

Automated Driving Roadmap

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ERTRAC Task Force "Connectivity and Automated Driving"

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2. SCOPE AND OBJECTIVES

This document provides an overview on the current status for Automated Driving technologies with regard to implementation in Europe. The ERTRAC roadmap is based on available documents for automated driving. The overall objective is to identify challenges for implementation of higher levels of automated driving functions. A lot of work has been done on this topic by various stakeholders and multi-stakeholder platforms (e.g. iMobility Forum, EUCAR, CLEPA, ERTICO, EPoSS) and in European Research Projects. Therefore, it is essential to avoid any duplication of activities and concentrate on the missing items, concerns and topics for future implementation.

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

- Safety: Reduce accidents caused by human errors.
- Efficiency: Increase transport system efficiency and reduce time in congested traffic.
- 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.

In technological terms the advancement towards highly Automated Driving is seen as an evolutionary process to ensure that all involved stakeholders can develop and evolve with the adequate pace. This process already started with the development of ABS, ESP and Advanced Driver Assistant Systems (ADAS) and will progressively apply to more functions and environments. In parallel, driverless automated systems can be deployed to provide transport solutions in restricted areas with dedicated infrastructure or at specific locations e.g. airports. The European community is nevertheless facing important challenges to enable or implement higher levels of Automated Driving in all environments. It is utmost important that these challenges and existing gaps (technology, legislation, regulatory, policy, etc.) are early recognized and appropriate measures are taken.

ERTRAC, the European Road Transport Research Advisory Council, acknowledges its important role and ensures a harmonised approach towards implementation of higher levels of Automated Driving functionalities. In 2014, ERTRAC established a task force with key stakeholders and key experts from ERTRAC member associations and individual members to define a roadmap for Automated Driving.

The document is structured in **Scope and Objectives, Common Definitions** and Deployment Paths, **State of the Art** including an overview on the current EU and international situation, the **Key Challenges** for Automated Driving and the ERTRAC **Roadmap** for Automated Driving.

3. COMMON DEFINITIONS

The ERTRAC task force acknowledges the definitions of SAE J3016 for Automated Driving (see Figure 1). This section contains common definition of the different automation function used in this document and different deployment paths. The focus lies on automated driving level 2-5. No estimation on the likelihood and impact of the different paths will be included in this version of the document but will come in later versions.

Summary of Levels of Driving Automation for On-Road Vehicles

This table summarizes SAE International's levels of *driving* automation for on-road vehicles. Information Report J3016 provides full definitions for these levels and for the italicized terms used therein. The levels are descriptive rather than normative and technical rather than legal. Elements indicate minimum rather than maximum capabilities for each level. "System" refers to the driver assistance system, combination of driver assistance systems, or *automated driving system*, as appropriate.

The table also shows how SAE's levels definitively correspond to those developed by the Germany Federal Highway Research Institute (BASI) and approximately correspond to those described by the US National Highway Traffic Safety Administration (NHTSA) in its "Preliminary Statement of Policy Concerning Automated Vehicles" of May 30, 2013.

Level	Name	Narrative definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Fallback performance of dynamic driving task	System capability (driving modes)	EASt level	NHTSA. Ievel
Hun	nan driver mo	nitors the driving environment		1				
0	No Automation	the full-time performance by the <i>human driver</i> of all aspects of the <i>dynamic driving task</i> , even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a	Driver	ņ
1	Driver Assistance	the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i> .	cific execution by a driver assistance system of either sceleration using information about the driving environment that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving task</i> Human driver					
2	Partial Automation	the <i>driving mode</i> -specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the <i>human driver</i> perform all remaining aspects of the <i>dynamic driving lask</i>	System	Human driver	Human driver	Some driving modes	Partially automated	14
Aut	omated drivin	g system ("system") monitors the driving environment	1					
3	Conditional Automation	the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene	System	System	Human driver	Some driving modes	Highly automated	10
4	High Automation	the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene	System	System	System	Some driving modes	Fully outomated	
5	Full Automation	the full-time performance by an <i>automated driving system</i> of all aspects of the <i>dynamic driving task</i> under all roadway and environmental conditions that can be managed by a <i>human driver</i>	System	System	System	All driving modes	1	3/4

Figure 1: Levels of Driving Automation for On-Road Vehicles [1]

3.1. Deployment paths

There are several systems for Automated Driving level 0 and level 1 on the market today. These systems will be the basis for developing the deployment path for both passenger and commercial vehicle (i.e. HGV) with a stepwise approach to higher level of automation. These systems will in the years to come, with increasing deployment, have a significant impact on driving efficiency and safety. Another alternative path is the urban environment system path. In specific areas in Europe today high automation in transit areas exist but with low speed and/ or dedicated infrastructure (see Figure 2). This will be the base for going to higher and higher vehicles speeds and maybe less specific requirements on the infrastructure.



Figure 2: The main automation deployment paths



3.2. Systems beyond human capability to act

There are several systems on the market today that intervene when it is beyond the human capability to act, like ABS (Anti-Lock System), ESC (Electronic Stability Control) and emergency braking. These systems are only mentioned covered in detail here, but they are active safety systems that will be building block for high levels of automation and will facilitate deployment.

Future version of these systems will include emergency evasion and emergency stopping.

3.3. Current and future vehicle Systems – Level O

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

3.3.1. LCA - Lane Change Assist

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

3.3.2. PDC: Park Distance Control

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

3.3.3. LDW: Lane Departure Warning

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

3.3.4. FCW: Front Collision Warning

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

3.4. Current Systems – Level 1

3.4.1. ACC - Adaptive Cruise Control

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

The driver sets the speed and the required time gap with buttons on the multifunction steering wheel or with the steering column stalk (depending on model). The target and actual distance from following traffic can be shown as a comparison in the multifunction display.

3.4.2. PA - Park Assist

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

3.4.3. ACC including Stop & Go

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

3.4.4. LKA - Lane Keeping Assist

Lane Assist automatically becomes active from a specific speed (normally from 40 mph) and upwards. The system detects the lane markings and works out the position of the vehicle. If the car starts to drift off lane, the LKA takes corrective action. If the maximum action it can take is not enough to stay in lane, or the speed falls below 40 mph LKA function warns the driver (e.g. with a vibration of the steering wheel). Then it's up to the driver to take correcting action.



3.5. Automated Passenger Cars Path



3.5.1. Automated Parking Assistance

3.5.1.1. Park Assistance (Level 2)

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

3.5.1.2. Parking Garage Pilot (Level 4)

Highly Automated parking including manoeuvring to and from parking place (driverless valet parking) In parking garage the driver does not have to monitor the system constantly and may leave once the system is active. Via smartphone or key parking manoeuvre and return of the vehicle is initiated.

3.5.2. Highway Pilot

3.5.2.1. Traffic Jam Assist (level 2)

The function controls the vehicle longitudinal and lateral to follow the traffic flow in low speeds (<30km). The system can be seen as an extension of the ACC with Stop&Go functionality. (i.e. no lane change support).

3.5.2.2. Traffic Jam Chauffeur (Level 3)

Conditional automated driving in traffic jam up to 60 km/h on motorways and motorway similar roads. The system can be activated, if traffic jam scenario exists. It detects slow driving vehicle in front and then handles the vehicle both longitudinal and lateral. Later version of this functionality might include lane change functionality.

Driver must deliberately activate the system, but does not have to monitor the system constantly. Driver can at all times override of switch off the system. Note: There is no take over request to the driver from the system.

3.5.2.3. Highway Chauffeur (Level 3)

Conditional Automated Driving up to 130 km/h on motorways or motorway similar roads. From entrance to exit, on all lanes, incl. 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. The system can request the driver to take over within a specific time, if automation gets to its system limits.

3.5.2.4. Highway Pilot (level 4)

Automated Driving up to 130 km/h on motorways or motorway similar roads from entrance to exit, on all lanes, incl. overtaking and lane change. The driver must deliberately activate the system, but does not have to monitor the system constantly. The driver can at all times override or switch off the system. There are no request from the system to the driver to take over when the systems in normal operation area (i.e. on the motorway). Depending on the deployment of cooperative systems ad-hoc convoys could also be created if V2V communication is available.

