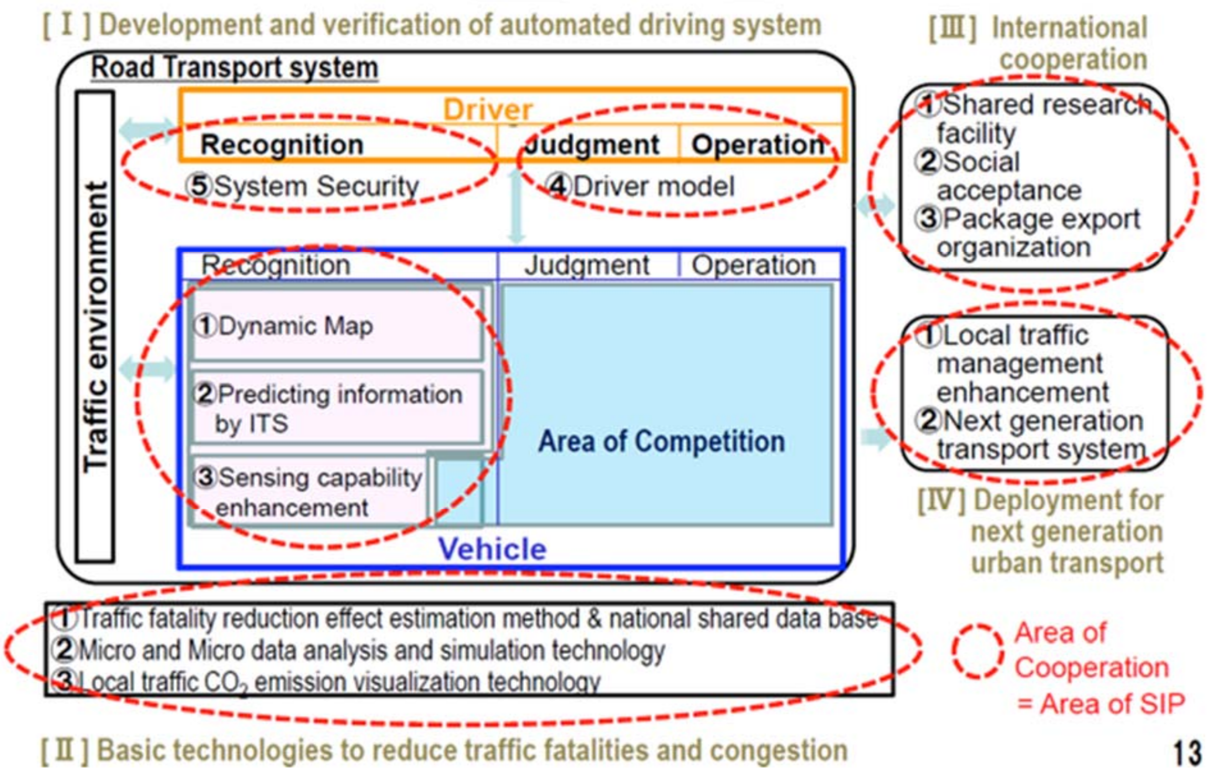

Figure 12: Japan Cross-Ministerial Strategic Innovation Promotion Program (SIP) Automated Driving System Research themes

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

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

5.4.1.3. South Korea

The South Korean government has designated autonomous vehicles as one of its top 13 Industrial Engine Projects. The focus is put on converging industries covering IT and automotive technologies. The main actors addressing this are the Korea Transport Institute (KOTI), the Korean Automobile Manufacturers Association (KAMA) and the Korean Auto Industries Cooperation Association (KAICA). To organize governmental activities, a Smart Car Council was established to coordinate actions across different ministries, including the Ministry of Science, ICT and Future Planning, the Ministry of Land, Infrastructure and Transport, and the Ministry of Trade, Industry & Energy.

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

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

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

5.4.1.4. China

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

The Ministry of Industry and Information Technology's (MIIT) strategy for the auto industry 2025, which is part of the larger "Made in China 2025" plan. In this, the government stresses the need for the development of intelligent connected cars with the objectives of reducing the

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number of traffic accidents by more than 30 percent, establishing a safe autonomous driving speed (120 km/h) and reducing energy consumption by more than 10 percent and greenhouse gas emissions by more than 20 percent. A specific (Draft) Strategy for Innovation and Development of Intelligent Vehicles was published by the National Development and Reform Commission (NDRC) in January 2018 and includes a 3-phase vision for CAD development.

