FINAL REPORT OF THE SINGLE PLATFORM FOR OPEN ROAD TESTING AND PRE-DEPLOYMENT OF COOPERATIVE, CONNECTED AND AUTOMATED AND AUTONOMOUS MOBILITY PLATFORM (CCAM Platform)

Bruxelles, July 2021

EUROPEAN COMMISSION

Directorate-General for Mobility and Transport
Directorate B — Investment, Innovative & sustainable transport
Unit B4 — Sustainable and Intelligent Transport

Contact: frederic MARCHAL

E-mail: *EU-CCAM-SINGLE-PLATFORM@ec.europa.eu*

Frederic.marchal@ec.europa.eu

European Commission
B-1049 Brussels

Table of Contents

1. BACKGROUND AND SCOPE 5

2. COMPOSITION AND ACTIVITIES 7

3. MAIN ACHIEVEMENTS AND CONCLUSIONS 8

4. DETAILED REPORT ON WORKING GROUP 1 "DEVELOP AN EU AGENDA FOR TESTING": 13

4.1. Context, objectives, expected impacts 13

4.1.1. Context and problem definition 13

4.1.2. Common vision, objectives and expected impacts 15

4.1.3. Necessity for a European Partnership 23

4.2. Planned Implementation 24

4.2.1. Activities 24

4.2.2. Partnership proposal (May 2020): 32

4.2.3. The Strategic Research and Innovation Agenda (June 2020) 33

5. DETAILED REPORT OF WORKING GROUP 2 "COORDINATION AND COOPERATION OF R&I ACTIVITIES": 35

5.1. Scope and objectives 35

5.2. Knowledge base 35

5.2.1. Context and relevance of the Knowledge Base 35

5.2.2. Key challenges and actions regarding the Knowledge Base 35

5.2.3. Priorities and methods 36

5.3. Common evaluation methodology 36

5.3.1. Context and relevance of the common evaluation methodology 36

5.3.2. Key challenges and actions regarding the common evaluation methodology 36

5.3.3. Priorities and methods 37

5.4. Test data sharing framework 39

5.4.1. Context and relevance of the test data sharing framework 39

5.4.2. Key challenges and actions regarding the test data sharing framework 39

5.4.3. Priorities and methods 39

5.5. Recommendations 41

6. DETAILED REPORT ON WORKING GROUP 3 "PHYSICAL AND DIGITAL ROAD INFRASTRCUTURE": 42

6.1. Definition of the WG3 scope and goals (Road Infrastructure) 42

6.2. The work of WG3 43

6.3. The draft list of road infrastructure elements/features and their attributes 43
6.3.1. The methodology followed 44
6.3.2. The outcome 44
6.4. Defining a matrix: methodology and main steps 46
6.5. First results and recommendations 50
6.6. What comes next 52
7. DETAILED REPORT ON WORKING GROUP 4 “ROAD SAFETY”: 53
7.1. Definition of the WG4 scope and goals 53
7.2. CCAM Platform WG4 Member Consultation 53
7.2.1. Scope of the testing activities targeted by the recommendation 54
7.2.2. WG4 statement on “What has been learnt?“ and “what are the safety gap identified” 55
7.2.3. Recommendations concerning on the legal framework for on road experimentations 57
7.2.4. Recommendation implementation – national experts suggestions 61
7.2.5. Horizontal cross WG issues 63
7.2.6. CCAM partnership topics 63
8. DETAILED REPORT OF WORKING GROUP 5 “ACCESS TO AND EXCHANGE OF DATA & CYBERSECURITY” 64
8.1. Definition of the WG5 theme 64
8.2. The process followed by WG5 65
8.3. Gap analysis 65
8.3.1. Cyber Security Maturity Criteria (CSMC) for the gap-analysis for deployment 66
8.4. Context and relevance 68
8.4.1. State of the art 68
8.4.2. CS maturity CS & evaluation of projects (“Matrix”) 71
8.4.3. Triangulation with ENISA Threat taxonomy 72
8.4.4. Future challenges 73
8.5. Major actions and core issues limiting deployment (How, Who and When) 74
8.5.1. Ations needed (How) 74
8.5.2. Stakeholders involved (who) 74
8.5.3. Time line for implementation (when) 74
8.6. Horizontal Cross WG issues 74
9. DETAILED REPORT ON WORKING GROUP 6 “CONNECTIVITY AND DIGITAL INFRASTRUCTURE”: 75

