European Roadmaps, Programs, and Projects for Innovation in Connected and Automated Road Transport

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Abstract This chapter is summarizing the current initiatives in support of connected and automated driving taken by public authorities, academia and industrial stakeholders in Europe. It is covering the actions by the European Commission, such as the GEAR 2030 strategy, the C-ITS platform, the cooperation of automotive and telecom industries for connectivity, and the strategic transport research and innovation agenda (STRIA). At the same time, the roadmaps of European technology platforms and public private partnerships such as EPoSS, ERTRAC, ECSEL and EATA are explained. Also, an analysis of funding calls and projects for the Automated Road Transport (ART) topic of Horizon 2020 is given, and additional programs such as ICT, ECSEL, PENTA, and the Urban Innovative Actions are introduced. The results of a worldwide benchmark study are reported as well. Finally, the two Coordination and Support Actions forming the connectedautomateddriving.eu initiative, SCOUT and CARTRE are presented and their efforts to establish a comprehensive roadmap to accelerate innovation of connected and automated driving in Europe are summarized.

Keywords Europe · Connected and automated driving · Horizon 2020 GEAR-2013 · C-ITS · STRIA · 5G · EPoSS · ERTRAC · EATA SCOUT · CARTRE

1 Introduction

In the 1990s, European vehicle manufacturers and automotive suppliers were among the pioneers to introduce advanced driver assistance systems like e.g. electronic stability control (ESC) after essential technologies had been developed within research and development programmes such as PROMETHEUS, heavily

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funded by European member states. Hence, ambitions are high to remain in the lead when it comes to the development, piloting and early deployment of connected and automated driving of SAE levels 3–5, despite many European countries are bound to the Vienna Convention. Thus, in the Amsterdam Declaration of 14 April 2016, European state leaders called for a shared strategy on automated and connected vehicles, and in a Letter of Intent signed by high level government representatives on 23 March 2017 in Rome, member states committed to jointly carry out testing and large-scale demonstrations of connected and automated driving. In parallel, the European Commission has launched a multitude of strategic initiatives and established research and innovation funding programs, acknowledging the roadmaps and recommendations by European Technology Platforms. The joint European strategy was discussed at the first European Conference on Connected and Automated Driving organized by the European Commission on 3–4 April 2017 in Brussels, and future research needs and roadmaps were compiled at an Interactive Symposium on Research and Innovation for Connected and Automated Driving in Europe, held on 19–20 April 2018 in Vienna.

2 European Union Policy Initiatives

The European Commission has established a number of policy initiatives to support an accelerated deployment of cooperative, connected and automated driving, recently.

2.1 Gear 2030

In view of the game-changing trends and challenges the automotive industry is facing, the Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs (DG GROWTH) of the European Commission in October 2015 established a High Level Group on Automotive Industry (GEAR 2030). The group, which involved representatives of European Member States, industrial and societal stakeholders, made recommendations to reinforce the competitiveness of the European automotive value chain. Its members jointly edited roadmaps that set objectives, specify milestones and define the responsibilities. Discussing the impacts of the introduction of autonomous vehicles in their final report, [1] they note that EU governance would be needed to take the full benefit of large scale testing and research and financing programs both at the EU and at Member State level, and they are pointing to the need for data handling rule, coherent traffic and vehicle rules, and new approaches for vehicle type approval. According to GEAR 2030, the required connectivity needed to be provided in the vehicle and the infrastructure, and the socio-economic impacts had to be assessed.

2.2 C-ITS Deployment Platform

The interaction between road vehicles and infrastructure is the subject of Cooperative Intelligent Transport Systems (C-ITS). Such systems provide road users and traffic managers with the opportunity to exchange data and to apply those data for traffic flow coordination. Communication between vehicles, infrastructures and road users is particularly essential to ensure the safety of automated vehicles and their integration in the transport system. Cooperation, connectivity, and automation thus are technologies that work together in a synergetic way. In 2014, the Directorate-General Mobility and Transport (DG MOVE) of the European Commission launched a C-ITS Deployment Platform that includes national authorities, C-ITS stakeholders and the European Commission for a dialogue on the path towards interoperable deployment of C-ITS. Based on the work of the platform, the European Commission adopted a European Strategy on Cooperative Intelligent Transport Systems (C-ITS) [2]. The objective of that strategy is the EU-wide coordination of investments and regulatory frameworks to prepare for the availability of C-ITS services in 2019 and beyond. The C-ITS platform is strongly liked to the C-Roads platform which is gathering real-life deployment experiences from various sites in the European Member States [3]. Currently, the C-ITS platform is working on draft security and certificate policies for C-ITS to enable connected and automated driving.

