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Connected, Cooperative and Automated Mobility Roadmap

Update of Chapter 2 "Agenda 2030" on Innovation Use Cases

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ERTRAC Working Group: “Connectivity and Automated Driving”

Disclaimer

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Foreword

This document provides an update of the ERTRAC CCAM Roadmap version 10 published in 2022: specifically reviewing its chapter 2, "Agenda 2030". A new revised structure in six innovation domains is presented. The ERTRAC CCAM Roadmap provides the position of an independent European Technology Platform, aiming at drawing an overall long-term picture together with next steps for realistic use cases. This “Agenda 2030” chapter update focus on these innovation use cases: they propose an operational agenda for research. This update should be seen as supplement to the SRIA of the CCAM Partnership, providing further concrete directions to better understand the feasibility of use cases for their application in Large Scale Demonstrations.

The reader should still refer to the full ERTRAC CCAM Roadmap for a complete overview, including the objectives of CCAM, its key enablers, and the long-term Vision towards 2050. As this roadmap update is clearly focussing on research and innovation, it is not intended to give short-term policy recommendations. As it gives rough guidance for future innovations and research programmes, it would be premature to already specify TRL levels.

Download the full CCAM roadmap on **www.ertrac.org**

Access the SRIA of the CCAM Partnership on **www.ccam.eu**

2. Agenda 2030

With the Agenda 2030, being the core of this roadmap, separate areas of innovation of CCAM products and services are described. They differ in various characteristics, develop in different timeframes and offer a large variety of use cases. In total they represent an operational agenda for research, standardisation, regulation and investments. The Agenda 2030 should be seen as supplement to the SRIA of the CCAM Partnership, providing some more concrete opportunities for applications within this timeframe. With the update of this chapter in 2023, parallel to the SRIA update of the CCAM Partnership, further concrete direction shall be given to better understand the feasibility of use cases for their application in Large Scale Demonstrations.

Framework conditions for Large Scale Demos

All the below listed use cases need infrastructure support in different ways, they need to be evaluated along societal needs and market adoption opportunities so priorities for large scale demos can be derived. Additionally, a differentiation concerning technological maturity will be delivered to distinguish innovations, which are close to deployment and are clear candidates for larger scale vs. development use cases, which will need still some years before deployment and so are possible candidates for demonstration, but at limited scale vs. research use cases which can deliver specific demos in small scale. What will stay after a Large Scale Demo project? The target for such demo projects is that technical standardisation shall be supported and type approval as well as road regulations and all operational aspects including cooperation models between stakeholders required to address the logistics sector shall be developed along the demo to deliver a trusted framework for users and infrastructure demonstrating value for users as well as mobility and logistics companies. Finally, the demo site shall have a sustainably improved situation after the demo project has ended with good insights of the value streams for users and society and so prepare the stage for ideally directly following commercial deployment of parts of the services demonstrated.

Opportunities created by infrastructure involvement

- The road Infrastructure, be it physical or digital, in its different qualities available is a set framework condition for all CCAM functionalities. Especially when it comes to higher levels of automation, it should be stated that these functionalities will not compromise safety if no infrastructure support is available, but in this case, the operational design domain may be quite fragmented. To deliver the societal effects on traffic safety and traffic flow, the automation use cases need to be defragmented by infrastructure support. Details are described in the ERTRAC Roadmap V10 chapter 4.1.

- To achieve the goals of green mobility, charging infrastructure is vital, with cooperation models being necessary to provide those in sufficient quantity, with appropriate power levels and where needed e.g. on the TransEuropeanNetwork for Transport (TEN-T) the Alternative Fuel Infrastructure Regulation (AFIR) will set the stage.

- Future of digitalisation in mobility is driven by data, with digital twin as necessity for CCAM, so cooperation models between OEMs and NRAs are being elaborated.

- Infrastructure is crucial in providing data that vehicles cannot gather themselves, and vice versa, e.g. improving services by receiving data from vehicles → create basis for bi-directional data sharing and extension of the e-horizon via communication technology e.g. C-ITS deployment and DFRS initiative, see also TM4CAD project of CEDR.

- Incident detection and management offer high potential to increase safety and efficiency on roads (e.g. quicker reaction times, reducing risk of occurrence). To make this happen, cooperation models between fleet management and traffic management centers can be beneficial, too. The TEN-T initiative and the ITS directive will provide a basis for this.