9.1. Definition of the WG6 theme - Connectivity and digital infrastructure for cooperative, connected and automated mobility....75
9.2. Context and relevance (why) 75
9.3. Key challenges and actions (what) 76
9.3.1. State of the Art 76
9.3.2. Future Challenges 77
9.3.3. What needs to be done 80
9.4. Major actions and core issues limiting deployment (How, Who and When) ..81
9.4.1. Priorities and methods (how) 81
9.4.2. Stakeholders involved (who) 82
9.4.3. Recommendations 83
10. CONCLUSION:....84
11. ANNEX: 85
11.1. WG3: PDI attributes Matrix....85
11.2. WG4: annexes....86
11.2.1. Results of CCAM Platform WG4 Member sub-group Consultation 86
11.3. WG6 annex: 94
11.3.1. WG6: uses cases 94
11.3.2. WG6 : Project assessment criteria 113
11.3.3. WG6 : project criteria quantification 130

1. BACKGROUND AND SCOPE

CCAM (Connected, Cooperative, Autonomous and Automated Mobility) has great potential to improve traffic management, road safety, liveability and comfort. Therefore, all over Europe companies and governments are preparing for the implementation of CCAM, which is a fundamental and complex transition of our mobility system.

On 17 May 2018, the European Commission adopted a Communication '*On the road to automated mobility: An EU strategy for mobility of the future'*[1] (COM(2018) 283 final), whereby the Commission announced its intention to establish a single EU-wide platform grouping all relevant public and private stakeholders to coordinate open road testing of Connected and Automated Mobility (CAM) and make the link with pre-deployment activities.

The Commission's Directorate-General for Mobility and Transport ('DG MOVE'), in agreement with other Commission departments, namely the Directorate-General for Communications Networks, Content and Technology ('DG CNECT'), Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs ('DG GROW') and Directorate-General for Research and Innovation ('DG RTD'), set up an informal group of experts in June 2019, the Single Platform for open road testing and pre-deployment of cooperative, connected, automated and autonomous mobility ("the group").

The platform's task was to provide advice and support to the Commission in the field of testing and pre-deployment activities for Cooperative, Connected, Automated and Autonomous Mobility (CCAM). In particular, the group assisted the Commission in the following CCAM related thematic areas:

a) The coordination of CCAM research, testing, piloting, and pre-deployment activities, herein collectively referred to as "testing and pre-deployment activities", in order to increase efficiency and effectiveness, and to integrate existing fora at EU-level.

b) Within the scope of testing and pre-deployment activities, there are important challenges towards the deployment of CCAM that the group addressed, such as those pertaining to data access and exchange, road transport infrastructure, digital infrastructure, communication technology, cybersecurity, road safety, and legal frameworks, etc.

c) In its Communication, the European Commission also announced that it would be establishing a partnership under the next European multiannual financial framework to give a clear long-term framework to the strategic planning of research and pre-deployment programmes on driverless mobility at EU and national levels. The single EU-wide platform advices on and supports the generation of the work programme for this partnership.

In particular within the scope of testing and pre-deployment activities, the platform adviced and supporedt the Commission in the following ways:

[1] https://ec.europa.eu/transport/sites/transport/files/3rd-mobility-pack/com20180283_en.pdf

a. To work towards developing an EU agenda for testing, in order to maximise coherence and complementarities between ongoing Research and Innovation (R&I) and testing activities in Europe, exploit synergies and identify possible fields for cooperation. This included the definition of common priority use cases while keeping testing environments open for a broad range of forward-looking innovative use cases;

b. To support the coordination of EU supported/financed R&I projects as well as pilots, demonstrations, large-scale testing and pre-deployment activities in Europe, with a focus on cross-border issues, related to highly automated vehicles and driving systems for passenger vehicles, freight transport and shared mobility services;

c. To gather and exchange experiences, best practices and knowledge on pilots, demonstrations and large-scale trials;

d. To develop a common evaluation methodology in order to allow for comparison of results between tests. This included establishing key performance indicators and common framework for the assessments of impacts from large-scale trials on safety, on mobility, and on the environment;

e. To promote collaboration between the various actors involved and, if required, give inputs on pre-normative activities, standards and technical specifications within the European Standards Organisations or any relevant organisation; work towards a safety assessment methodology for Connected and Automated Vehicles (CAVs) that takes into account acceptable behaviour (especially in mixed traffic);

f. To identify how access to, and exchange of, vehicle and infrastructure data may be facilitated through testing and pre-deployment activities, and assist in establishing a data governance framework in this context, taking into account the provisions and the implementation of relevant Commission Delegated Regulations under the Intelligent Transport Directive (2010/40/EU);

g. To find, through testing and pre-deployment activities, common ground for addressing technical and legal issues that are relevant to access to, transfer, sharing, use and storage of data, including the use of data by artificial intelligence solutions;