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

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

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

5.4.1.5. Singapore

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

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

5.4.1.6. Australia

The National Policy Framework for Land Transport Technology 2016-2019 provides policy principles and guidance on governance and actions to support AV deployment in Australia. The document outlines a full action plan for the introduction of new transport technologies and cover key issues in deploying new transport technologies such as; Safety, Security and

Privacy; Digital Infrastructure; Data; Standards and Interoperability; and Disruption and Change. The state government further backed its support for the development of automated road transport technology with an AU$ 10 million Future Mobility Fund for R&D projects over the three-year period.

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

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

6. Common definitions

6.1. Levels of Automation

The ARCADE joint stakeholder network acknowledge the definitions of SAE J3016 defining the Levels of Automated Driving. Their latest version shall be used, after the revision adopted in June 2018, as accessible on: https://saemobilus.sae.org/content/j3016_201806. The figure below is a summary of these definitions.

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

Figure 13: SAE Levels of Driving Automation for On-Road Vehicles (June 2018, copyright SAE); terms: dynamic driving task (DDT) operational design domain (ODD); object and event detection and response (OEDR); Automated Driving System (ADS)

6.2. Operational Design Domains (ODD)

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

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

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

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

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

6.3. Vehicle and infrastructure interaction

6.3.1. Long term vision

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

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

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6.3.2. ISAD

The environmental perception of automated vehicles is limited by the range and capability of on-board sensors. Road infrastructure operators already employ numerous traffic and environmental sensors and provide information that can be perceived by automated vehicles. In order to classify and harmonize the capabilities of a road infrastructure to support and guide automated vehicles, we support a simple classification scheme, similar to SAE levels for the automated vehicle capabilities, following the work of the EU research project INFRAMIX[45]. This project is preparing the road infrastructure to support the transition period and the coexistence of conventional and automated vehicles. Its main target is to design, upgrade, adapt and test both physical and digital elements of the road infrastructure, ensuring an uninterrupted, predictable, safe and efficient traffic. Although INFRAMIX is targeting mainly highways, since they are expected to be the initial hosts of such mixed traffic, its key results can be easily transferred to urban roads.

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

Figure 13 “ISAD levels” shows the description of the five ISAD levels, along with the information that is provided to automated vehicles.

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

Figure 14: "ISAD Levels"

Infrastructure support levels are meant to describe road or motorway sections rather than whole road networks. This reflects common practice of infrastructure deployment: Traffic control systems (sensors and VMS) are usually deployed on motorway sections where traffic often reaches the capacity limit (e.g. in metropolitan areas), whereas other motorway sections need no fixed installations of traffic control systems because traffic flow is rarely disrupted. The five levels increase in added support from E to A. This example (Figure 14) illustrates how

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

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ISAD levels can be used for a simple description of what automated vehicles can expect on specific parts of a road network.