- NRAs could offer not only the environment for large scale testing, but also the associated infrastructure support and data for a digital twin and e-horizon to enable safe and efficient introduction of automated vehicles, which gives new cooperation opportunities.

- Cooperation opportunities with NRAs are currently being developed in the CCAM Partnership (e.g. States Representative Group) as well as CEDR-EUCAR cooperation.

- In shared mobility context, efficient incident response is needed to ensure a high level of service quality combined with safety and security of passengers and other road users. For instance, emergency management needs to be put in place to avoid that automated ride-hailing services interfere with emergency vehicles. The operators of shared fleet and the city authorities should work together (as they do today in the context of manually driven public transport services) to establish communication mechanisms for smooth fleet management.

Domains for innovation

We structure the agenda in five innovation domains. These are distinguished according to their traffic complexity. They are supported by a horizontal layer for connected and cooperative services. The domains structure this agenda through their applications, complexity, technical maturity, market readiness and societal needs.

The aim is to bring as many application areas, stakeholders and use-cases together to enable the economy of scale and best use of synergetic effects for society, specifically addressing the affordability of mobility and transport and value generation to end users like citizens as well as mobility, transportation and logistics providers.

The five domains are:

- **Parking** – Including Automated Valet Parking (AVP) with strong infrastructure support (Type 2) and based mainly on vehicle technologies (Type 1).

- **Confined areas** - Various use cases will be implemented in confined areas following specific requirements on environment, traffic and legal requirements. Early demonstration will further drive industrialization, adding newly designed service functions with higher levels of automation.

- **Highways** – ODD extension for all vehicle types on the primary road network with infrastructure support to demonstrate robust and reliable automated driving interoperable across countries and brands.

- **Urban and peri-urban transport for people and goods** - The most important contributor to the societal objective of energy efficiency and liveability in urban areas, linked to peri-urban areas generating traffic due to commuting transport needs, and first and last mile.

- **Rural and secondary road network** - The biggest challenge, combining high vehicle speed with full traffic complexity, with even in the long-term limited coverage of digital infrastructure (mobile network, HD maps, etc.). The most important contributor to the societal objectives of safety, inclusiveness and accessibility, including the accessibility of urban and peri-urban areas for the rural population.

These are supported by the layer of **Connected and cooperative services** - Improving traffic and logistics/mobility services also without higher levels of automation, adding connectivity and digitalisation to existing services (including remote assistance and management). This is horizontal to all the application areas (see image below).

2.1. Connected and Cooperative Services

In this field, traffic and logistics/mobility services can be much improved also without higher levels of automation by adding connectivity and digitalisation to existing services.

Innovation: ITS / C-ITS open source/publicly available services based on RTTI & SRTI regulations and others

There are corresponding regulations in place and large efforts are made by all relevant stakeholders to make these services a reality in daily traffic. One such example is the new Data Act, which came into force this January and has many implications to the gathering and sharing of vehicle data. And even with this legal framework, there are still some hurdles to overcome. As long as there are only few business models in the value chain between publicly available traffic data und vehicle data governed by the vehicle fleet operator, e.g. for map providers, the data flow between vehicles and authorities is not available in both directions. So, the roll-out of safety, traffic management including digital traffic information services and automation data flow use cases on local, regional and national levels needs to be pushed by demonstrations to showcase functions enabled by standardized digital twins of road infrastructure including digital traffic regulations. This will support existing initiatives like Data For Road Safety, Mobility Data Space initiatives, NAPCORE and C-ROADS.

Innovation: Fleet management & Carsharing schemes

Novel services for corporate fleet, but also private and shared fleet based on connectivity and fleet data management (e.g. integrate services on vehicle to grid and parking, fleet services, destination charging) can push the transition to electromobility, but also the overall rollout of carsharing and pooling. Basic technologies like digital vehicle keys and smartphone interfaces / cloud solutions would accelerate a lot when large scale demonstrations push standardization and so enable e.g. small group carsharing schemes, local carsharing and -pooling in villages etc.

Innovation: Logistics services

As a further development of the work in Horizon Europe project MODI, specific commercial vehicles fleet services can be further developed to improve business cases and so push the rollout, but also improve the overall traffic flow by these more efficient fleet services including bi-directional data exchange, e.g. when it comes to incident management. The value generation streams of the services will be assessed in real logistics operations, use cases and scenarios.