h. To carry out an assessment of the state-of-play of the cybersecurity framework for CCAM, identify possible gaps to tackle cybersecurity challenges for CCAM both at vehicle system and infrastructure system level, and identify best practices to ensure security of smart vehicles against cyber threats for car manufacturers and other actors of the smart mobility ecosystem. This included addressing vulnerability and robustness issues of artificial intelligence systems, and procedures for reporting cyber incidents;

i. To identify how the physical and digital road infrastructure (such as signage, markings, traffic management centres, digital maps etc.) as well as the data requirements that support road usage applications/services (e.g. traffic regulations translated into a harmonised digital representation) can support automated mobility and improve road safety. The safety aspects to be addressed shall cover areas such as vehicle safety (including ability to cope with the different quality and type of roads, markings and signage), vehicle safety assessment/validation, interaction with other road users and road authorities e.g. by reporting incidents, driver reaction time, driver training, issues linked to mixed traffic conditions in the different physical infrastructures (motorways, urban and suburban roads), and whether, or how, these could lead to a possible classification in a harmonised way. The group also promoted collaboration between the various actors (e.g. public authorities, traffic managers etc.) to ensure high quality standards and accuracy of data.

j. To support the coordination of activities that focus on telecommunication infrastructure including satellites and cellular networks, the internet of things, data storage, and information and communication technology (ICT) platforms that support CCAM and related services, and identify those hurdles that need to be overcome (e.g. spectrum, silo approaches);

k. To identify how satellite navigation, notably Galileo and the European Geostationary Navigation Overlay Service (EGNOS), as well as satellite communication, can support the pre-deployment of automated vehicles; monitor progress and propose new activities for research and pre-deployment;

l. To work on identifying actions to address societal and environmental concerns and support public awareness that are decisive for public acceptance, and consequently the uptake of connected and automated mobility by the diverse user groups;

m. To review those legal issues that could affect the testing and pre- deployment of CCAM, such as traffic rules, vehicle legislation, processing of data and privacy, and how legal hurdles for testing and pre-deployment could be addressed in the context of projects.

2. COMPOSITION AND ACTIVITIES

In accordance with the composition and appointment rules defined in the call for application, **the CCAM platform gathered** all relevant public and private stakeholders to coordinate open road testing of connected and automated mobility and to link with pre-deployment activities. The Platform was composed of 20 reprensentatives of relevant European Institutions, 8 individual experts (type A members), 114 organisations (type C members), representatives of 27 member states (type D members), Norway and Switzerland (type E), as well as 113 observers, and some ad hoc participants for **a total of almost 400 experts**.

To make its activities more efficient, the platform decided to create the following thematic working groups (WG):

- WG 1 , under the Co-chair of DG MOVE and DG RTD, focussed on the development of an EU Agenda for testing;
- WG2, under the co-chair of DG RTD and DG MOVE, on the coordination and cooperation of research and innovation activities;
- WG3, under the chair of DG MOVE, on the definition of the CCAM relevant attributes of the physical and digital road infrastructure;
- WG4, under the co-chair of DG MOVE and DG GROW, on road safety;
- WG5, under the co-chair of DG GROW and DG CNECT on the access to and exchange of data and cybersecurity;

- And WG 6, under the chair of DG CNECT, on the connectivity and digital infrastructure.

The platform organized four plenary meetings since its creation, to report on the progress of its work and to give an outlook. WGs also met regurlarly, once or twice per quarter, on the same logic as for the plenaries and organized mini task-forces on a voluntary basis to focus on specific topics, which did not required the mobilization of all WGs participants.

3. MAIN ACHIEVEMENTS AND CONCLUSIONS

WG1: development of an EU agenda for testing:

WG1 prepared a scoping paper which defines the objectives and priorities for a future EU agenda for research, testing and pre-deployment of Connected, Cooperative and Automated Mobility (CCAM).

After the completion of the WG1 scoping paper many additional insights were obtained in the process of the WG and CCAM partnership discussions. A partnership proposal was published in May 2020, which further developed the content of the WG1 scoping paper. **The final output is a Strategic Research and Innovation Agenda, paving the way to the further work of the CCAM Partnership** to be launched in June 2021 under Horizon Europe.

WG2: coordination and cooperation of research and innovation activities:

WG2 worked on the following scope and objectives:
- A knowledge base has been set up to gather and exchange experiences, best practices and knowledge on pilots, demonstrations and large-scale trials.
- A common evaluation methodology to allow for comparison of results between tests.
- A common test data sharing framework for sharing of lessons learnt and test data arising in the context of large-scale demonstrations.

WG2 recommends that the work on the Knowledge Base, the Common Evaluation Methodology and the Test Data Sharing Framework is continued, especially under the upcoming CCAM Partnership cluster 7 dedicated to coordination. This should lead to a common and comprehensive R&I action under the Horizon Europe Working Programme 2021.