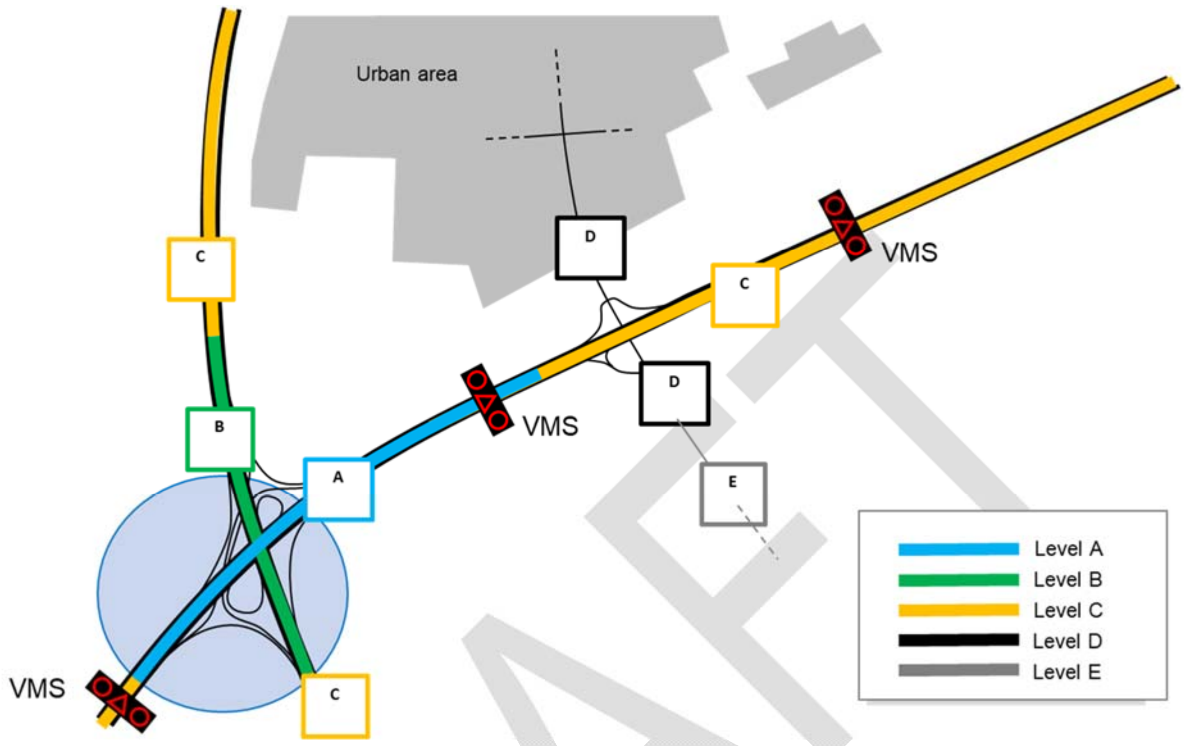

Figure 15: "ISAD Example"

6.4. Regulatory and standardisation framework for Automation

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

Additional research needs to be carried out and a joint approach between telecom and vehicle industry as well as cross-border pilot projects and the adaptation of road traffic rules in Member States can all support to reach a consensus in this field. The deployment of CAD may be hampered if there are no collaborative actions towards a coordinated and quick development of European-wide regulations and laws enabling testing and use of automated vehicles on public roads. By solving regulatory issues, the public will start to accept and use automated vehicles sooner, leading to a better market penetration and a competitive advantage for the EU on the field of automated driving.

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

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

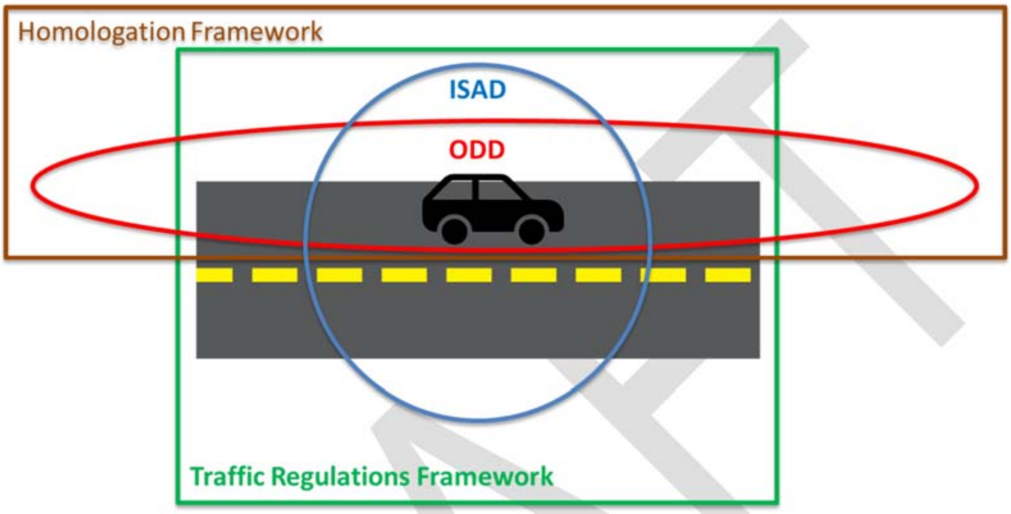

Figure 16: Regulatory and standards framework for Automation

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

6.5. Connectivity as a requirement for vehicle-infrastructure interaction

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

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

An overview of the data exchange of national road authorities (NRA) can be seen in Figure 16 “Stakeholders in NRA data exchange”.