Research / Development: Bus auto-follow at stations and other supporting functions

Improving traffic and logistics/mobility services also without higher levels of automation could deliver much better services for the private and public transport of people in urban surrounding, maybe also rural by assistance functions for drivers of buses, shuttles and pooling cars. The equipment which is used for parking and highway functions today could also be applied to those vehicles (360° sensors for assistance, Cooperative perception) and when combined with infrastructure, improve traffic around stations, allow curb/sidewalk management and enable pickup/dropoff points. Also the need of space for shuttles waiting or out of service can be understood better and the support of the driver in complex situations can be evaluated.

2.2. Parking

Description

Automated parking, also known as Automated Valet Parking (AVP), allows vehicles to maneuver safely on its own to and back from a parking lot in e.g. a multi-storey parking garage. AVP ISO-Type 1 is based on vehicle-centric Level 3 driving according to ISO 23374. Most of the relevant features have to be integrated in the vehicle: the route planning, object & event detection as well as reaction, localization of vehicle, trajectory calculation and vehicle motion control are subject of the vehicle. The infrastructure of the parking site must provide only destination of the parking spot, HAD map of the parking facility and stop signal from emergency stop device. AVP ISO-Type 2, also according to ISO 23374, is less demanding for the vehicle as only vehicle motion control is mandatory. Dedicated to infrastructure are destination assignment, the route planning, object & event detection as well as reaction, localization of vehicle, trajectory calculation and vehicle motion control.

Motivation

The use-case has been classified as one of the very attractive possibilities to apply automated driving features and major development efforts of both supplier as well as OEM's have been undertaken. On the evolution towards Level 4 driving, the application, especially AVP Type 2, is less complex coming along with less requirements on computing power, number and specification of sensors. Consequently, AVP Type 2 is the first released L4 driving use-case being in operation since 2022. As the TCO per AVP process can be as low as EUR 1 once the system has been industrialised and scaled the outlook for roll-out is positive.

Societal benefits and demonstrations

The main benefit is that the driver can drop-off the car at the entrance of the parking-garage and does not have to care about driving on a narrow and winding pathway. The time to park and un-park the vehicle summing up easily to more than 15 minutes can be saved and used for other endeavours. Beyond, the driver enjoys higher level of personal security when entering or leaving the building. Also, collision with pedestrians or with other obstacles can be omitted completely. Further advantages are reduction of energy consumption as no time-consuming search for a parking lot is necessary, available parking space is used more efficiently and a combination with smart charging facilities, Automated Valet Charging (AVC), offer high level of synergies and once more improving convenience.

Use cases

Typical use cases are parking in a parking-garage at Airports or shopping centers; adjacent use-cases are all where cars have to be transferred in driverless mode in short ranges with low speed e.g. for picking-up or returning a rental car safely and comfortably. Also, in the vehicle manufacturing process vehicles can be transferred at end of line without drivers (Automated Vehicle Manoeuvring at plant, AVM-P) or improving the logistic process (Automated Vehicle Manoeuvring Logistics, AVM-L) wherever moving of vehicles are involved e.g. in mobility or logistics hubs.

Enablers

The technical requirements differ with respect to the AVP Typ. For Type 1, a common digitalization platform is needed while for Type 2 the safety according to ISO as already been implemented in series today (e.g., Mercedes Benz). The entry barrier for OEM is considered as low due to small vehicle cost adders (no additional sensor set required compared to L3 capable vehicle) and the given high scalability across OEMs. While modern EE-architectures are being more and more integrated these allow easily to add the additional Software and communication interfaces. The ODD can be extended to outdoor usage and next to ISO 23374/1 the new ISO 12768-1 for Automated Valet Driving System gains relevance.

Standardisation

The vehicle has to be equipped in any case with electric parking brake and steering, ESP, remote engine start/stop and communication unit. Cloud backend, computing power, connectivity hardware and stereo cameras are required, too. For EV's a further increase of comfort can be realized by applying charging robots or inductive charging additionally to allow for Automated Vehicle Charging. Standardization including the communication interface will contribute to price drops due to economies of scale.

Regulation

In Germany, the technology for AVP Type 2 has been released and is available as series solution since 2022 (Mercedes, Bosch, APCOA). For roll-out in Europe national laws in other countries have to be changed accordingly.