In the meantime, WG2 recommends that:
- **Work on the Knowledge Base is continued and intensified under the ARCADE Coordination and Support Action (CSA)**, and strongly encourages stakeholders to contribute results from all relevant CCAM actions (also going beyond Horizon 2020) in a timely and proactive manner to the Knowledge Base.
- **Work on the Common Evaluation Methodology and the Test Data Sharing Framework is continued**, where feasible and relevant, under the current and upcoming **demonstration projects under Horizon Europe** (e.g. L3Pilot, ENSEMBLE, SHOW, AWARD, Hi-Drive).

WG3: Physical and digital road infrastructure:

The main goal of WG3 was to identify how can physical infrastructure advancements support CCAM, and which are the improvements to road infrastructure that will be

necessary to enable a mobility transformation, including meeting the requirements of the ODD, with a focus on SAE L4 Automated Vehicles (AV).

In order to achieve this goal, **WG3 developped a matrix of road infrastructure elements, considering:**

- **Attributes (physical and digital):** specifying for each element the main characteristics which render it necessary for the realization of automated driving. A distinction within digital and physical element was often possible, but not always, as some elements can have impact on both layers. The list produced is not intended to be exhaustive, but rather to represent the most important (or urgent) elements needed for CCAM.
- **Link to automated driving:** to meet expectations from the OEMs, WG replaced uses cases by three categories of generic basic driving tasks: Sensing & Perception, planning and actuation. The road infrastructure digital and physical attributes have thus been mapped to these 3 categories, indicating specific explanation on the way they impact on and support automated driving.
- **Investments:** for each attribute, the WG decided to define, when possible, **recommendations in terms of investments** (priority, nature, frequency, pertinence).
- The WG also analysed **the pertinence of each attribute according to relevant circumstances and environment.**
- Finally the Group decided to point out **which added value and usefulness each attribute could bring to automated vehicles and to human operated vehicles and general traffic safety.**
- **Priorization of attributes:** the matrix now consists of a streamlined list of attributes reduced to 29 elements, 19 of them being considered digital twins, 6 coming under C-ITS and 4 being a mix. It was not possible at this stage to converge on a clear attributes priorization.

The group believes the current matrix can be a useful tool in further advancing understanding on how PDI and vehicles can work together, thus guiding towards the most efficient ways to enable highly automated mobility services, it is also recognized that more work is needed.

In terms of general recommendations about digital support for CCAM, WG 3 proposes the following:

- **Investments in digital and operational infrastructure should increasingly complement and strengthen investments in physical infrastructure**. In the long term this might even reduce the necessary investments in physical infrastructure. **Within an overall increase of investments for transport infrastructure the share of digital and operational increases as well**.
- **The former is particularly true for investments in new infrastructure**. Investments in new transport infrastructure should always include the relevant digital components.
- **As the transition phase will be long**, mixed traffic will exist for multiple decades, and one should **prioritize investments that benefit both human driven and automated vehicles**.
- Digital infrastructure already enables dynamic traffic management today. For example, variable message signs are used for dynamic setting of speed limits or direction of travel. When available, this **information should be replicated in the digital twin (e.g. via a National Access Point)**, making it available for HD maps, **as well as being shared through C-ITS messages**, reducing latency and creating

redundancy. **The relevant public authority (local, regional or national) should take responsibility for all representations of PDI data in equal manner**.

- To maximise its potential in supporting CCAM, the digital and operational infrastructure needs to be reliable, up to date, trusted and secure. Though particularly for C-ITS some of these elements are already addressed, the recommendation remains that **digital infrastructure needs to fully embrace functional safety**.

The WG also formulated recommendations related to specific and challenging situations (road works, complex intersections and crossing, underground parking or urban canyons..), for which the use of connectivity and particularly C-ITS is necessary to enhance cooperation between infrastructure and vehicle.

WG4: Road safety

Road safety is one of the targeted impacts of automated driving as it is expected that it will reduce the number of accidents and consequently also the number of people injured or killed in traffic. **The aim of WG4 was to identify the key research topics that need to be addressed to ensure that also the testing (with expert drivers) and pre-deployment (with restricted user groups) of CCAM can be executed safely and that the automated vehicles are ensured to be safe before they enter the public roads**. Next to the R&I topics **also the legal framework** to allow testing and pre-deployment is addressed.