3.5.3. Fully automated private vehicle (level 5)

The fully automated vehicle should be able 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: no realistic time estimation exists on this system.

3.6. Automated Commercial Vehicle Paths



Figure 4: The Automated Driving deployment path for commercial vehicle

3.6.1. Platooning

3.6.1.1. C-ACC Platooning

Partially automated truck platooning, in which trucks are coupled by cooperative ACC (CACC), implementing engine and brake control keeping a short but safe distance to the lead vehicle, while the drivers remain responsible for all other driving functions.

3.6.1.2. Truck platooning

This function enables platooning in specific lane. The vehicle should be able to keep it position in the platoon with a fixed distance or fixed time difference from the front vehicle. The behaviour of the first vehicle (e.g. braking and steering) should be transmitted be V2V communication. The function should also handle vehicle that wants to leave the platoon.

Up scaling and deployment can be reached as follows:

- 1. Start with trucks as there is a strong financial incentive due to 10% to 15% fuel savings.
- 2. Start with small platoons of only 2 trucks and co-operation with fleet-owners in high density truck area.
- 3. Start with a system where drivers are still in the following truck, for legal reasons.

Setup an (open) fleet management system for trip matching between equipped trucks of different fleet owners.

3.6.2. Highway Pilot

3.6.2.1. Traffic Jam Assist (level 2)

The function controls the vehicle longitudinal and lateral to follow the traffic flow in low speeds (<30km). The system can be seen as an extension of the ACC with Stop&Go functionality (i.e. no lane change support).

3.6.2.2. Traffic Jam Chauffeur (Level 3)

Conditional automated driving in traffic jam up to 60 km/h on motorways and motorway similar roads. The system can be activated, if traffic jam scenario exists. It detects slow driving vehicle in front and then handles the vehicle both longitudinal and lateral. Later version of this functionality might include lane change functionality.

Driver must deliberately activate the system, but does not have to monitor the system constantly. Driver can at all times override of switch off the system. Note: There is no take over request to the driver from the system.

3.6.2.3. Highway Chauffeur (Level 3)

Conditional Automated Driving up to 90 km/h on motorways or motorway similar roads from entrance to exit, on all lanes, incl. 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. The system can request the driver to take over within a specific time, if automation gets to its system limits. Later version of this functionality might include lane change and overtaking functionality.

Highway Pilot with ad-hoc platooning (level 4)

Automated Driving up to 110 km/h on motorways or motorway similar roads from entrance to exit, on all lanes, incl. overtaking and lane change. The driver must deliberately activate the system, but does not have to monitor the system constantly. The driver can at all times override or switch off the system. There are no request from the system to the driver to take over when the systems in normal operation area (i.e. on the motorway). Depending on the deployment of cooperative systems ad-hoc convoys could also be created if V2V communication is available, see 3.6.1.

3.6.3. Fully automated truck (level 5)

The fully automated Truck should be able to handle all driving from point A to B. no driver need to be in the vehicle. Note: no realistic time estimation exists on this system.

3.7. Urban Environment Systems¹

The path is 'Low Speed High Automation'. In specific areas in Europe today high automation in transit areas exist but with low speed and/or dedicated infrastructure. This will be the base for going to higher and higher vehicles speeds and maybe less specific requirements on the infrastructure.

- Cybercars. These are small automated vehicles for individual or collective transportation of people or goods, with the following characteristics: a) fully automated on demand transport systems that under normal operating conditions do not require human interaction;
 b) they can be fully autonomous or make use of information from a traffic control centre, information from the infrastructure or information from other road users; c) they are small vehicles, either for individual transport (1-4 people) or for transport of small groups (up to 20 people); d) they can either use a separated infrastructure or a shared space.
- High-Tech Buses. These are buses on rubber wheels, operating more like trams than like traditional buses, with the following characteristics: a) they are vehicles for mass transport (more than 20 people); b) they use an infrastructure, which can be either exclusive for the buses or shared with other road users; c) they can use various types of automated systems, either for guidance or for driver assistance; d) they always have a driver, who can take over control of the vehicle at any time, allowing the vehicles to use the public road.
- Personal Rapid Transit (PRT). This is a transport system featuring small fully automatic vehicles for the transport of people, with the following characteristics: a) PRT operates on its own exclusive infrastructure (there is no interaction with other traffic); b) they are fully automated systems that un-der normal operating conditions do not require human interaction; c) they are small with a capacity usually limited to 4 to 6 persons per vehicle;
 d) PRT offers an on-demand service, where people are transported directly from the origin station to the destination station without stopping at inter-mediate stations, without changing vehicles and ideally without waiting time.

- Advanced City Cars (ACC): new city vehicles integrating zero or ultra-low pollution mode and driver assistance such as ISA (Intelligent Speed Adaptation), parking assistance, collision avoidance, stop&go, etc. These vehicles should also incorporate access control coupled with advanced communications in order to integrate them easily into car-sharing services.
- **Dual-mode vehicles:** developed from traditional cars but able to support both fully automatic and manual driving. The first applications of automatic driving will be for relocation of shared cars using platooning techniques but these vehicles could become full cybercars in specific areas or infrastructures. Dual-mode vehicles represent the migration path from traditional cars to automatic driving.

Level	Established	2015	2016	2017	2018	2019	2020	2022	2024	2026	2028	2030
Level 5: Full automation										Aut	omated taxi	
Level 4 High Automation	Cybe Last Iow : Autom in segre	ercars mile taxi in speed ated bus/PR ated lane	Τ			Cyber ca last milet Automat in dedicat	ted bus/PRT			Auto bus/ in mi	omated PRT xed traffic	
Level 3 Conditional Automation												
Level 2 Partial Automation												
Level 1: Driver Assistance												
Level 0: Driver Assistance & ADAS beyond human Cabability to act												

Figure 5: The Automated Driving deployment path for public transport applications

3.7.1. Last mile solutions

3.7.1.1. Cybercars, Gen 1 (level 4)

The last mile solution is fully automated in its area of operations with a maximum speed of 40 km/h. It operates in a specific area with dedicated infrastructure.

3.7.1.2. Cybercars, Gen 2 (level 4)

The last mile solution is fully automated in its area of operations. It operates in a specific area with adapted infrastructure.

3.7.1.3. Automated Cyber Solutions (level 5)

Fully automated driving that can in principle take the passenger to all places. Note: no realistic time estimation exists on this system.

3.7.2. Automated bus or PRT

Automated bus or Personal Rapid Transit.

3.7.2.1. Automated bus or PRT in segregated lane, Gen 1 (level 4)

The automated bus drives in segregated bus lanes and dedicated infrastructure, with a maximum speed of 40km/h.

3.7.2.2. Automated bus or PRT in dedicated lane, Gen 2 (level 4)

The automated bus drives in dedicated bus lanes and supporting infrastructure with normal city vehicle speeds.

Additional functionality such as adaptive urban traffic control system that controls the traffic lights and gives speed advices and priority can be introduced when these systems reach the market.

3.7.2.3. Automated bus (level 4)

The automated bus drives in mixed traffic in the defined area of operation.

4. STATE OF THE ART

European projects:

The European Union has a long history of funding collaborative research projects contributing to the development of automated driving. The following graph is giving an overview of projects, which are being funded partially or fully by the EC. The projects are illustrated for the period of last ten years of research and sorted in four different categories: a) Networking and Challenges, b) Connectivity and Communication, c) Driver Assistance Systems and d) Robot car. A complete overview of these projects is listed in Annex containing also additional information on duration, significant results and the focus of realized research.

A number of EC-funded projects gave remarkable results in the field of vehicle automation contributing to an overall traffic safety and security. One of the pioneer projects was the EUREKA PROMETHEUS project that contributed enormously to the development of radar technology. In recent years, SARTRE demonstrated advantages of platooning, HAVEit delivered a temporary auto pilot and interactIVe designed and developed intelligent vehicle systems (IVS). Furthermore, CATS and CityMobil demonstrated successfully the application of robotic vehicles for shuttle services in protected environments.



Figure 6: An overview of the EC funded projects that support development of automated driving. The analysis has been done for the period of last ten years. Red arrows, completed projects are shown and with green ones, the projects that are still running. See Annex for detailed list of all projects.