2.3 Connectivity for Automated Driving

Safety concerns would limit the feasibility of higher level automated driving, particularly at SAE levels 3–5, to very few use cases of reduced complexity, if the environment perception of cars were based on in-vehicle sensors only. Vehicle-to-vehicle data communication, and even more, connectivity with sensor systems in the infrastructure and links to dynamic maps, artificial intelligence and big data analytics in the backend, could increase the capabilities of automated vehicles to understand complex traffic situation. They may even become a requirement for allowing the operation of self-driving cars e.g. in urban environments. This requires data links providing high bandwidths and low latencies, as they are offered by either (long range) 5G mobile communication or (short range) wireless internet. EU-Commissioner Guenter Oettinger (then in charge of the Digital Agenda) in 2015 launched a round table to bring together the automotive and telecom sectors for a closer cooperation and development of a roadmap on connected and automated driving [4]. As a result, the European Automotive Telecom Alliance (EATA) was formed.

2.4 Strategic Transport Research and Innovation

The research and innovation needs in connected and automated driving are covered in the roadmap "Connected and Automated Transport" of the Strategic Transport Research and Innovation Agenda (STRIA) that the Directorate-General Research and Innovation (DG RESEARCH) of the European Commission compiled in 2017 [5]. Like the other six STRIA reports, it was published as part of the European Commissions communication package "Europe on the Move" [6]. According to this roadmap, short-term research needs are seen in: Large-scale cross border demonstration, human factors, testing and validation procedures and in the assessment of socio-economic and environmental impacts of connected and automated driving. On the longer term, perception systems and artificial intelligence ensuring road safety, and infrastructures supporting the integration of connected and automated vehicles into the wider transport system will require additional research. Currently, the European Commission is setting up a governance structure for the implementation of the STRIA roadmaps. It involves EU institutions, Member States, local administrations and other relevant stakeholders. Since 2016, research and innovation projects have been funded in the framework of the Automated Road Transport (ART) section of the Transport Work Program.

3 European Stakeholder Positions and Roadmaps

European stakeholders from industry, academia and civil society are contributing significantly to the strategic discussions on research, innovation and deployment of connected and automated driving through a multitude of platforms. With the support by their members and an in close cooperation with associations such as European Council for Automotive Research (EUCAR), European Association of Automotive Suppliers (CLEPA), European Automotive Research Partners Association (EARPA), ERTICO—ITS Europe, and the Cities and Regions for Transport Innovation (POLIS), the European Technology Platforms ERTRAC and EPoSS, the Joint Undertaking ECSEL and the European Automotive-Telecom Alliance (EATA) recently have released roadmaps and strategic positions.

3.1 ERTRAC

The European Road Transport Research Advisory Council (ERTRAC) just recently published a new edition of its Automated Driving Roadmap that had originally been released in 2015 [7]. It summarizes the challenges of connected and automated driving in three categories: vehicles, systems and services, and society. For vehicles, in—vehicle technology enablers, as well as production and industrialization

are listed as fields requiring further research. For systems and services, human factors, connectivity, digital and physical infrastructure, big data and artificial intelligence, new mobility services, shared economy, and business models are mentioned. For society, user awareness and societal acceptance and ethics, needs for policies, regulation and European harmonization, socio-economic assessment and sustainability, as well as safety validation and roadworthiness testing are considered. Recommendations are derived for the 2018–2020 calls for proposals of the Horizon 2020 work programs.

3.2 EPoSS

In its "European Roadmap Smart Systems for Automated Driving" the association of the European Technology Platform on Smart Systems Integration (EPoSS e.V.) is describing the goals and challenges as well as the state of the art of automated driving [8]. A particular focus is put on the enabling role of smart electronic systems and architectures. These include navigation systems for localisation and positioning, sensing and perception systems, sensor networks and fusion, vision systems for guidance and control as well as self-learning algorithms. The sensor suite of a highly automated vehicle comprises several smart systems such as high-end laser scanners creating a 3D surface map of the environment, as well as camera and radar sensors that complement each other by lateral and spatial resolution. The roadmap covers evolutionary and revolutionary development paths and related milestones. Action fields have been classified in the following categories: Technology inside car, infrastructure, big data, system integration and validation, system design, standardization, legal framework and awareness measures. For each of the action fields, the content and the timescale of actions in R&D, demonstration and industrialisation is indicated. Currently, this roadmap is being complemented by an EPoSS position paper that emphasizes the user centric perspective, a vision for connected and automated driving 2030, the links to robotics, safety and security issues of automated driving, and synergies between automation, electrification and shared mobility.