The results of WG4 can be summarized as follows:

- **The key challenges for automated driving in relation to road safety have been identified at the vehicle level, the interaction with other road users and on the traffic level.** For these challenges the specific challenges for safe testing in the R&D phase have been derived as well as the challenges in the pre-deployment phase. This provides a first indication of the aspects to consider for the legal requirements to allow testing and pre-deployment with adequate safety levels. For an EU-wide approach the legal requirements should be harmonized. It is also concluded that the requirements may be different for passenger cars, freight vehicles and urban mobility vehicles.
- **The topics for safety related actions have been identified** using the input from the members of WG4. The list of actions is extensive, and it has been used to propose several research projects. **A key element of these research projects should be the safety assessment, which will provide the information for legal and regulatory frameworks required for testing and pre-deployment activities**. The legal aspects of the frameworks will need to be defined with involvement of stakeholders to ensure that the requirements can be fulfilled by the identified stakeholders with reasonable cost and within reasonable timelines. The deployment agenda of CCAM needs to be considered, however safety assurance seems to a large extent independent of the deployments planned.
- **The specific safety topics for CCAM can be linked quite well to ERTRAC's Road-safety roadmap**, and it is concluded that most technological aspects seem to be covered in existing and planned research, but also that mainly human-related aspects require more exploration. An overview is provided of the relevant topics related to the ERTAC roadmap for Human Factors, specifically CCAM and some general topics. Specific testing actions are also identified.
- The **recommendations on the legal framework** for road testing are provided considering the typical process that is followed in the approach process for different member states, i.e. intake, desk research, vehicle testing, admittance and evaluation.

The list of recommendations is quite extended, and proposed studies will take a considerable time to execute.

- **Road-safety is a topic with cross-links with all other working groups of the CCAM Platform**, and to achieving the required levels will involve many disciplines and a needs the support of a wide variety of stakeholders that represent the physical and digital environment of the automated vehicle.

WG5: Cyber-security and access in-vehicle data linked to CCAM

WG5's task was to identify for the V2X case how testing and pre-deployment activities can remove cybersecurity barriers for the uptake of CCAM. WG5 experts compiled the state-of-the-art, identified and discussed these barriers and potential pre-deployment activities. The main conclusions can be summarized as follows:

- **in the Connected and Cooperative Mobility Domains**, systems are operational, and cybersecurity is at a sufficiently high Technology Readiness Level (TRL). Yet, **compliance monitoring and enforcement is not yet sufficiently operationalized to guarantee CCAM's compliance with applicable national and European regulations including ePrivacy, GDPR and telecom regulations.** EU guidance is needed to ensure that Member States implement specific legal and technical frameworks on cybersecurity for testing in a consistent manner. National agencies should be actively involved in pre-deployment activities.
- **in the Connected Mobility domain, one of the remaining issues to settle is to regulate access to in-car data** in such way that innovation is not hampered, and fair market access is guaranteed. The governmental agencies of the member states should further collaborate with stakeholders to improve CCAM data exchange and cybersecurity mechanisms.
- **The Coordinated Mobility Domain** would benefit if governmental agencies are supported to set-up national trust networks, e.g. organisations involved with the establishment of Public Key Infrastructure, managing cyber incidents;
- **in the automated and autonomous Mobility Domain one should focus on the issues of tampering with sensor input and AI**. One car reuses the cybersecurity and in-car data access concepts from Connected and Cooperative Mobility.
- the WG5 findings have been compared with the results of ENISA 2019-publication[2] on the "good practices for the security of smart cars" and the recent UN Type Approval Regulations for cybersecurity. Here too we find confirmation that **pre-deployment activities should include governmental partners in order to cover institutional aspects of cybersecurity, encompassing explicitly (cross border) monitoring and enforcement activities.**
- one should start early as institutional adjustment to the deployment of CCAM services will cost time.

Finally the future challenges in the field of cybersecurity have one common deployment issue: the need to improve the common know-how of governmental agencies and the collaboration with companies that deploy CCAM services.

[2] https://www.enisa.europa.eu/publications/smart-cars

WG6: Connectivity and digital infrastructure for CCAM

Connectivity is vital for cooperative and automated vehicles, other road users, road-side systems and cloud services to realise the vision of CCAM. The digital infrastructure is the communication infrastructure that connects all devices and systems in CCAM. The focus of WG6 was on testing and pre-deployment and addressed the short-range, long-range and broadcast communication infrastructure from technological perspectives, in order to establish further needs for co-existence and interoperability testing.