2.3. Confined Areas

Confined areas typically have the surrounding under control with perimeter protection and gates to prevent un-authorized entry of vehicles and people. In this domain there could be mixed traffic with manually operated vehicles, Automated Guided Vehicles and other automated vehicles. Vehicles in confined areas might also operate at lower speeds and there could also be specific traffic regulations. Since confined areas are usually under supervision there is much lower risk for un-authorized vehicle and people presence. Typical examples of confined areas are "Logistics terminals and port areas", "Construction sites" and "Bus depots and Bus terminals". Different confined areas might also be connected trough hub-to-hub operation, linking different terminals trough dedicated. restricted or even open road networks.

Motivation

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

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

The lack of professional drivers, particularly for repetitious driving tasks in confined areas, is also reason for operators to introduce automated vehicles. The automated vehicle is also available for 24/7 operation all year.

Use Cases

Typical high-level use-cases for operation in the confined areas are.

Innovation: Shuttles in slower speed in restricted areas for people and freight for example at airports.

Innovation: Bus depot: Bus self-maneuvering in depots operation

Innovation: Automated trucks for operation in logistics terminals, quarries and construction sites.

Research: Trucks in hub-to-hub operation between terminals, "Drayage operation", for example moving containers in ports or haul goods between terminals using roads with restricted access.

Societal benefits

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

Autonomous vehicles in confined areas could also help to address the issue of driver shortage for repetitious driving tasks. It might also be an opportunity for hazardous transportation tasks. For the operator it would also have the potential to reduce costs of operation and increase productivity.

Demonstrations

Demonstration activities should further support deployment to ensure of perceived usefulness, actual value for mobility and logistics companies and safety. The scope of the demonstrations needs to address the whole logistics use case and implications of adoption of L4 operations to create sensible applications. There is also a need to proceed with European harmonization of confined area use-cases to further reduce costs and speed up deployment. It is also an opportunity to replicate solutions for confined areas in Europe and beyond internationally.

Vehicle Enablers

- L4 vehicles capable of autonomous operation for dedicated ODDs.
- High bandwidth low latency connectivity to enable remote surveillance and control.

Infrastructure Enablers

- Realtime Traffic control and surveillance in place.
- Secure high-bandwidth low-latency connectivity and coverage over the confined area.
- Perimeter safety control using for example automated gates, fences and geo-fences.
- Mechanism to ensure acceptable performance and system redundancy also in non-perfect conditions (e.g. weather, traffic, deviation).
- High-definition dynamic digital maps of the confined areas.

Validation Enablers

- Functional Safety of the whole traffic system.
- Efficient validation toolchain complying with certification and confined area requirements.

Standardisation

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

Regulation

- Safety operation in confined areas.

2.4. Highways

Highway automation and the assisted corridors domain enable SAE L3/L4 commuting, hub-to-hub truck operation and cooperative assistance. Consequently, vehicles are deployed with the Cooperative, Connected and Automated Mobility (CCAM) functionalities in this domain. The Trans-European Transport Network[1] (TEN-T) and, in particular, motorways provide the backbone for road traffic in Europe. Motorways in Europe are generally dual-carriageway highways with a physical division between traffic in opposing direction and usually more than one lane in each direction.

On motorways, the vehicles equipped with Advanced Driver Assistance Systems (ADAS) will be a majority. The share of cooperative driver assistance systems is likely to increase by means of V2X technologies together with lower level (SAE L0 to SAE L2) automated vehicles. Conditional- and high level automation (SAE L3- SAE L4) will be possible depending on regulation as the technology maturity increases especially, by means of vehicles' enhanced situational awareness enabling defragmented Operational Design Domain (ODD).

In 2019 and 2020, the L3Pilot European project piloted SAE L3 motorway- and traffic jam chauffeur functions on public roads in different European countries. Positive results of the safety impacts of these piloting activities will accelerate the deployment of automated driving functions in motorway scenarios. The developed testing methodology for automated driving with data sharing and data management techniques laid foundation for later large-scale demonstrations and cooperation between different brands in Europe.