3.3 ECSEL

The Joint Undertaking Electronic Components and Systems for European Leadership (ECSEL) is a public-private partnership of the European Union, Member States and three associations, EPoSS e.V., AENEAS and ARTEMIS-IA, representing the actors from smart integrated systems, micro- and nano-electronics, and embedded or cyber-physical systems domain. In its recently published Joint Strategic Research Agenda, "Transport & Smart Mobility" is considered an important application field, and "Ensuring secure, connected, cooperative and

automated mobility and transportation" is seen as a major challenge [9]. According to the roadmap a number of issues require further research, development and innovation, in particular environment recognition, localization, maps and positioning, control strategies, hardware and software platforms for control units for automated mobility and transportation (including also support for artificial intelligence), communication inside and outside the vehicle, testing and dependability, swarm data collection and continuous updating, predictive health monitoring for connected and automated mobility, functional safety and fail-operational architecture and functions (sensors, electronics, embedded software and system integration), as well as management of mixed automated and manual traffic. To enable the related functionalities, electronic components and systems (ECS) are considered to be key, e.g. interacting information systems for safe and secure connection between vehicles and between vehicles and infrastructure, intelligent on-board traffic management and navigation systems, energy harvesting sensor and actuator systems, multi-core/many-core-based architecture, AI-based systems, safe fallback vehicle sensing and actuation systems as well as methods and tools to virtually validate and approve connected, cooperative, automated vehicles. ECSEL recently launched the Lighthouse Initiative Mobility.E that shall increase the impact of research and innovation projects promoting collaboration and fostering a continuous dialogue with the ECS community and between the ECS community and technology users, decision-making bodies and society. It is supported by a Lighthouse Initiative Advisory Service" (LIASE) that shall develop, maintain and implement a dedicated Lighthouse Initiative Roadmap.

3.4 EATA

The European Automotive Telecom Alliance (EATA), an umbrella organization of companies and associations, recently presented a roadmap for the deployment of connected and automated driving functionalities [10]. According to that roadmap, the deployment shall happen in three steps. At first, highway chauffeur and high-density truck platooning shall be supported by the pre-deployment of hybrid communications, network slicing, and LTE broadcasting in five EU countries. Thereafter, also valet parking shall be added and cross border functionality be available on motorways, then building also on 5G radio and evaluation relative localization, and finally, automated driving shall be deployed and commercialized on authorized highways. Part of the planned activities are co-funded by the European Commission and some partners of EATA in the project "Connected Corridor for Driving Automation" (CONCORDA).

4 Programs and Projects

The European Union has funded research and innovation in the domain of automated driving for more than a decade. The EUREKA project "PROgraMme for a European Traffic of Highest Efficiency and Unprecedented Safety" (PROMETHEUS) which took place between 1987 and 1995 and received 749 million euros in funding from the EUREKA member states, already covered many of the issues of automated driving that sometimes are still of concern today [11]. Automated driving also was the subject of funding in the European Commission's sixth and seventh research framework programs. In the current Horizon 2020 program, specific call sections of the transport work programs have been dedicated to "Automated Road Transport" (ART, for 2015/16) [12] and "Digitising and Transforming European Industry and Services: Automated Road Transport" (DT-ART, for 2018–20) [13] with an allocated funding budget of more than 200 million euros. A summary of call topics and budgets is shown in Table 1.

Additional European funding opportunities for the topic of connected and automated driving have been provided by the ECSEL Joint Undertaking and the EUREKA cluster PENTA on micro and nano electronics [14]. Recently, the Directorate-General Communications Networks, Content and Technology (DG CONNECT) of the European Commission also launched a call for proposals on the topic "ICT-18-2018: 5G for cooperative, connected and automated mobility" providing a total of 50 million euros for Innovation Actions [15].