WG6 worked on the following key challenges and deliverables:

- **Project Assessment Criteria** –Criteria to assess the quality of pre-deployment tests, projects and proposals. It identified pre-requisites for pre-deployments, criteria for the scope and scale, and for validation, as well as reference values for assessment metrics.
- **Analysis of priority road transport services** – Selection of a short list of priority use cases that spans connectivity requirements for the CCAM-domain. For each use case, requirements and challenges were formulated for connectivity, communication technologies and co-existence. Future use cases were also considered.
- **Stakeholder ecosystem –** WG6 provided a platform to discuss challenges and strategies to improve the competitiveness of the European ecosystem on connectivity and the digital infrastructure for CCAM, and especially to improve testing and pre-deployment of communication technologies for CCAM. Key challenges were identified, but many still need to be developed further into actions and plans. An important outcome of this platform is the development and release of the 5G Strategic Deployment Agenda.
- **Further outcome is an in-depth exploration on the strategic investments, focus of alliances and related investments.** The review included the review of the strategic steps over the last five years of the most salient important companies working on autonomous vehicles technologies; also several identified alliances of companies across major trade blocks were covered. Although the USA and European brands seem to dominate the landscape this is blurred by several key cross-country alliances. The most notable companies are Ford-Volkswagen, BMW, Intel, Mobileye, and Nisan-Renault. Asian companies that are heavily investing in automated driving include APTIV, BALBAI-DU and Huawei (China) and Samsung and Hyundai (South Korea) both countries have automotive, software or telecom companies with associations with European and USA companies. The analysis of the diverse strategies clearly shows that the full autonomous driving car remains far in the future. However, SAE level 3 automation is achievable within the next 5 years for mass deployment and opens new ways to create value through data analytics and mobility services. A major part of the expected value added of cars in the next five to ten years will be created by the content of information and communication technologies embedded in the car and the connection to a broader ecosystem of services beyond the company producing the car. This is expected to create a market for data such as demonstrated by typical digital platforms that provide intermediary and other services. The future competitive landscape of the vehicle seen as a product is likely to be strongly related to the future dominance of the electric vehicle market. This development in conjunction with the new technologies required to enable autonomous driving is likely to created new value chains feeding into the existing automotive industry. These new value chains might include new battery technology, software and computing platforms enabling V2X communication, sensor in vehicle technologies and HMI interfaces.

4. DETAILED REPORT ON WORKING GROUP 1 “DEVELOP AN EU AGENDA FOR TESTING”:

WG1 prepared a scoping paper describing the overarching context at an early stage of the process which has been completed by the end of 2019. A partnership proposal was published in May 2020[3], which further developed the content of the WG 1 scoping paper. The final output is a first draft of Strategic Research and Innovation Agenda delivered in June 2020.

The aim of the scoping paper was to define the objectives and priorities for a future EU agenda for research, testing and pre-deployment of Connected, Cooperative and Automated Mobility (CCAM). This included the definition of the objectives and scope of a possible future European partnership on CCAM.

4.1. Context, objectives, expected impacts

4.1.1. Context and problem definition

Mobility is crossing a new – digital – frontier with increasing connectivity, allowing vehicles to “talk” to each other, to the road infrastructure and to other road users. This will enable a coordination and cooperation at an entirely new level (e.g. warning messages not limited by line-of-sight or congestion management using real-time information). At the same time, automated vehicles can have a 360° vision of the surrounding environment and can reduce reaction times. Current road vehicles already provide ever more advanced assistance, and intervene when a dangerous situation is detected. Future systems will be able to control the vehicle for extended periods and at some point will no longer rely on a human back-up. Combining connectivity, cooperative systems and automation could go even further and allow automated and fully orchestrated manoeuvres, and bring us closer to Vision Zero[4]. Furthermore, this combination will also enable the provision of new mobility services, fostering benefits for users and for the mobility system as a whole, with the aim of making transport safer, greener and more accessible.

Reaching these objectives however requires solving a multitude of challenges that need to be addressed at several levels: human, technical, societal, economic, operational and regulatory. Examples include the development of vehicle technologies, their interaction with the surrounding environment, connectivity and data sharing, mixed traffic management, real world-testing but also public and policy makers' awareness and acceptance by the expected users, infrastructure readiness and investments, development of skills and insurance models.

Significant investments will be needed to develop, test and deploy the relevant technologies, systems and services, to create the infrastructure support and to ensure social acceptance as well as user and market uptake of automated mobility solutions. While most of the investment will come from the private sector, the EU provides significant stimulus for research and innovation and for targeted infrastructure investments. To maximise the benefit from public funding, the Commission must link the support measures to key transport policy and regulatory initiatives for CCAM.

[3] file:///C:/Users/MARCFRE/AppData/Local/Packages/Microsoft.MicrosoftEdge_8wekyb3d8bbwe/TempState/Downloads/CCAM_Partnership_Proposal_13-04-2020.pdf

[4] By 2050, move close to zero fatalities in road transport. In line with this goal, the EU aims at halving road casualties by 2020. Make sure that the EU is a world leader in safety and security of transport in all modes of transport(https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0144&from=EN).