5. EU AND INTERNATIONAL SITUATION

5.1. Actions beyond EU

Public authorities around the world recently presented action plans to facilitate the development and introduction of automated vehicles. At the same time many announcements and demonstrations from automotive companies and research groups showed that the industry is globally moving closer to a scenario where the driving task will be gradually transferred from the human to the computer. Beyond Europe, recent developments in the U.S. and in Japan are of particular importance. Also South Korea, China are present with their national programmes and initiatives on a vehicle automation landscape.

5.1.1. USA:

The U.S. Department of Transportation (DOT) has announced a national program on vehicle automation [22], with an ambitious goal to "position industry and public agencies for the wide-scale deployment of partially automated vehicle systems that improve safety, mobility and reduce environmental impacts by the end of the decade". Thus, the 5-year-automation-programme-framework should cover research and development in all levels of automation as defined by NHTSA: a) Level 1, development and testing of Human-in-the-loop (HITL) Connected Driving Assistance, b) Level 2/3, Conditional Automation Safety Assurance , and c) Level 4, Limited Driverless Vehicle Operations (see Figure 1). Besides, from the perspective of the DOT, the potentials of automation can only be achieved if vehicles are seamlessly connected to infrastructure.

A regulatory framework for the testing and operation of autonomous vehicles on public roads has already been established in California, USA, in September 2014. "Senate Bill No.1298" states that the Department of Motor Vehicles should also adopt novel regulations on autonomous vehicles by January 1st, 2015 at the latest [23]. This follows from the fact that solutions for the different stages of automation, according to the SAE definition are already available on the market. At the same time, solutions for Level 3 are now on trial, whereas solutions for Level 4 are already being developed. These regulations will thus enable manufacturers' testing of autonomous vehicles in public. Similar legislations are being passed in Nevada, Florida, the District of Columbia and Michigan, and further states will follow [24]. The inherent differences between the self-certification procedure (US, Canada) and the type approval process (UN ECE WP29) as well as the Vienna Convention play a decisive role in this respect. Interestingly, the mentioned regulatory framework in the US allows foreign vehicle manufacturers to test automated driving solutions. Recently several European Vehicle Manufacturer and Tier 1 supplier obtained an official approval for testing automated vehicles on public roads in California.² Also Canada as the neighbour country intends to initiate a five-year pilot programme for the testing of autonomous vehicles [26].

5.1.2. Japan:

The Japanese government³ stresses the importance of communication between vehicles and infrastructure for the introduction of automated vehicles and introduced the "ITS spot" technology which enables such communication with high bandwidth. 1600 "ITS spot" locations have now been installed with appropriate transmitters in Japan and more than 100,000 vehicles communicate with them. They already provide information and warnings on traffic and will in future be combined with lane keeping assist and adaptive cruise control, so as to avoid traffic congestion. The Japanese "autopilot system council" announced in an interim report roadmaps that will lead to practical employment of highly automated driving on Japanese highways until 2020 [27]. In May 2014 an Automated Driving System Research Program as a part of the Cross-Ministerial Strategic Innovation Promotion Program (SIP), has been announced [28]. The program recognizes development and verification of automated driving system, development of technologies that will contribute to the reduction of traffic fatalities and congestion, international cooperation and deployment for next generation urban transport. Herewith, considerable reduction of traffic accident fatalities is to be expected, in future. Symbolically, Olympic and Paralympic Summer Games in Tokyo 2020 are chosen as the central milestone for demonstrating autonomous driving in Japan.

5.1.3. South Korea:

The Korean Ministry of Land, Infrastructure and Transport (MOLIT)⁴ has created an agenda towards the development of safety technologies in transport sector, with the goal to drastically decrease the number of accidents on Korean roads until 2016. Also private Korean companies are promoting the relevance of automated driving. For instance, Hyundai-Kia Motors is organizing a biennial "Future Autonomous Technology Contest" [29]. Vehicles have to successfully accomplish a 3,4 km long race along mixed paved and unpaved roads, demonstrating the ability to overcome hurdles that are typical for automation such as road obstacle avoidance, managing narrow road passes and vehicle avoidance, passenger recognition, escaping in case of accidentally moving obstacles and similar. Apparently, research facilities in Korea are at the moments differentiating between two types of self-driving vehicles: the autonomous vehicle that collects information from in-vehicle sensors and the second type which uses the "Automatic Vehicle Guidance System" (AVGS), that is, the vehicle receives information in a combined manner, from in-vehicle sensors and a roadside infrastructure. The Electronics and Telecommunication Research Institute (ETRI) has started research on autonomous vehicles by further developing its IT Convergence technology towards AVGS [30].

5.1.4. China:

Analysing traffic conditions in China coupled to the continuous growth of car owners leads to the conclusion that in future, automated (and safety) systems will become a decisive criterion for the development of autonomous vehicle market in China. Not only different OEMs have recognized this opportunity, also Chinese Government sees automated driving as pure reality already in 2020. Near Beijing, in the city of Tianjin, first tests with the driverless GM EN-V 2.0 vehicle took place [31].

³ MLIT - Ministry of Land, Infrastructures, Transport and Tourism, www.mlit.go.jp

⁴ MOLIT - Ministry of Land, Infrastructure and Transport, http://english.molit.go.kr/intro.do

5.1.5. Singapore

In order to explore the opportunities and challenges of automated driving, the Land Transport Authority of Singapore (LTA)⁵ has signed a five-year Memorandum of Understanding with the Agency for Science, Technology and Research (A*STAR)⁶ for starting a joint partnership "The Singapore Autonomous Vehicle Initiative" (SAVI). SAVI will provide a technology platform for managing R&D (autonomous vehicles, autonomous mobility system and automated road system) and diverse trials for automated driving for public and industrial stakeholders. The LTA will undertake a regulatory role for implementing automated driving in Singapore's transport network, while A*STAR will use its expertise for the development of technologies and roadmaps. Together with JTC Corporation⁷, the LTA will start with the driverless vehicles testing on public roads in the north of Singapore starting from January 1st, 2015. Besides SAVI, there are already several ongoing trials for automated driving on Singapore's roads, for instance between MIT⁸ and the National University of Singapore (NUS). Within this project a fleet of autonomous golf buggies is currently tested for car-sharing concepts⁹.

5.1.6. Australia

Contrary to self-driving cars, gigantic self-driving trucks known as "Autonomous Haulage System" are already in use for mining purposes by Rio Tinto in the Pilbara region in West Australia.¹⁰ The machines are programmed to drive and navigate themselves with the help of sensors, GPS and radar guidance technology, being supervised by the controller stationed in Perth, 1800 km away from Pilbara. Besides, each of the 53 trucks contains the total of 200 sensors and is being operated by Cisco networking technology. The fleet of self-driving trucks should grow up to 150 until the end of 2015. Besides, other iron ore producers at Pilbara like BHP Billiton and Fortescue will set on self-driving trucks as well, primarily due to the sinking of costs and safety increase of entire mining process.¹¹ However, not only the mining industry is profiting out of vehicle automation. Preparing roads for automated cars and the advent of Cooperative ITS (C-ITS) equipped vehicles, the Association of Australian and New Zealand road transport and traffic authorities "Austroads"¹² has endorsed the so-called C-ITS Strategic Plan. This plan is seen as an emerging platform assuring a two-way communication between motor vehicles and roadside infrastructure.

5.1.7. United Arab Emirates

Already in 2011, ten Personal Rapid Transit (PRT) vehicles and three Freight Rapid Transit (FRT) vehicles have been tested on Masdar's streets.¹³ Using virtual routes in defined areas of the city, these driverless electric pods are able to drive with speeds of around 25 km/h. Even though the project was not meant to expand beyond its pilot scheme due to its high costs, it represents the pioneer step towards automated driving concepts in protected environments.