The European project ENSEMBLE (2018 - 2021) paved the way for multi-brand truck platooning as an effective means to improve traffic safety and fuel efficiency in particular for motorway freight transport. The project focused on cooperative systems, connectivity and lower-level automation as a basis for European standardisation. However, more work is required to demonstrate the benefits for the logistics sector also meeting the infrastructure requirements. Further work will be needed to develop and demonstrate "safe auto-follower" and "automated hub-to-hub transport" use-cases.

Several assisted corridors will be selected, where the road infrastructure and communication system fulfil the deployment requirements of CCAM vehicles. Candidate corridors need to be implemented with hybrid communication capabilities consisting of a smart mix of short- and long-range communication

[1] https://transport.ec.europa.eu/transport-themes/infrastructure-and-investment/trans-european-transport-network-ten-t_en

technologies owing to the European projects on 5G corridors (e.g. 5G-MOBIX) and the C-ROADS Platform. Assisted corridors will meet specific traffic needs for enhanced safety and efficiency improvements for better network utilization.

Motivation

- Enhanced road safety by means of automated vehicle lateral and longitudinal control.
- Improved traffic flow on motorways and assisted corridors.
- Reduced driver workload and increased travel comfort.
- Early introduction of conditional and high automation (SAE L3, SAE L4) when mature to enhance safety, traffic flow and travel comfort.
- Demonstrating the potential of Cooperative Connected Automation in extending Operational Design Domain.
- Enhanced cooperation between road operators, authorities and industry.
- Boosting deployment activities of automated driving functions in Europe and overseas.
- For logistics: improve safety and traffic flow to improve productivity and costs.

Societal Benefits and Demonstrations

The use of CCAM is expected to supply a potential solution to manage foreseeable traffic growth on the motorway network. It is of paramount importance to demonstrate that users are aware, perceive and accept CCAM solutions, and they meet societal needs. For this reason, it is not only technical challenges that need attention. Equally important is to understand the minds and behaviour of users, as well as the minds of those who are responsible for transport governance, who build and operate infrastructures and cities. Public awareness and acceptance may take far longer than the remaining technical challenges. For logistics it is also important to address the issue with shortage of truck drivers and improve the working environment for logistics professionals to attract new drivers.

For wide uptake and demonstration of CCAM capabilities, the selection criteria needs to focus on:

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

Use Cases

Typical use-cases for highway automation and assisted corridors for both cars and trucks are listed below with different degrees of maturity.

Innovation: SAE L3 traffic jam

First market entrants deliver functions up to 60km/h, following the vehicle in front, no lane change. Scalability potentially is limited by sensor quality and computing power. Needs HD maps, geofencing, GNSS and electronic traffic regulation. Incremental ODD extension but still fragmented ODD due to restricted situational awareness of the vehicles.

Development: SAE L3 vehicles commuting

A typical functional design would be to raise speed up to 100km/h, e.g. to be able to follow trucks and buses with extended ODD, but not yet lane change.

Development: SAE L4 Truck safe auto-follow

Single-fleet, multi-brand, up to 80km/h in safe distance depending on permissions, where e.g. 1st truck is in L2 mode, 2nd truck to follow in L4 mode.

The requirements for cars feature the availability of dynamic HD map, real-time traffic sign info and road clearance based on the map. The performance depends also on the availability on the type of a sensor suite and on board computing power. V2X and precise positioning support enable extended and defragmented ODD.

Reduced distance, short-range communication between trucks. Regulations on vehicles and drivers, coordinated traffic and fleet management, incident management and value generation and distribution for carriers.

Research: SAE L3/L4 driving on highways

This use case is expected to deliver full highway driving from entry to exit and up to 130km/h, including lane change, lane merge, tunnels, all types of roadworks. Degradation steps with lower speed and reduced functionality and minimum risk maneuver in a safe location would enable it.

The research phase use cases will focus on small-scale demonstrations with more complex traffic environment and activities. Furthermore, research use cases will include cooperative approaching scenarios like vehicles, constructions sites (more complex road works signalling) and motorway ends. Enhanced, AI-supported sensor data fusion making use of Global Navigation Satellite Systems (GNSS), inertial sensor technology MEMS and V2X are also addressed. Infrastructure support will be investigated to develop a trusted framework. Motorway chauffeur with support of negotiations for on-ramp sections is included.