Many Research and Innovation (R&I) actions as well as large-scale tests are already ongoing in Europe: at industry, local, national and EU level. Many of these are supported by the Commission through research funding programmes or deployment projects including cross-border testing. For 2014-2020, a total budget of around EUR 300 million from the EU's framework programme for research and innovation "Horizon 2020" has been allocated to support research and innovation on automated road transport. Additionally significant EU R&I funding has been invested in closely related R&I projects, for instance more than EUR 200 million under the ECSEL Joint Undertaking on electronic components and systems. In order to avoid fragmentation and foster seamless deployment across the EU, sharing knowledge and comparing test data from CCAM projects is vital. Aligning public and private sector R&I actions and their subsequent implementation, and engaging all relevant stakeholders – e.g. public transport operators when addressing urban mobility related applications - are key mechanisms to more effectively match use cases developed by industries with the needs of public authorities (including local and regional ones) for the benefit of both and also that of the user of the mobility system as a whole.

There are high costs, risks, barriers and lead times before R&I investments in CCAM will lead to innovative new products and/or services being widely applied. Automated mobility, particularly in road transport, is characterised by complex interactions within the overall mobility system. The interdependency of different parts of this system requires that a specific innovation (e.g. new vehicle automation or communication system) needs to be accompanied by timely innovation and roll-out in other segments, such as infrastructure or business models, for it to have a beneficial impact on the overall system. It also requires synergies with other actors and sectors of the value chain (e.g. semiconductors, processing technologies, digital maps, IoT, AI) and innovative business models (e.g. electronic commerce, 'mobility as a service', 5G services) to really pay off. Moreover, the advent of automated vehicles opens important new challenges in relation to security and privacy topics.

Many of the required steps towards CCAM therefore have to be planned consistently across sectors, and in cooperation with the Commission and the Member States, as they are highly interdependent. If not planned comprehensively, and matched with the proper framework conditions, e.g. in the regulatory domain, the innovation process may slow down or may not trigger the expected benefits. Resources and investments could be wasted and Europe may miss the opportunity to benefit from CCAM for its society and economy.

This EU agenda for research and pre-deployment relates to Cooperative, Connected and Automated Mobility (CCAM). The focus is on road transport, but it takes into consideration relevant interfaces with other modes (for instance rail-way crossings, but also transfers and integration with public transport) in order to make sure that safety is ensured, that efficiency and the optimal use of available infrastructure are improved and that new multi-modal services can be developed for the benefit of users and society as a whole. Connectivity aspects that are not related to the advancement of CCAM (e.g. entertainment) are out of scope.

The reference to mobility is essential as the goal is to create more user-centred, all-inclusive mobility, while also increasing safety, reducing congestion and contributing to decarbonisation. This requires a system approach to innovation, rather than developing automated vehicles by themselves.

4.1.2. Common vision, objectives and expected impacts

Vision

In the Communication "On the road to automated mobility: An EU strategy for mobility of the future"[5] the European Commission lays down its vision on Connected, Cooperative and Automated Mobility (CCAM).

The vision for the next 10 years is to make Europe a world leader in the development and deployment of connected and automated mobility services and systems, making a step-change in Europe's mobility system in bringing down the number of road fatalities towards zero, increasing traffic efficiency and enhancing traffic planning, fostering cooperation between different transport modes, reducing harmful emissions from transport and reducing travel time and congestion as well as increasing accessibility at lower population density areas and for impaired people.

Within this period, CCAM shall foster and support new mobility concepts, shifting design and development from a driver-centred to mobility-user oriented approach, providing viable alternatives for private vehicle ownership while increasing inclusiveness of mobility. CCAM solutions will be integrated in the whole transport system (including public transport), accompanied by the right support measures of the public sector (e.g. incentives, legal frameworks) to fully exploit the potential benefits of CCAM and minimise potential adverse effects, such as increased traffic in our cities or new risks in mixed traffic environments.

Automated vehicles will benefit from increased connectivity with other vehicles, the infrastructure and other road users. This will allow them to better coordinate their manoeuvres, making use of active infrastructure support and enabling smart traffic and fleet management for improved throughput and increased safety.

Shared, automated mobility services will become widely available, providing seamless door-to-door mobility for people and freight, leading to healthier, safer, more accessible, greener, cost-effective, demand-responsive and more sustainable transport everywhere.

CCAM solutions will ultimately be based on connected and highly automated vehicles with very high levels of robustness and reliability even in particularly challenging and complex traffic environments. The operational design domains (ODD) of these vehicles should be expanded to the point where they become economically viable and ready for (pre-) deployment.

This is not expected (in any short or medium term) to expand up to SAE Level 5, which means the ODD becomes "unlimited"[6]. Developing automated vehicles at SAE Level 5 is therefore not the focus of this European R&I agenda. However, this should not be seen as a limitation for enabling CCAM services with real societal impact. On the contrary, the most efficient and cost-effective solutions are likely those that are optimised for a specific ODD, and provided this is sufficiently large it can be integrated into the overall transport system to provide door-to-door solutions.