⁸ Massachusetts Institute of Technology

¹² Austroads Publication Online

⁵ www.lta.gov.sg

⁶ www.a-star.edu.sg

⁷ JTC Corporation is Singapore's leading agency for planning, promotion and the development of the dynamical industrial landscape

⁹ Joint Release by the Land Transport Authority, JTC & A*STAR - A SAVI Step Towards Autonomous Transport, 2014

¹⁰ Forget self-driving Google cars, Australia has self-driving trucks, 2014; Rio Tinto improves productivity through the world's largest fleet of owned and operated autonomous trucks, 2014

¹¹ Rio rolls out the robot trucks, 2014

¹³ Masdar City's Pod Car Makers, 2011

5.2. EU Member States Initiatives

Even though it is not quite visible that Europe has also been active in implementing and further developing innovative concepts for automated driving, there are approaches that represent magnificent progress in this field, nevertheless mostly at national level.

5.2.1. France:

Recently, the French government presented a plan containing 34 different innovation fields that will contribute to the development of a new industrial France [32]. One of the goals is to build autonomous vehicles equipped with sensors and radars in order to achieve safer transport, in future. The role of major ICT manufacturers and providers is to continue the development of sensors, software, control systems and services that will lead to affordable and thus, more competitive autonomous vehicles and components until the year 2020. The motivation lies in the fact that autonomous driving will contribute to a more flexible and adaptable traffic flow and allow elderly and disabled persons to take an active role in daily traffic. The project leader for "Autonomous Vehicles" is Carlos Ghosn, CEO of Renault/Nissan.

5.2.2. Germany:

Recent formation of "Round Table Automated Driving", guided by the German Federal Ministry of Transport and Digital Infrastructure, resumes in the first place the issues concerning legal frames, infrastructure and technological regulations for automated driving. The round table consists of experts from the fields of politics and insurance, OEM and vehicle manufacturer and suppliers, with the main target to find a legal framework that would support automated driving on roads [34]. The testing of automation technology is, on the other hand side, already initiated from vehicle manufacturers. The German Federal Ministry of Transport and Digital Infrastructure recently announced the establishment of a test field for connected and automated driving on the A9 motor way in Bavaria.

In the recent past the German Federal Ministry of Economic Affairs and Energy has funded a series of research and development projects with a focus on advanced driver assistance systems (ADAS) and cooperative systems (e.g. simTD, AKTIV, UR:BAN, CONVERGE, etc.). Prospective the ministry intend to continue the supporting of technology projects in the field of new vehicle systems, like ADAS and automated driving. Actually projects focussing on the development of automated driving systems (SAE J3016, level 3) and testing methods are in preparation and consultation with the round table. The Federal Ministry of Education and Research has been also funding a multitude of projects on intelligent vehicles and advanced driver assistance systems. The Federal Ministry for Education and Research recently launched a R&D funding program related to the links of electric mobility and automated driving.

5.2.3. United Kingdom:

There has been a growing level of interest in the subject of Intelligent Mobility in the UK over the past decade. During this period, the emphasis has moved away from the continued development of massive, infrastructure-centric systems, and has swung towards agile, vehicle-centric systems. This has led to a sea-change in the perception of new business opportunities.

Intelligent Mobility is one of five focus areas for the UK Automotive Council, established in 2009 to enhance dialogue and strengthen co-operation between UK government and the automotive sector. It is jointly chaired by the Secretary of State for Business, Innovation and Skills (BIS) and by a leading Industrialist. The Council is made up of senior figures from across industry and government. A proposed UK strategy was published in 2011 (Intelligent Mobility - A National Need?) and a national roadmap is also available via the UK Auto Council website. In addition, a Transport Systems "Catapult" has also been created to accelerate innovation which is funded by both Government and Industry to commercialise new technologies and services with a core focus on intelligent mobility.

Focussing on the need to increase the flow of traffic on the already congested national road network, the UK Government's supportive efforts seek to increase movement capacity by 30-50% over current levels without a proportional increase in road-building. This must also be achieved whilst simultaneously reducing the number of road traffic accidents, reducing the volume of emissions and consumption, and reducing the levels of congestion. In support of these objectives, a number of investments and incentive schemes have been introduced in recent years. Examples of innovative products which have been encouraged within this environment include the ULTRA driverless passenger transfer system at Heathrow Terminal 5, and the city-centre Low-Speed Autonomous Transport System (L-SATS) which is being currently explored in Milton Keynes (the LUTZ Pathfinder programme)¹⁴. In addition to these examples, government funded programmes are currently being used enable road-going trials for the convoying and platooning of heavy goods vehicles, and to support the implementation in three UK cities of a £40M programme of research into driverless cars. There is also a further a further £75M government money in the pipeline for 2015 - 2018 to support the continuing development of Intelligent Mobility solutions with an emphasis on system-wide approaches and in-field demonstrations.

5.2.4. Sweden:

The launch of the joint initiative "Drive Me – Self driving cars for sustainable mobility", endorsed by the Swedish Government and motivated by the vision of zero traffic fatalities, will enable research within different areas associated with self-driving cars on public roads [36]. Beside Volvo Car Group, the Swedish Transport Administration, the Swedish Transport Agency, Lindholmen Science Park and the City of Gothenburg are involved in this pilot project. Over approximately 50 kilometres of selected roads in and around the area of Gothenburg, 100 self-driving Volvo-cars will be daily used by real costumers. An added value of the project lies in the fact that automated driving will be tested on typical commuter areas strained by congestion. The main objective of the project is however to conduct necessary research on how autonomous driving will affect the road transport (both vehicle and infrastructure), considering the worldwide challenges such as safety, energy efficiency and traffic flow. In addition, the project will also explore all accompanying factors such as infrastructure requirements, traffic situations, and surrounding interactions and social benefits of autonomous driving.

Also Scania is planning for automated transport with heavy trucks starting with mining carriage in 2016. The next step will be automated platooning for long distance transport which is planned in 2018.

5.2.5. The Netherlands:

The Netherlands are already introducing self-driving vehicles on the Dutch roads, thus showing a very big ambition and a lot of activities in the field of automated vehicles.

The Netherlands has experience since 1998 in demonstrating and testing automated driving as when a large demonstration event was organized to show the state of the art. A platoon of three fully automated Buicks provided by PATH (University of Berkeley) was the highlight of that even. Following this event several Field Operational Tests (FOTs) with Advanced Driver Assistance Systems such as ISA, LDW, ACC have been carried out. With the emergence of cooperative systems and participation in the European projects CVIS and SAFESPOT the first steps were taken towards incorporating C-ITS in a national policy.

The Dutch government has announced in June 2014 that it will pass new innovative legislation to make large scale testing possible for self-driving vehicles on Dutch public roads. The new legal framework is expected to pass early 2015. The Netherlands want to team up with other nations, partners and manufacturers who have similar ambitions. Learning by doing and making it happen is the key element in this approach. There are a lot of organisations working on innovation and self-driving vehicles in The Netherlands.

The Dutch Automated Vehicle Initiative (DAVI) [37] is a public private partnership initiated by TU Delft¹⁵, RDW¹⁶, Connekt¹⁷ and TNO¹⁸. The role of DAVI is to investigate and demonstrate automated driving on public roads. Beside trial engagements, the Netherlands is quite active towards development of cooperative Information and Technology Services (ITS) necessary to support automated driving. Within such frame "The Amsterdam Group", a strategic alliance, is aiming at a large-scale deployment of cooperative ITS in Europe [38]. The core of the group are Europe's umbrella organizations which are dealing with harmonization and standardization issues, thus facilitating the implementation of novel ITS: C2C-CC¹⁹, Polis²⁰, ASECAP²¹ and CEDR²². One of prominent efforts of the Amsterdam Group is a joint initiative between Dutch, German and Austrian governments that will enable a pan-European deployment of the roadside cooperative ITS infrastructure [39]. Two cooperative ITS services: **a**) Roadworks Warning²³ and **b**) Probe Vehicle Data²⁴, should be offered by 2015 on a corridor between Rotterdam and Vienna with an ultimate goal of improving traffic flow and motorway safety.