Minimum risk manoeuvre (MRM)

Minimum risk manoeuvres for vehicles equipped with Level 3 and Level 4 automation represent critical procedures aimed at ensuring safe and efficient autonomous operations. In Level 3 automation, where the vehicle can handle most driving tasks but still requires human intervention in certain situations, minimum risk manoeuvres involve safely guiding the vehicle to the side of the road (or a designated safe area). These manoeuvres prioritise maintaining a safe distance from obstacles, identifying potential hazards, and executing controlled braking or steering actions to avoid collisions or other dangerous situations, while transitioning control back to the driver. If the driver does not take over at all, the vehicle is stopped, hazard lights switched on and e-call executed.

At Level 4 automation, where the vehicle can operate autonomously in specific conditions or environments without human intervention, minimum risk manoeuvres focus on dynamically adjusting the vehicle's route to the nearest highway exit or safe location if the system encounters an issue beyond its capabilities. These manoeuvres may involve rerouting the vehicle to the next exit or designated stopping area, ensuring the safety of both the vehicle occupants and other road users.

Overall, minimum risk manoeuvres are essential for the operation of autonomous vehicles on highways. Thus, a clearly defined framework for how to safely execute them needs to be established between road operators and autonomous vehicles' operators.

Vehicle Enablers

- Affordable vehicles with L2-L4 enabling capabilities based on a sensor suite supported by AI, precise positioning and V2X. For higher levels of automation, the sensing platform and decision-making need to be able to provide with defragmented ODD.
- Defined parameters for real-time-reaction baseline of CCAM safety functions.

Infrastructure Enablers

- Real-time Traffic control.
- Precise positioning also in adverse weather conditions.
- C-ITS enabled adequate connectivity coverage, quality of service and data trustworthiness.
- Infrastructure safe-zones available (e.g. hard-shoulder).
- L4 highway description and standardised definition.

Validation Enablers

- Functional Safety of the whole traffic system.
- Efficient validation toolchain complying with certification requirements.
- Methodology for automated driving functions testing.

Standardisation

- Connectivity Interfaces for V2X e.g. ITS-G5, LTE and 5G technology.
- Functional Safety of Infrastructure.
- Common evaluation of perception performance for both vehicles and infrastructure.
- Rules and principles for „safe-stop areas“ (e.g. ethic and legal dimensions using hard shoulders and emergency lanes – what if an accident occurs and safely stopped vehicles occupy the lane or shoulder?).
- Standardisation of the ODD description.

Regulation

- Safe operation of higher level of automation (L3-L4) in Assisted Corridors.
- Harmonized regulation for testing connected and/or automated vehicles in the different European Member States.
- Driving & rest time regulation for professional drivers.

2.5. Urban and peri-urban transport for people and goods

In the short and mid-term, improving safety, accessibility and liveability in metropolitan areas and cities is one of the most important societal objectives. Self-driving vehicles have the potential to crucially contribute to solve the increasing challenges of urban mixed mobility. At the same time a key question is how to integrate automation into a multimodal mobility system that includes a wide variety of vehicles with different technical solutions, delivery services and transport of goods, public and private transport, as well as pedestrians, bicyclists, powered two-wheelers and micro-mobility solutions.

Therefore, an incremental approach considering the large variety of use cases and linked ODDs appears being the most promising way to deploy road automation in urban applications. Pre-commercial deployments have been already demonstrated within EU projects (e.g., SHOW & MODI) and success factors have been identified that need to be reproduced and scaled-up at the European level.

Motivation & societal benefits

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

Safety: In 2018, 38% of all EU road fatalities occurred in urban areas (Key figures 2020 – Road safety targets, DG MOVE), and the number of non-fatal crashes with personal injuries is disproportionately higher in urban areas compared to non-urban roads. Therefore, safety-enhancing measures in cities will be effective in the reduction of the overall number of road fatalities and, probably even more, in the reduction of injuries. In particular, largely unprotected road users, such as pedestrians and bicyclists, are likely to benefit significantly from improved road safety in urban areas. Automated driving is expected to reduce road crashes caused by human errors, thereby contributing to the so-called Vision Zero, i.e. no road fatalities and serious injuries by 2050.

Accessibility and social inclusion: With automated and inclusive on-demand mobility services, people with reduced mobility will have a new source of affordable and easy-to-use mobility providing them with better access to city centers as well as more remote locations. Automated driving allows people to meet their unmet travel needs, stay mobile for longer and achieve greater participation in all aspects of their lives—from school, to work, to play; both economic and social. Globally, urban populations will continue to grow in the coming years – and with it the need for transport. This growth combined with automation will complement existing mobility options (taxis, public transportation, micromobility, etc.) in cities, rolling out in a Mobility-as-a-Service (MaaS) and Logistics-as-a-Service (LaaS) approach.