All current and previously funded EU-funded research and innovation projects on connected and automated driving are summarized in Fig. 1, distinguishing four research fields: Networking and Challenges, Connectivity and Communication, Driver Assistance Systems and Highly Automated Urban Transport Systems.

Automated road transport is covered by the "Urban Mobility" theme of the Urban Innovative Actions that provide funding from the European Regional Development Fund (ERDF) for highly innovative technology deployment projects to municipalities in Europe. Shared automated vehicles were among the most prominent solutions presented by the 86 applications submitted to the second call for proposal [16]. Two of the selected projects will receive funding for such solutions, namely "Transforming Urban Planning Providing Autonomous Collective mobility" (TUPPAC) by the City of Albertslund in Denmark, and "Collaborative Mobility Management for Urban Trafic and Emissions reduction" (COMMUTE) by Toulouse Metropole [17].

Table 1 Automated road transport calls in the EU Horizon 2020 program

Call ID	Topic	Type[a]	Budget (million euros)
ART-02-2016	Automation pilots for passenger cars	IA	48
ART-04-2016	Safety and end-user acceptance aspects of road automation in the transition period	RIA	13
ART-05-2016	Road infrastructure to support the transition to automation and the coexistence of conventional and automated vehicles on the same network	RIA	
ART-06-2016	Coordination of activities in support of road automation	CSA	3
ART-01-2017	ICT infrastructure to enable the transition towards road transport automation	IA	50
ART-03-2017	Multi-Brand platooning in real traffic conditions	IA	
ART-07-2017	Full-scale demonstration of urban road transport automation	IA	
DT-ART-01-2018	Testing, validation and certification procedures for highly automated driving functions under various traffic scenarios based on pilot test data	RIA	6
DT-ART-02-2018	Support for networking activities and impact assessment for road automation	RIA/ CSA	6/3
DT-ART-03-2019	Human centred design for the new driver role in highly automated vehicles	RIA	8
DT-ART-04-2019	Developing and testing shared, connected and cooperative automated vehicle fleets in urban areas for the mobility of all	IA	30
DT-ART-05-2020	Efficient and safe connected and automated heavy-duty vehicles in real logistics operations	tba	50
DT-ART-06-2020	Large-scale, cross-border demonstration of highly automated driving functions for passenger cars	tba	

[a]*CSA* coordination and support action, *IA* innovation action, *RIA* research and innovation action

5 International Benchmark

In a recent study on behalf of the European Commission, the maturity of the transportation systems was assessed in six different countries—Brazil, China, India, Japan, South Korea, USA—in comparison to the EU. The study covered all transportation modes and had five focus areas including automation and connectivity. It also provided actions plans on how to overcome existing European barriers towards a single and innovative European Transport System based on best practices and lessons learned in the countries under study. In addition to the actions plans, the recommendations for international collaboration were made [18].

According to the results of the study, the degree of maturity automated and connected transport is about alike ("good") in Europe, the U.S. and Japan, whereas

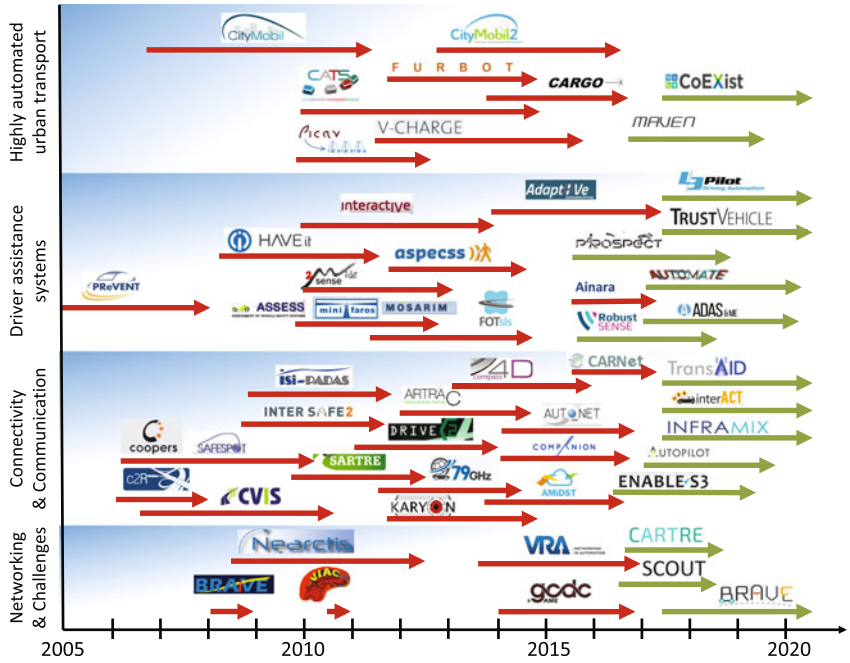

Fig. 1 EU-funded research and innovation projects in connected and automated driving