- ¹⁸ Netherlands Organisation for Applied Scientific Research TNO; www.tno.nl
- ¹⁹ CAR 2 CAR Communication Consortium; www.car-2-car.org
- ²⁰ European Cities and Regions Networking for Innovative Transport Solutions; www.polisnetwork.eu/about/about-polis
- ²¹ The European Association of Operators of Toll Road Infrastructures; www.asecap.com
- ²² Conference of European Directors of Roads; www.cedr.fr/home
- ²³ Roadworks Warning (RWW) connects traffic control centers with drivers over the roadside infrastructure

¹⁵ Delft University of Technology; www.tudelft.nl

¹⁶ RDW is a public service provider in the mobility chain; www.rdw.nl

¹⁷ Connekt is an independent network of companies and authorities with the mutual goal of improving mobility in the Netherlands in a sustainable way; www.connekt.nl

²⁴ Probe Vehicle Data (PVD) - vehicles that patrol on the road transmit the data to the infrastructure further to the control centers

5.2.6. Spain:

The Spanish Ministry of science and innovation funded diverse projects which focused on the development, implementation and validation of methodologies for supporting system control and navigation of automated vehicles.²⁵ Just recently Spanish researches from the University of Alicante succeeded in developing an automated driving system that is capable to learn from an environment on its own.²⁶ Interactive sensors are used for mapping the area and the vehicle camera supports the navigating system. Even though the tests are currently being performed on a golf cart, apparently in this way, every conventional vehicle could be transformed into an automated system. At the current stage such vehicles can be used in warehouses due to their ability to identify obstacles and move objects, choosing an optimal path for reaching a certain point.

Regarding detection of driver condition, Institute of Biomechanics of Valencia (IBV) finished in 2014 the HARKEN project that aimed at detecting the level of attention and drowsiness of drivers under different scenarios by means of seamless on-board technology.

SISCOGA is one of the key initiatives carried out in Spain in the domain of cooperative systems. It was initiated by CTAG and DGT in 2010, creating a permanent cooperative corridor of more than 100 km to carry out field operational tests and pilots to test in real roads cooperative safety and efficiency applications. The cooperative corridor includes interurban (AP9, A52 and A55) and urban scenarios (Vigo City) with more than 50 cooperative road side units connected to the DGT and Vigo Council Traffic Management Centres. Within this cooperative corridor, several national and European FOTs and pilots have been carried out or are nowadays running like SISCOGA national FOT²⁷, DRIVE-C2X²⁸, COMPASS4D²⁹ or CO-GISTICS³⁰. During these FOTs and pilots several safety and efficiency cooperative applications have been developed and extensively tested. Some examples of implemented applications are traffic jam ahead warning, accident ahead warning, road works warning, variable speed limits, adverse weather warning, alternative route information, FCD, GLOSA, energy efficiency intersection service and red light violation warning. Evaluation results have clearly shown the potential of cooperative systems to reduce accidents and to increase efficiency³¹.

CO²peratuoS², started in January 2013, is a relevant national R&D funded project under the Spanish INNTERCONECTA program that explores future cooperative automated applications, especially addressed for urban environment. It includes different local stakeholders as ESYCSA or AUTELEC (ITS infrastructure providers), VITRASA (Public buses fleet operator), RLA (Ambulance manufacturer), Little Cars (electric vehicle manufacturer), CTAG (R&D organisation) and Vigo Council (Public Authority). The applications addressed within CO²peratuoS² include cooperative ACC, cooperative traffic jam chauffer, cooperative autopilot and cooperative automated functions for public buses. All of them handle form a micro- and macro-perspective that considers the individual vehicles (combustion cars, EVs, buses, ambulances), the infrastructure cooperative elements (e.g. traffic lights) and the mobility management centre³².

²⁸ www.drive-c2x.eu/project

²⁵ Polytechnic University of Valencia

²⁶ Automated driving system capable of learning, 2014

²⁷ "SISCOGA - a Field Operational Test in the North West of Spain on future C2X Applications". F.Sanchez, A.Paul, D.Sanchez, M.Saez. EAEC European Congress. Valencia, June 2011.

²⁹ www.compass4d.eu

³⁰ www.cogistics.eu

³¹ "Vigo ITS Test Bed – Towards Harmonised Deployment of Cooperative ITS" . F.Sánchez. Workshop ITS for Urban Mobility. ITS European Congress. Helsinki, Junio 2014.

³² "CO²perautoS²: Towards Cooperative Automated Vehicles". Francisco Sanchez, Rosa Blanco, Roberto Fernández, José Luis Díez, Diego Bernárdez, Miguel Segovia, Virginia Sixto, Juan Manuel Martínez, Diego Casas. 10th ITS European Congress, Helsinki, June 2014.



5.3.1. iMobility Forum

5.3.2. ERTICO

5.3.3. EPoSS

6. KEY CHALLENGES AND OBJECTIVES

Automated driving is an opportunity to address several important societal challenges of road transport: **safety, energy efficiency, reliability of schedules, and urban accessibility. These are the key societal needs identified in the Strategic Research Agenda of ERTRAC,** illustrated in figure 7. Other benefits could be delivered, such as social inclusion, offering mobility to all users including elderly and impaired users, and deploy new solutions for shared mobility and public transport, which could have important impacts on our city environments. These benefits can be brought to both passenger and freight transport. The topic involves the different research domains of the transport system (e.g. vehicles, infrastructure, services), making it a typical topic requesting an integrated approach. Moreover, the implementation can be done in the key elements of the road transport system: in urban mobility environments, and on long distance transport, but should also be considered for inter-urban and at transport interfaces. **Automated driving matches therefore very well with the ERTRAC System approach to improve the overall efficiency of road transport.**



Figure 7: ERTRAC Strategic Research Agenda, System approach to Road Transport Societal Challenges

The option to switch to "automated driving mode" will give drivers more freedom in terms of individual mobility. With the market introduction of highly automated vehicles by 2020-2025, drivers will be able to manage their driving times better. At the same time, an automatically controlled vehicle will be even safer thanks to the increased interaction with itself and its environment. Furthermore, the energy management and driving characteristics of the vehicle will be optimized enabling more energy-efficient driving. Highly automated road transport will have a significant impact on our mobility behaviour, road safety and traffic efficiency in interurban (motorway/freeway) and urban applications. Especially in cities, impacts could be very important: improvements in transport reliability and urban centres accessibility would lead

to evolving demands and request changes of the business models, requiring private companies and public authorities in charge of transport to assess and anticipate future needs.

6.1. Environmental Detection and Perception

How to ensure technological advancements to enable sufficient environmental recognition by recognizing the requirements for functional safety, reliability, fault tolerance etc. ? How to implement by fusing of sensor and other data sources? How to reduce costs and increase performance (detection horizon, reliability, affordability, etc.)

In order to enable automated driving functions the vehicle needs to be able to perceive the environment with very high precision and reliability. Special focus is on false positive detection of sensors. Different sensor types need to be integrated and sensor fusion of different data sources plays an important role as the main enabler for automation. Furthermore the performance of sensors may need to meet regulatory requirements. Based on the environmental model driving strategies need to be calculated which take the dynamic interaction of all traffic participants into account.

6.2. Demonstrating Reliability, Safety and Robustness of Technology

How to demonstrate the technological readiness (maturity), reliability and safety of the automated driving function in a European Scale with all stakeholders involved on public roads? How to convince the public decision makers on the proper functionality and impact/benefits of such systems?

The basic technical prerequisite for the implementation of automated driving is system reliability and safety. A fail-safe/fault tolerant architecture is required to guarantee that automated vehicles operate in a safe state in in any event or under adverse conditions.

Large-scale field operational trials (FOTs) are conducted to demonstrate the technological readiness and analyse the interaction between the driver, the vehicle and the traffic environment (including other road users). These studies reveal insights into automated driving under different conditions (e.g. traffic, weather, lighting, road class). Further, the behaviour of other traffic participants e.g. non-automated vehicles in mixed traffic and VRUs such as pedestrians are analysed and additional data for impact assessment (road safety, traffic conditions, efficiency, etc.) is generated.

6.3. Legal and Regulatory Framework

How to prepare a harmonised European approach for adapting nation road codes/laws to allow and avoid fragmented solutions for a.) automated driving for testing and b.) automated driving in general? How to deal with liability issues and how to involve insurance companies to adapt their models on these new requirements?

Legal issues are currently considered as one of the main concerns for the introduction of highly automated driving systems (level 3 and level 4 acc. to SAE). The responsibility and liability of all stakeholders (the vehicle manufacturers, automotive suppliers, road users, insurance companies, road and traffic authorities, the EU Member States, etc.) relating to the use of highly automated vehicles requires clarification before market introduction.