Liveability in cities with enhanced traffic efficiency and reduced emissions: Passenger cars are responsible for 61% of total CO_2 emissions from EU road transport (in 2022), which is accentuated by a low occupancy rate (only 1.6 people per car in Europe in 2018 (EU parliament: https://www.europarl.europa.eu/news/en/headlines/society/20190313STO31218/co2-emissions-from-cars-facts-and-figures-infographics). While efforts are made at city levels to increase the occupancy of vehicles thanks to car sharing models and efforts to promote multi-modal transportation (including public transport, active mobility - cycling and walking), automation technologies will extend the options for individuals willing to drive less and share rides. Indeed, if well integrated to the local transportation system, automation can improve the attractiveness of public transport by increasing the areas covered (where it is too expensive now to run a PT regular service) and/or to extend operation hours of the service (while several cities in Europe suffer from a driver shortage). This in turn will also bring new riders to public transport systems, improving revenues and service delivery opportunities. Attractive, reliable and efficient automated on-demand and/or shared mobility has the potential to reduce car dependency and ownership, with less cars driving and parked in the city. This will reduce CO_2 and pollutants emissions consistent with the UN SDGs, as well as making more space available in the city for other purposes (e.g., recreational). Furthermore, automation has the potential to increase the efficiency of the transport system and reduce traffic congestion. In turn, smoother traffic and less kilometres driven will decrease energy consumption and emissions.

Demonstrations

Demonstration projects shall support the impact assessment of L4 automation use cases like shuttle services and automated ride-hailing/pooling services and facilitate the assessment of acceptance, value streams and affordability. Moreover, demonstration projects will offer room for the early deployment of L4 automated driving in public transport, goods delivery and municipal services in urban areas.

In order to reach economic viability of the automated mobility service, the ability to drive autonomously without a safety operator on-board is required, i.e., Level 4 applications. Deployment will happen stepwise and according to defined ODDs (starting typically with low speed).

Use Cases

Innovation: City waste management and urban sanitation (vocational services), conceivable in low velocity environments such as pedestrian, bicycle or other restricted lanes.

Innovation: Fully driverless shuttle services within large, confined areas (typically industrial sites like Les Mureaux, the aero spatial center in France, or on privately owned areas such as recreational parks like Terhills, Belgium)

For such deployments, slower speeds are both technically feasible and acceptable, and further investigation can be undertaken about how street right of-way can be negotiated with multi-modal roadway users.

Development: Residential last mile transport of people and goods, with regard to urban space sharing and curb management, with shared / shuttle services on semi-fixed or fixed routes with mixed traffic.

For such deployments, following technological enablers may require further exploration:

- Reliable HD Sensors and digital traffic lights/signs, 3D HD map on fixed route, lidars markers along the route for localization, on-demand booking platform, system infrastructure enabling multi-brands, dispatching & pooling.
- Standardisation/interoperability needed, otherwise no scalability will be foreseeable since each route is a new project with its specific challenges.
- Sharing of digital & physical infrastructure with public transport services targeting complementarity instead of competition.

Research: On-demand MaaS or LaaS working on flexible routes in a defined road network.

For these deployments, the potential enablers include: the ability to gather vehicle edge computing and its interface to the cloud computing; full sensor coverage, complex remote operation and remote supervision requirements (number and connection to business model requirements).

Research and exploration are need for:

- Trusted framework at test site with all involved stakeholders including authorities, operators, fleet managers, users and OEMs.
- Investigation of the best balance between vehicle and cloud intelligence.
- Policy and business models to ensure complementarity of services between public and private stakeholders.

On the vehicle side, and for all the use cases listed above, main enablers are based on predictive, automated driving with a situational understanding. The prerequisites for this include, for example, an understanding of topology, traffic guidance, intentions, road rules, patterns of behaviour and the interaction between road users.

Research along these lines should be conducted on:

- The ability of sensing and perception technologies to cope with more and more complex traffic situations in use for urban mixed-traffic applications.