South Korea and China are just slightly lagging behind ("fair"). In terms of best practices, in particular the advanced regulatory framework for automated and self-driving cars in California and the comprehensive strategic initiative, SIP-ADUS, in Japan are highlighted. Moreover, the pilots of automated, electrified and shared vehicles in Singapore are considered to be trend-setting. Consequently, the study recommends for Europe (a) to establish the necessary regulations for testing and usage of automated driving in early anticipation of and parallel to the innovation process, (b) to integrate the three revolutions automation, electrification and mobility-as-a-service under one funding scheme, and (c) to combine research, piloting and deployment of connected and automated cars in one strategic program.

6 Comprehensive Roadmaps

The European Commission in 2016 launched two Coordination and Support Actions to assist the strategy development processes and the network building in the field of connected and automated driving: CARTRE, funded by DG RESEARCH, and SCOUT, funded by DG CONNECT. Both initiatives appear under one common umbrella and coordinate their work in terms of content development and dissemination, e.g. jointly supporting the European Commission in the preparation

of the first European Conference on Connected and Automated Driving in 2017 and the Interactive Symposium on Research and Innovation for Connected and Automated Driving in Europe in 2018 [19]. In particular, both the CARTRE and SCOUT projects in close cooperation with ERTARC and EPoSS are working on strategic recommendations and comprehensive roadmaps for research and innovation in connected and automated driving in a mutually complementing way.

6.1 CARTRE

CARTRE focuses on identifying detailed research needs in a multitude of relevant technical and non-technical domains, including in-vehicle technology enablers, physical and digital infrastructure, connectivity, shared an automated mobility services, human factors, user acceptance and societal awareness, as well as socio-economic assessment. CARTRE therefore has established a wide network of working groups involving a multitude of relevant stakeholders.

6.2 SCOUT

SCOUT aims to establish a comprehensive and structured roadmap for connected and automated driving that reveals the interdependencies of technical and non-technical issues and identifies opportunities for accelerating the innovation process. The project therefore assesses use cases as well as societal goals and challenges, and formulates a vision for connected and automated driving. It also analyses the state of play in technologies and business models and identifies gaps and risks for the development and deployment of connected and automated driving.

The vision for connected and automated driving developed within the SCOUT project is putting the user into the center and tries to describe a desirable 2030 future scenario from his or her perspective. This has been achieved with the support of various stakeholders from e.g. city governments, vehicle manufacturers and telecommunication experts. The vision combines a number of solutions for connected and automated driving spanning a geographical sphere starting from cities over suburban, rural and interurban environments towards international areas. The suggested solutions such as robot taxi, universally designed vehicles and services, logistic hubs as well as connected traffic systems have been categorized into four areas of interest, namely mobility as a service, passenger transport, goods delivery and infrastructure. It turns out, that the essence of that vision consists in level 4 and 5 automated driving in different use cases. The technical challenges are very similar, though, and may be solved by smart systems that combine sensing with connectivity and intelligent decision-making. However, as such most advanced automated or self-driving functionalities have not yet reached full maturity, depend on a complex interplay of technical and non-technical issues, and are not

yet allowed in most places, the process of roadmap development is particularly challenging.

The SCOUT consortium decided to apply the five-layers model that already was found to be appropriate for a description of the state of the art [20] to also grasp the complexity of the action plan to be established. According to that model, besides the technical layer as a basis for connected and automated driving functions, further layers describe the relevant non-technical issues, i.e. human factors, economics, legal, and societal aspects. The layers are strongly interlinked and they each are covering three interrelated topics, the driver (or passenger), the vehicle and the environment.