The main objective is to reach a harmonised regulatory approach for automated driving at EU- level, supporting innovations for safe, efficient and clean transport. The unresolved legal issues are an inherent bottleneck and pose a risk for the successful introduction of automated driving systems. Notably, the expected legal solutions should preserve the users' and societal acceptance.

The regulatory and legal framework for the introduction of highly automated driving on European roads goes beyond the Horizon 2020 programme. The EU Member States are already acting within their own jurisdictions. However, initiatives to support the harmonised approach across all EU Member States to adapt regulations allowing for innovation are required. A common strategy at EU level is needed. Otherwise fragmented regulatory approaches in Europe will hinder implementation and jeopardize European competitiveness. The industry needs global solutions. In order to identify a harmonised regulatory approach for road transport automation, the EU Member States and the EU automotive industry should convene.

The following topics shall be addressed:

- Adapt legal and regulatory framework to allow for testing of highly automated vehicles, on a European scale (short term);
- Adapt legal and regulatory framework to allow for the commercialisation and use of highly automated vehicles at a European level (mid – long term);
- Clarify roles and responsibilities of all stakeholders.

As automated driving evolves, liability issues need to be properly addressed by all stakeholders i.e. road users, industry, insurance companies, public sector (incl. infrastructure and service providers), etc. Lessons learned from automotive and other transport sectors shall provide useful recommendations. Ongoing activities may provide the initial grounds for the required adaptation of regulations (e.g. RESPONSE4 within AdaptIVe, WP26 of Citymobil2, the EC DG MOVE C-ITS platform). It is important to notify the activities in other parts of the world e.g. US, Japan, Singapore. Finally, the UN discussions and developments (e.g. inWP1 and WP29) must I be considered.

6.4. Users' and Societal Acceptance

How to address and overcome user concerns regarding automated driving? How to meet customer expectations regarding affordability? How to ensure the security, privacy and public acceptance? How to ensure trust between automated vehicles, drivers and other road users?

Customer and societal acceptance is one of the key issues for automated driving. Affordability is still seen as one of the biggest hurdles for customers to buy into these technologies. Further, societal acceptance is pending with issues like safety, trust, security, privacy concerns, etc. The concerns and the complexity of the problems grow comparing a motorway/highway situation to a complex city environment. Furthermore, the acceptance is linked to a unanimous understanding and agreement of the benefits from automated driving (comfort, efficiency, safety, social inclusion, etc.). However, this will require a better understanding of the impacts on society as a whole: impacts and concerns addressed by professional drivers; issues and concerns regarding driver monitoring; social inclusion by enabling public transport in remote areas where today it is not feasible; impacts on multimodality and urbanization, etc. Benefits but also potential negative impacts have to be studied.

6.5. Driver Attention and Involvement

What are the requirements to ensure the appropriate driver involvement and attention (due to the classification and level of automated driving)? How to ensure save vehicle handling with reduced driver attention to the driving task? What "other" tasks can a driver safely carry out while in automated driving?

Specifically with the introduction of partial automated driving the reaction of users towards the system is important. Safety implications and user acceptance need to be well understood. The driver engagement and driver re-engagement for various levels of automation in a safe and conclusive manner is important. Therefore, the various applications for automated driving at different levels of automation have to consider human factors as decisive design criteria. HMI (visual, haptic and acoustic) must take into account the role of the driver in highly automated vehicles and an enable a safe interaction and usage. Further the user acceptance for partially and highly automated vehicle depends on human factors and the intuitive usability.

6.6. Common Validation Procedures and Testing Requirements

What are proper validation procedures and tests for automated driving functions? What are the key performance indicator? Is certification properly addressed? How to enable cost effective testing?

Automated driving requires reliability of the system and all components in terms of functional safety and performance. In order to ensure these requirements, a common validation procedure will be required: the interaction between all involved automated components and functions needs to be evaluated with focus on automation in particular regarding miss usage/false usage by the driver, e.g. falling asleep or not taking back control functions after take over request. In this context the driver awareness plays a significant role. This has to be managed in a safe manner, in order to keep the vehicle control under all circumstances stable. Beside the technical development and validation procedure, the legal aspects and liability issues require further considerations. A non-homogenous set of rules and legislations to test automated driving exist in Europe at local, regional and national level: a further harmonisation is requested. This applies to safety but also to security: data security and system integrity need to be ensured, but here as well harmonisation will be requested.

Activities in this direction are closely linked to the principle of liability, and actors such as insurance companies will be associated to these developments.

6.7. Infrastructure Requirements

What are the requirements for the physical infrastructure to enable/support higher levels of automated driving? What level of connectivity (communication) and what databases (enhanced map databases, digital infrastructure) are required for what level of automated driving (3, 4, 5)?

The implications and requirements of higher levels of automated driving for our physical infrastructure is not yet clear. The infrastructure performance (visibility, state of repair, etc.) regarding traffic signs, signals and road markings to support higher levels of safe and reliable automated driving have to be recognised. This shall involve common standards and harmonisation. Due to the already heavy burden on road maintenance budgets in many European member states the dependency and impact on asset management and maintenance planning need to be reduced to a minimum. The inherent relation between infrastructure performance and sensor requirements/vehicle dynamics might put more emphasis on in-vehicle systems and requires cost optimization. On the other hand, expected cost savings and societal benefits (specifically in urban areas) by more efficient road transport infrastructure requires careful evaluation.

Furthermore, additional information from other road users and from the infrastructure (connectivity, digital infrastructure) can increase the performance for automated driving. Based on this information the vehicle/system can adapt the driving strategy according to the received information (e.g. upcoming congestion, traffic accident). Enabling this functionality requires the integration of validated communication devices into the vehicles. The security issues for this communication is of major interest for automated driving as unsecure communication may open the system for abuse, criminal or terroristic attacks.

7. ROADMAPS

The roadmaps below show for three key application areas the proposed activities to reach milestones and the objectives of market deployment.

Starting from currently projects running, which constitute the state of the art, the roadmaps show the different kinds of activities requested, using a scale of Technology Readiness Levels (TRL):



Conditional Automated Driving



Automated Commercial Vehicles



Automated Urban Road Transport

Activity	TRL		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Industrialisation	8 - 9											Automa Tran	ated Urban sport (Lvl	Road 4/5)
Regulation / standards	<u>.</u>	1		1	1			1	[Ac Rep for	dapting gulation Lvl 4/5		1	
Pilot / large scale demonstrator	5-6-7						Large ur auton exis	scale der ban road nation inf ting publ	nonstrati transpor tegrated v ic transpo	on of t / with ort	Mile- stone 3			
Technological research	2-3-4		City MG3.6 Design legal 1 pro Shoo Se	Mobil2, , ECSE Guideline ramework poposal; wcases; ensors	Techn for pe connec safety a or autur roa ERTRAC	ical solu rception tivity en nd accepomated u d transpo Recomm	tions and abling otance irban ort	1 for WP	2016-201	7 (in 32 a	nd 34)			

Recommendations for Horizon 2020 Work Programme 2016-2017

Based on the roadmaps, recommendations are done for activities at European level in the coming years, addressing the Transport Programme of the European Research and Innovation Programme "Horizon 2020". The four recommendations below are draft for discussion among the research stakeholders, the European Commission and the Member States representatives.

The numbering of the topics refers to the full set of recommendations prepared by ERTRAC for the Work Programme 2016-2017.

32. Framework & solutions for safe automated road transport

Specific challenge: Different circumstances leading to drivers' inappropriate situation assessment, inattention or distraction are among the main causes for road accidents. Increased levels of vehicle automation could contribute in this context by eliminating or easing conflict situations.

There are still many challenges to overcome in various areas ranging from environment perception capabilities of sensor systems, vehicle dynamics, functional safety, testing and certification, human machine interaction, monitoring strategies up to new aspects of product liability. A big challenge is the handling of the transition period with mixed traffic participants leading up to full automation. Automated driving may also have a positive influence on emissions by reducing congestions around major metropolitan areas; however all these benefits have to be assessed and evaluated. In parallel, there is a strong need to assess the infrastructure requirements for higher levels of automation in interaction with in-vehicle sensor systems to enable a safety for all traffic participants.