- The extent to which sensing the environment should be supplemented using digital map information validated by sensors.
- Reliability of data provided by HD sensors, and the need of digitally traffic lights and signs as well as the need for LIDAR markers along a fixed route for localisation.
- Potential needs for V2X to fleet management and connection to the supervision centre and connectivity within the public transportation framework.

On the infrastructure side, the automated vehicles should incorporate traffic rules that include scenarios occurring at crossings and urban intersections, which address the limitations of current technology – potentially making it necessary to supplement sensor / on-board information with precise digital map and other off-board information.

Research and exploration are need for:

- Availability of up-to-date HD maps of the urban road network.
- PDI connectivity, including real-time traffic information, ideally shared by the city/authority.
- Provision of additional infrastructure support (fleet management, vehicle supervision centre).

All these efforts should complement the broader objectives of improving safety, accessibility and liveability in cities consistent with societal goals toward sustainability, equity and climate mitigation as is particularly in many of the UN SDGs. The research will complement and harmonize-with existing and future regulatory frameworks for type approval (already on going at UN/EU levels) as well as policy on streamlining exemption procedures for L4 FOTs / living labs, sandboxes, or enabling commercial services at city levels.

2.6. Rural and secondary road network

Mobility for all includes those living and working in rural areas and accounting for almost 30% of the EU population[2]. In many EU Member States, car dependence is high for the rural population, and options to use public transport may be few, with challenging business cases. Driverless vehicles are therefore seen as a great opportunity to improve rural mobility of people and goods.

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

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

- In the short term, advantage can be taken from existing CAV systems to improve road safety in rural environments without ODD limitations. For mature technology, the focus will be on increasing market up-take and extending functionalities. At the same time, there may be room for the further development of technology and respective regulation in the coming years.
- In the longer term, the development of highly automated mobility solutions can enhance rural living and needs to be accelerated until 2030. This includes services for people and goods, e.g. providing first mile/last mile services to access points as well as shared and/or public transportation. Business cases play an important role here.

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

Motivation

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

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

Societal benefits

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

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

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

Demonstrations

Large-scale demonstration projects may support the impact assessment of lower levels of automation in terms of safety and facilitate the assessment of acceptance and affordability. Moreover, large-scale demonstrations of urban transport and mobility services may offer room for extending specific services at limited scale from urban into peri-urban and rural areas, e.g. in public transport, goods delivery and municipal services.

Use Cases

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

Research: Driverless shared and/or public shuttle services operating on pre-defined routes, automated municipal services, e.g. waste collection, as well as first mile/last mile delivery services with very compact, low-speed automated vehicles

These use cases show a high potential as early use cases of highly automated driving in rural areas. Due to labour costs savings, such services may be attractive from an economic point of view despite high costs of the required technology and even if initially operating in very limited ODDs on precisely defined routes. Moreover, higher quality and availability of shared and/or public transport services would already mean important progress in terms of inclusivity for those who cannot drive themselves.

Enablers

General enablers for higher levels of automation include on-demand scheduling, routing, placement and design of stops and their access points, ticketing and business models, also for first mile / last mile services, information systems on schedules, destinations, payment etc. and support functions ("helpdesk", on vehicles, at stops...).

Vehicle enablers are constantly improving environment perception, reducing costs for increased market up-take of lower levels of automation and the ability to cope with limited PDI support incl. bad road surface conditions, not perfectly groomed greenery. Decreased sensitivity /dependence on perfect infrastructure and maintenance are additional vehicle enablers for higher levels of automation.

Infrastructure enablers (primarily for higher levels of automation) will be reliable connectivity and real-time traffic information plus precise information on local weather conditions in rural areas, especially when weather conditions are exceptional, being part of safety related traffic information according to Delegated Regulation 886/2013. The availability of up-to-date HD maps of the rural road network will also support lower levels of automation with continuously refreshed contents (roads signs, speed limits etc.)). Non-stationary infrastructure support (e.g. drones, delivering information on short-term road works) may constitute another enabler of higher levels of automation on rural roads.

Validation enablers include the increased use of virtual validation methods for cost reduction, complying with certification requirements, also for lower levels of automation. The inclusion of human-machine interaction in validation procedures (mode awareness) and the integration of safety-critical scenarios specific to rural roads in an EU wide scenario database are additional enablers for higher levels of automation (incl. diverse lighting / road conditions + edge cases).

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