At two public workshop with the involvement of dedicated experts for all the five layers, actions were identified for each layer, linked to actions in other layers, and aligned on the time scale. It turns out that technical and non-technical challenges are highly related to each other with one action requiring the outcome of another one before it can start. The many inter-dependencies are creating a kind of Gordian knot indicating that the development and deployment of level 4 and 5 connected and automated driving may be heavily delayed if it is not comprehensively coordinated—a typical feature of complex innovation processes that touch a multitude of technical and nontechnical dimensions.

However, as can be seen from the simplified structure of the 5-layer roadmap of connected and automated driving (Fig. 2), solutions are possible and the innovation process is accelerated if roadblocks are anticipated and agile shortcuts are taken.

7 Conclusions and Outlook

In view of the legacy of innovation in technologies for connected and automated driving in Europe, and acknowledging the arising global competition in this domain, public authorities, academia and private stakeholders have launched a number of strategic initiatives: The European Technology Platforms ERTRAC and EPoSS have compiled research needs, the European Commission has allocated substantial budgets, and networks like the CARTRE and SCOUT project created added benefits by analyzing programs, bundling projects and giving advise for future directions. The various actions are still quite diverse and at risk to loose momentum if not comprehensively coordinated mutually and with the actions by European member states. One issue is the complexity of the paradigm shift connected and automated driving is representing due to the strong interplay of technical and non-technical factors. As shown in this paper, a more agile innovation process may be a way out. If well coordinated with all stakeholders, critical mass could be generated, and the multitude of diverse competencies available in Europe could be leveraged. In the near future, there will be a number of opportunities for this, ranging from the implementation process of the STRIA roadmap on connected and automated driving with the involvement of Member States, via potential new public-private partnerships under the upcoming Horizon Europe framework

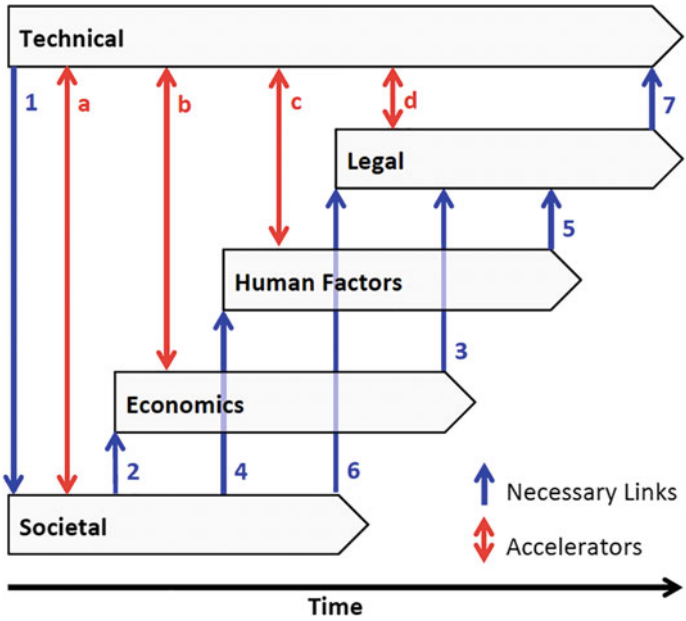

Fig. 2 Simplified structure of 5-layer roadmap for the highly interlinked innovation process in connected and automated driving. Delays are caused by sequences of actions on different layers that are determined by necessary links: (1) invention—e.g. a new robotic driving feature, (2) customer demand—e.g. readiness to pay more for the feature, (3) business model—e.g. sharing concept to operate the car and generate revenues, (4) user needs—e.g. requirements by other road users, (5) product design—e.g. new functionalities for communication with pedestrian, (6) norm—e.g. expected safety level of automated road transport, (7) regulation—e.g. approval for operation of new vehicle. The process may be accelerated by creating agile short cuts: (a) demonstration—e.g. automated driving pilots allowing the public to experience the pros and cons, (b) sandboxes—e.g. hackathons to develop new digital financing schemes, (c) co-creation, e.g. sessions applying universal design rules, and (d) living labs e.g. experimental legislation and standardization

program of the European Commission, to the game-changing "missions" the European Union intents to promote. Hence, there is a unique chance that Europe will drive forward disruptive innovation in connected and automated road transport as one of the main levers of the imminent transformation of mobility towards higher integration across the modes, better sustainability and greater societal benefit. This is well in line with the ambitions objectives expressed in a recent communication of the European commission [21].

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