Scope and Content:

- Optimize and integrate sensors for environment and driver status perception in complex and critical conditions, e.g. through sensor fusion, in order to meet safety requirements.
- Develop fail safe and fail operational systems. Understand what degree of reliability and robustness is required in the data or information processing. Technologies, systems and functions needed to support gradual progress towards full automation.
- Develop the prerequisites and requirements enabling assessment and/or testing of safety levels of automated systems and solutions. Develop and adapt certifications schemes for automated driving.
- Human machine interaction/ monitoring strategies: Decision & Control Algorithms: develop and evaluate safe, cooperative, human compatible decision and negotiation methods, planning algorithms and distributed control strategies in urban environments; methods for offline and online verification of algorithm characteristics and quantifiable safety to support highly and fully automated driving and emergency situations.
- Evaluate infrastructure requirements to enable high-level automated driving. Develop adaptation schemes (including maintenance and durability considerations) for existing road networks.

- Analyse the interaction of automated vehicles with the environment and other road users (i.e. Other, non-automated driven vehicles, pedestrians, Powered Two Wheelers) to enhance preventive safety and to enable integration in a mixed (progressively automated) environment.
- Social inclusion and acceptance.
- User centric approach and user acceptance: define and harmonize interfaces and requirements for the environment model, including common reference frames and semantic concepts.

Expected Impacts: Increasing the level of automation in driver assistance and driving functions means reducing situations in which misperception, excessive demands, inattention, reduced vigilance and distraction of the driver can occur and result in serious consequences. Safety of non-automated vehicles will be enhanced through V2X technology systems which may lead to better integration with automated vehicles. The update of the existing road network will allow the introduction of automation on Europe's roads and optimisation of cooperative services to maximise the impact on driver behaviour and reduction of crashes. As these situations account for a prominent subset of all accident causations, vehicle automation must be seen as a major contributor towards Vision Zero.

Type of action: RIA, EUR 15Mio expected funding.

33. Enabling functionalities from Partial Automation to Conditional Automation

The Vienna Convention, more specifically the interpretation in member states traffic codes have to be adapted to enable level 3 - conditional automated driving. Moreover, the technical regulations for type approval at UN ECE (WP29) have to be amended to enable conditional automated driving functionalities: Steering (UN R79); Braking (UN R13, R13H); Lighting (UN R48), etc. .The basic technical prerequisite for the implementation of automated driving is system reliability and safety. A fail-safe/fault tolerant architecture is required to guarantee that automated vehicles operate in a safe state in any event or under adverse conditions.

Large-scale field operational trials (FOTs) are conducted to demonstrate the technological readiness and analyse the interaction between the driver, the vehicle and the traffic environment (including other road users). These studies reveal insights into automated driving under different conditions (e.g. traffic, weather, lighting, road class). Further, the behaviour of other traffic participants e.g. non-automated vehicles in mixed traffic and VRU such as pedestrians are analysed and additional data for impact assessment (road safety, traffic conditions, efficiency, etc.) is generated. This allows as well to address legal concerns prior the introduction of highly automated driving systems (level 3 and level 4 acc. to SAE). The responsibility and liability of all stakeholders (the vehicle manufacturers, automotive suppliers, road users, insurance companies, road and traffic authorities, the EU Member States, etc.) relating to the testing, demonstrating and use of highly automated vehicles requires clarification before market introduction.

- A European Large Scale Field Operational Trial across borders following a harmonized legal framework to demonstrate robustness and reliability of the conditional automated driving.
- Demonstrating technologies, systems and functions needed to support gradual progress towards full automation. In particular from level 2 Partial Automation (Human driver monitors the driving environment) to level 3 Conditional Automation (Automated driving system monitors the driving environment).
- Evaluate effects in mixed traffic conditions with automated and non-automated vehicles.
- Human factors: focus on the in-vehicle evaluation under real traffic conditions of the driver in particular during the transition of control from vehicle system to driver and vice versa e.g. expectations, adoption, acceptance, trust, usability driver position; Secondary task Human Vehicle Interaction/ monitoring strategies. Evaluate fail operational solutions (e.g. emergency stop).
- Conduct impact assessment (environmental benefits, energy efficiency, efficient transport system, safety benefits,...) on real world data sets.
- Establish a pan-European common catalogue on necessary characteristics of cooperative decision, planning and control algorithms, including self-adaptation and learning features and ethical questions.
- Fulfil all security requirements to protect the system to any threats and avoid any conscious manipulations for information enabling automated transport systems.

The objective is to enable level 3 - conditional automated driving in Europe based on a harmonized legal framework. Therefore the active involvement of member states' experts and advisors is seen as beneficial for the implementation.

Type of action: IA, EUR 20-30Mio expected funding.

34. Large scale demonstration of urban road transport automation integrated with existing public transport

Specific Challenge: The feasibility of low speed self-driving in urban environments has been shown by previous projects (CyberCars, CyberMove, CityMobil, CATS and CityMobil2). It would be a good complement to mass transit to reach low to medium demand areas with high quality transport. However, a large-scale demonstration of SAE Level 4/5 automated driving is missing. I has to be built on advancements in environment perception technologies, data fusion and and connectivity, and should address economic, acceptance and legal issues in complex scenarios. The integration within the (existing) public transport system needs to be tested and validated at a pan-European level. The demonstrated systems need to provide evidence of their safety level and to show reliability and fault tolerance. Infrastructure requirements have to be addressed as well. Impact assessment regarding safety, efficiency and environmental benefits shall provide evidence for a costs/benefit. The demonstration shall address all stakeholders' needs and raise awareness for highly automated driving.

Scope: Such Large scale demonstration of high level automated driving in complex scenarios (urban environment) should:

- Analyse complex traffic scenarios (with automated, non-automated, pedestrians, cyclists, PTW, etc.).
- Integrate within existing public transport services.
- Demonstrate efficiency for urban logistics.
- Demonstrate the technical maturity and reliability of sensor and data fusion systems for traffic environment perception.
- Enable reliable and secure communication by seamless and transparent integration of different communication technologies and develop and improve data fusion algorithms to combine V2X information with on-board sensor information.
- Assess interoperability, low latency, increased throughput, congestion strategies, data verification, data integrity data ownership.
- Evaluate impacts and benefits (efficiency, environmental benefits and safety, social inclusion, socio-economic, etc.).
- Automation and advanced active safety systems improving safety and efficiency of urban logistic; explore market & business cases, deployment opportunities, and use-case automating truck terminal and traffic operations and adapting infrastructures (e.g. loading area layouts, file markings, suitable traffic signs but also traffic control).
- Assess and evaluate impacts and benefits on the integrated transport system: understanding the wider socio-economic consequences of partial and full automation. Conduct impact assessment (environmental benefits, energy efficiency, efficient transport system, safety benefits,) on real world data sets.
- Make recommendations for national and local authorities on deployment measures policies.

35. Multi-Brand platooning and self-driving heavy duty vehicles in real traffic conditions with adaptation of infrastructure standards

Specific challenge: Multi-Brand platooning and self-driving of heavy duty vehicles for long-distance transport are effective technologies to improve energy efficiency, safety and the usage of limited road capacity.

In the past years, there have been significant efforts in RTD to develop the required technologies for vehicles and infrastructure.

However, substantial challenges remain on the path to a Europe wide deployment of platooning and self-driving vehicles. This includes:

- Platooning with different types of vehicles (weight, size and performance, manufacturer) in real, mixed traffic conditions (i.e. including cars) and across national borders.
- Impact on road infrastructure (e.g. bridges and pavements) and traffic organisation.
- Perception and behaviour of other road users in presence of road trains and self-driving heavy duty vehicles.
- Logistical requirements and improvements due to change in cost structures (especially for unmanned self-driving), gain sharing of the cost savings between the trucks (leading truck higher costs) and optimization of platoon compositions.

• Requirements/performance of data/information exchange at operational/vehicles level and logistical level.