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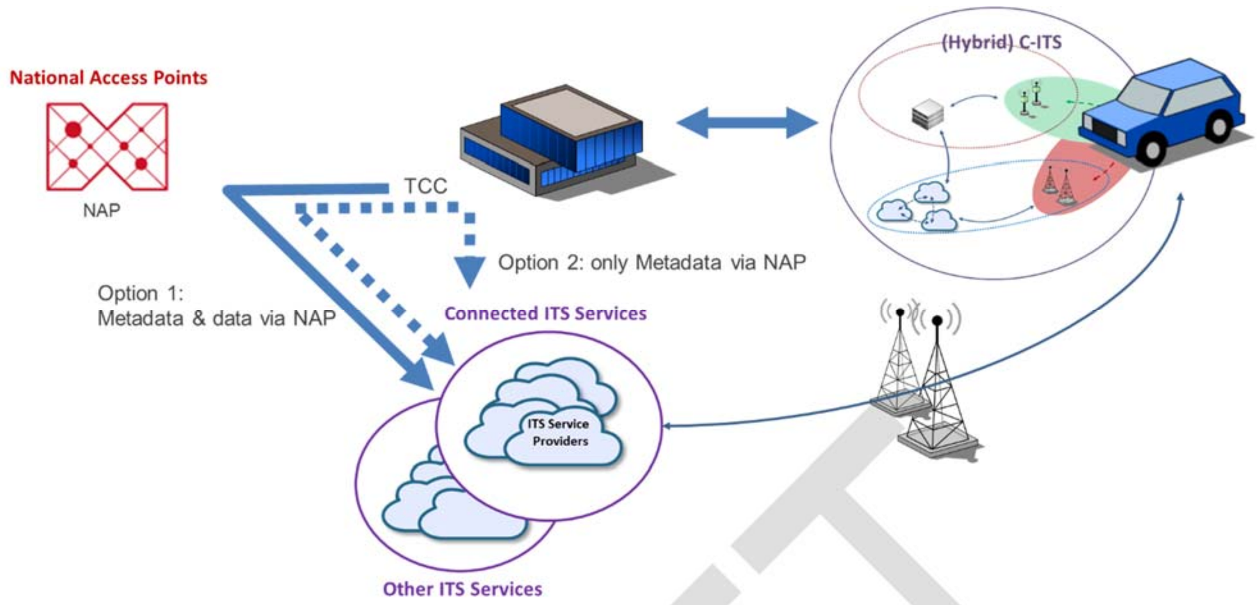

Figure 17: "Stakeholders in NRA data exchange source: ARCADE stakeholder network"

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

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

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7. Conclusions, Recommendations and Next Steps

7.1. Conclusions

The main objective for the ARCADE consolidated Roadmap 2019 is to bring together a consolidated multi-stakeholder view on the development of Connected Automated Driving (CAD) in Europe into three development paths, highlight ongoing activities and identifying challenges and key priorities extracted from the thematic areas.

- The ARCADE consolidated roadmap 2019 has been developed through an iterative process involving the ARCADE stakeholder network (WP2), thematic areas (WP3) and inputs from projects.
- The ARCADE consolidated roadmap 2019 has provided key input to the *ERTRAC CAD roadmap 2019*[46], the *STRIA CAT 2.0*[47] and is providing input to the *CCAM Single Platform*[48] *(ongoing task)*.
- The development paths for Passenger Vehicles, Freight Vehicles and Urban Mobility Vehicles have been developed with close interaction with the joint stakeholder network and has been presented and discussed at various conferences and events during the first year of ARCADE (i.e. EUCAD 2019, ITS-Europa, ERTRAC WG meetings).
- This report concludes that the focus for the coming 10-year period in the development paths will be on highly automated vehicles (SAE L4) in mixed traffic and a selection of use-cases has been identified to illustrate this development as elaborated in the roadmap.
- Key priorities have been identified by the thematic areas within ARCADE and together with the ARCADE stakeholder network. These key priorities are presented in Figure 9: Consolidated Key Priorities per Use-Case vs Thematic **Area**. This matrix is the result of joint work in WP3 and WP2 and was finalized together with the task and thematic area leaders at the consolidation workshop in September 1-3, 2019. Each of the key priority area has been further elaborated in the tables in sections 4.3, 4.4 and 4.5.
- The ARCADE consolidated roadmap 2019 provide a (non-exhaustive) listing of the main initiatives, activities and projects in Europe and beyond. Further details are available in the ARCADE Knowledge base[49].
- The ARCADE consolidated roadmap 2019 provide the common definitions of key importance such as; SAE Automation Levels, Operational Design Domains (ODD), Infrastructure Support Levels for Automated Driving (ISAD) and Connectivity