Scope: The scope of the project has to cover a wide range of RTD activities, which may include the following:

- Investigation of automated transition from single self-driving vehicles (but still with a driver on board) to platoons.
- Analysis of dynamic requirements and proper performance prerequisites on platooning vehicles.
- Development of effective and safe functionalities for self-driving, the forming of platoons, running and dissolution, with different vehicles from different manufacturers.
- Analysis of different platooning strategies (incl. Logistical optimisation) to achieve good costbenefits.
- Integration in intelligent traffic and logistical information systems.
- Road users' perception of platoons, and how they behave in their presence.
- Investigation of suitable lane management including questions such as: Which side of the road for the platoon? How to integrate road train concepts in existing lane management systems?
- Investigations of the impact of road trains on infrastructure (e.g. bridges, road wear) and the adaptation of infrastructure standards (for different platooning strategies).
- Optimization of road infrastructure to optimally support platooning (technical, capacity, management).
- Design of the road interfaces between corridors for platooning and non-adapted roads.
- Analysis on the impact on todays and future regulations.
- Supporting models for forming and dissolution of platoons or joining and leaving a platoon across national borders and assessment of logistical (cooperation) and gain sharing options.
- Testing and validation of concepts, technologies, functionalities and robustness of platooning and self-driving heavy duty vehicles under living lab conditions with a real corridor use case.

Expected impact:

- Platooning of trucks and buses is expected to increase energy efficiency by about 10%. It will
 improve traffic safety.
- Higher traffic throughput due to more efficient utilisation of road capacity.
- Tailored infrastructure and infrastructure management to optimally support platooning.
- Total cost reduction of logistics and supply chain leading to improved competitiveness of the EU in general.
- Increased competitiveness of European OEMs and supply industry in specific.
- The impact on driving time and rest periods of drivers will be an innovative business case for operators.
- Long term road map for platooning with self-driving HDV's including the investigation of options of a transitions of the labour market related to replacing the truck driver profession with alternative jobs to be created by the improved competitive position of the EU.

Type of action: RIA, 15Mn expected funding.

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9. **BIBLIOGRAPHY**

[Will be centralised and harmonised in final version]



List of European projects in the area of Connectivity and Automated driving

Category	Acronym	Name	Duration	Purpose / Keywords
Robot car	CityMobil	Towards Advanced Road Transport for the Urban Environment	02/2004 - 01/2008	Safety applications and technologies: safe speed and safe following, lateral support, intersection safety, active 3D sensor technology for pre-crash and blind spot surveillance.
Robot car	PICAV	Personal Intelligent City Accessible Vehicle	08/2009 - 07/2012	Passenger transport, urban traffic, car sharing, networking, assisted driving, vulnerable road users.
Robot car	CATS	City Alternative Transport System	01/2010 - 12/2014	Robotic driverless electric vehicle, passenger transport, transport management, urban transport.
Robot car	FURBOT	Freight Urban RoBOTic vehicle	11/2011 - 10/2014	Fully electrical vehicle for freight transport in urban areas, robotics.
Robot car	CityMobil2	Cities demonstrating automated road passenger transport	09/2012 - 08/2016	Automated road transport system, automated vehicle, driverless, urban transport, safety, infrastructure, legislation.
Driver assistance systems	PReVENT Preventive and Active Safety Application		02/2004 - 01/2008	Development and demonstration of preventive safety applications and technologies (advanced sensor, communication and positioning technologies).
Driver assistance systems	HAVEit	Highly Automated Vehicles for Intelligent Transport	02/2008 - 07/2011	Automated assistance in congestion, temporary auto-pilot.
Driver assistance systems	MiniFaros	Low-cost Miniature Laser- scanner for Environment Perception	01/2010 - 12/2012	Develop and demonstrate innovative low-cost laser scanner.
Driver assistance systems	MOSARIM	MOre Safety for All by Radar Interference Mitigation	01/2010 - 12/2012	Interference mitigation, automotive short-range radars.
Driver assistance systems	2WideSense	WIDE spectral band & WIDE dynamics multifunctional imaging SENSor ENabling safer car transportation	01/2010 - 12/2012	Development and testing of next generation imaging sensors, new camera systems.
Driver assistance systems	interactIVe	Accident avoidance by active intervention for intelligent vehicles	02/2010 - 06/2013	Development of safety systems supporting the driver (joint steering and braking actuators).

Driver assistance systems	AdaptIVe	Automated Driving Applications and Technologies for Intelligent Vehicles	01/2014 - 06/2017	Automated driving, cars, trucks, motorways, transport in cities, close-distance manoeuvres.
Connectivity & Communication	COM2REACT	Cooperative Communication System to Realise Enhanced Safety and Efficiency in European Road Transport	01/2006 - 12/2007	Road and in-car communication systems, cooperative system, involvement of two-way communication systems: V2V and V2I, contribution for standardization and harmonization throughout Europe.
Connectivity & Communication	SAFESPOT	Cooperative Systems for Road Safety	02/2006 - 01/2010	Implementation and demonstration of V2V-based technology, Local Dynamic Maps, multi-sensor data fusion.
Connectivity & Communication	COOPERS	Co-operative Networks for Intelligent Road Safety	02/2006 - 01/2010	Development of intelligent transport systems (ITS), I2V technology, co-operative traffic management.
Connectivity & Communication	cvis	Cooperative Vehicle- Infrastructure Systems	07/2006 - 06/2010	Development of a technology platform that provides wide- ranging functionality for data collection, journey support, traffic and transport operations and driver information.
Connectivity & Communication	Intersafe2	Cooperative Intersection Safety	06/2008 - 05/2011	Development of a Cooperative Intersection Safety System (CISS) - detection of static and dynamic components of the traffic environment.
Connectivity & Communication	ISI-PADAS	Integrated Human Modelling and Simulation to Support Human Error Risk Analysis of Partially Autonomous Driver Assistance Systems	09/2008 - 08/2011	Joint Driver-Vehicle-Environment Simulation Platform, prediction of driver errors in realistic traffic scenarios, driver modelling, Human Error Risk Analysis.
Connectivity & Communication	SARTRE	Safe Road Trains for the Environment	09/2009 - 10/2012	Development of strategies and technologies allowing vehicle platoons to operate on public highways - introduction of the vehicle platoons concept.
Connectivity & Communication	DRIVE2X	DRIVing implementation and Evaluation of C2X communication technology in Europe	01/2011 - 12/2013	Creation of harmonized Europe- wide testing environment for cooperative systems, promotion of cooperative driving.

Connectivity & Communication	79GHz	International automotive 79 GHz frequency harmonization initiative and worldwide operating vehicular radar frequency standardization platform	07/2011 - 06/2014	Global harmonization, 79GHz band, automotive short-range radars.
Connectivity & Communication	AMIDST	Analysis of Massive Data STreams	01/2014 - 12/2016	Big data, stream processing, software development, automotive.
Connectivity & Communication	COMPANION	Cooperative dynamic formation of platoons for safe and energy- optimized goods transportation	10/2013 - 09/2006	Application of platooning on heavy-duty vehicles; concepts development for platoon applications in daily transport operations (off- a on-board systems for coordinated platooning, multimodal user interfaces).
Connectivity & Communication	AutoNet2030	Co-operative Systems in Support of Networked Automated Driving by 2030	11/2013 - 10/2016	Development and testing of a co-operative automated driving technology with a time-horizon between 2020 and 2030.
Networking/ Challenges	BRAIVE	BRAin-drIVE	2008	A prototype vehicle development by VisLab, designed for the testing of concepts, sensors and specific HMIs. The prototype was also used for the design of new ADAS.
Networking/ Challenges	Nearctis	Network of Excellence for Advanced Road Cooperative Traffic Management in the Information Society	07/2008 - 06/2012	Academic network for traffic management and optimization with focus on cooperative systems able to cope with safety, energy consumption, environmental impacts and congestion.
Networking/ Challenges	VIAC	VisLab Intercontinental Autonomous Challenge	07/2010 - 10/2010	Challenge conceived by VisLab as an extreme test for automated vehicles.
Networking/ Challenges	VRA	Support action for Vehicle and Road Automation network	07/2013 - 2/2016	Creates a collaboration network of experts and stakeholders working on deployment of automated vehicles and its related infrastructure.
Networking/ Challenges	GCDC	Grand Cooperative Driving Challenge	10/2013 - 10/2016 (annually)	Is arranged by the i-GAME project that is aiming at speeding up real-life implementation and interoperability of wireless communication based automated driving.





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