7.2. Recommendations and Next steps

The ARCADE consolidated roadmap 2019 provide the results from the first year of ARCADE and builds on the earlier CARTRE and VRA projects. Annual updates of the ARCADE consolidated roadmap will be done in 2020 and a 2021.

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[46] https://www.ertrac.org/uploads/documentsearch/id57/ERTRAC-CAD-Roadmap-2019.pdf

[47] https://ec.europa.eu/research/transport/pdf/stria/stria-roadmap_on_connected_and_automated_transport2019-TRIMIS_website.pdf

[48] https://connectedautomateddriving.eu/mediaroom/european-commission-launches-ccam-single-platform/

[49] https://knowledge-base.connectedautomateddriving.eu/

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The recommendations for further actions are listed in *Figure 9: Consolidated Key Priorities per Use-Case vs Thematic* **Area**. Each key priority area has been further elaborated in the tables in sections 4.3, 4.4 and 4.5.

7.3.Next steps

The next steps, plan for ARCADE WP2 year 2, will focus on the following activities;

- Perform joint stakeholder networks workshops to further elaborate, develop and rank the key priorities as identified in the *Figure 9: Consolidated Key Priorities per Use-Case vs Thematic* **Area**. This is planned for in February 2020 (Task 2.3)
- Continue the international exchange through the Trilateral working group meetings (in Japan Nov 2019, EU April 2020 and USA July 2020) (Task 2.2)
- Further developing the extended international collaboration towards selected countries (Task 2.2)
- Provide exchange through the project concertation to identify, establish links and map projects (Task 2.4)
- Prepare, perform and follow-up at the planned EUCAD symposium at TRA in April 2020 in Helsinki.
- Perform year 2 consolidation at the consolidation workshop, planned in September 2020. (Task 2.1)

The steps above will serve as input for the update of the ARCADE consolidated roadmap version 2020.

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8. References

CAD website: http://connectedautomateddriving.eu/

ARCADE Deliverables:

- D3.1: Technical thematic areas: challenges and scenarios
- D3.4: Systems & Services thematic areas: challenges and scenarios
- D3.7: Society thematic areas: challenges and scenarios

ERTRAC Connected Automated Driving Roadmap 2019[50]

STRIA CAT 2.0[51]

[50] https://www.ertrac.org/uploads/documentsearch/id57/ERTRAC-CAD-Roadmap-2019.pdf

[51] https://trimis.ec.europa.eu/sites/default/files/roadmaps/stria_roadmap_2019-connected_and_automated_transport.pdf

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9. Glossary: Acronyms and definitions

Term	Description
AD	Automated Driving
ADS	Automated Driving System
ARCADE	EU H2020-DT-ART-2018-2019/H2020 CSA project Aligning Research & Innovation for Connected and Automated Driving in Europe, GA number 824251
ART	Automated Road Transport
AV	Automated Vehicle
BRT	Bus Rapid Transit
CARTRE	EU H2020 ART06 CSA project Coordination of Automated Road Transport Deployment for Europe, GA number 724086
CAD	Connected Automated Driving
CAT	Connected Automated Transport
C-ITS	Cooperative Intelligent Transport Systems
CSA	Coordination and Support Action
DDT	Dynamic Driving Task
EATA	European Automotive-Telecom Alliance
ERTRAC	European Road Transport Advisory Council
GEAR2030	High Level Group for the automotive industry
ISAD	Infrastructure Support for Automated Driving
ODD	Operational Design Domain
OEDR	Object and Event Detection and Response
PPP	Public Private Partnership
PRT	Personal Rapid Transit
SAE	Society of Automotive Engineering
SCOUT	EU H2020 MG-2015 CSA project Safe and Connected Automation in Road Transport, GA number 713843
STRIA	Strategic Research and Innovation Action plan
TA	Thematic Area
VRU	Vulnerable Road Users

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