[5] COM(2018)283

[6] "Unlimited ODD" means that the Automated Driving System (ADS) can operate the vehicle under all driver-manageable on-road conditions. This means, for example, that there are no design-based weather, time-of-day, or geographical restrictions on where and when the ADS can operate the vehicle. [SAE J3016]

Objectives and expected impacts

The EU agenda shall provide a clear long-term framework for the strategic planning of research, innovation and testing activities, linking with pre-deployment programmes for CCAM, making sure that investments at local, regional and national level, both of public and private nature, complement each other more effectively.

Through the implementation of this EU agenda, the following overall objectives shall be achieved:

1. Ensuring safety and security of the transport system;
2. Meeting societal and market needs and reducing environmental impacts of the transport system and
3. Increasing the effectiveness of R&I and contributing to maintaining and extending industrial leadership.

The following table presents the main R&I action areas to be implemented and its expected outcomes by 2030. In addition, the table presents how the planned R&I areas and their expected outcomes can contribute to realise a large number of strategic objectives, which will in turn help achieving the three overall objectives mentioned above.

The expected outcomes are to be understood as directly related to the R&I action areas, and while they are also expected to contribute greatly to the strategic objectives, the latter may require more than R&I alone.

The table does not provide direct mapping between the individual R&I areas and the individual outcomes, or strategic objectives. This will be part of a later and more detailed exercise, including milestones and timeline.

Overall objectives	Strategic objectives	Expected outcomes[7] by 2030	R&I action areas
Ensuring safety and security	• Reduced number of fatalities and injuries in road transport • Safe and efficient co-existence between automated and non-automated "conventional" traffic for a long transition period of mixed traffic • Physical and digital infrastructure (PDI) to support increased deployment of CCAM • Harmonised CCAM vehicle approval scheme (including highly	• Functional safety for CCAM • EU-wide/global definitions of Operational Design Domains (combining vehicle and infrastructure elements) • Secure and trustworthy interaction between road users, vehicles, infrastructure and third-party services • Agreed safety standards for highly automated driving systems to operate and function on public roads, including on respecting traffic rules • Revised requirements and	**Environment perception** - Reliable environment perception to identify and predict all hazards of automated driving systems **Cyber-security** - Fail-operational and cyber secure electronics and software control architectures for CCAM **Passive and active safety for CCAM** - Integrated safety systems for accident avoidance and enhanced protection enabled by CCAM **On-board decision making** – reliable localisation and dynamic map technologies, digital traffic rules **Validation of CCAM systems** – scenario-based validation and verification of the vehicle and its operation in the

[7] Resulting from the R&I action areas and contributing to realising the strategic objectives

Overall objectives	Strategic objectives	Expected outcomes[7] by 2030	R&I action areas
	automated driving functionality, OTA, etc.)	guidelines for driver training, testing and licenses, taking into account CCAM developments	intended ODD to ensure safety, reliability and security **Human-Machine interaction and interface design -** for on-board users and surrounding road users. **Remote operation** and surveillance to ensure safety of CCAM in particularly complex and challenging situations **Physical and digital infrastructure (PDI)** - PDI ecosystem for CCAM, covering infrastructure needs, in all areas, for different automation levels, supporting the full system ODD **Connectivity / cooperative systems** - secure solutions to facilitate and improve CCAM, interaction between CAVs, infrastructure, traffic management services and all other road users and authorities **Artificial Intelligence** - Concepts, techniques and models for CCAM applications and services

Overall objectives	Strategic objectives	Expected outcomes[8] by 2030	R&I action areas
Meeting societal and market needs and reducing environmental impacts of the transport system	• Increased availability, use and usability of automated driving systems and shared automated mobility and freight delivery services • High quality user-centric mobility services for all users; in particular for elderly and people with disabilities • High public acceptance and adoption of CCAM with clear understanding of its benefits and limits • Increased efficiency of transport flows on all types of roads, leading to better use and protection of infrastructure capacity and public space • Reduced transport emissions and congestion • Improved level of mobility does not lead to unwanted rebound effects, such as increased traffic,	• New mobility concepts shifting design and development from a driver-centred to mobility-user oriented approach • Shared automated mobility and freight delivery services are proven and tested • Resulting (safety, efficiency, environment) socio-economic impacts and wider economic impacts – incl. spatial, temporal and sectoral distribution – are sufficiently assessed and accepted among the actors of the European partnership • Principles for co-investment, co-sharing of benefits, risk determination and mitigation are accepted among the actors of the European partnership	**Smart, shared, automated mobility solutions -** understand user needs and requirements of smart, shared, automated mobility solutions and foster the development of technologies and business models, in particular to encourage shared mobility **Fleet and (mixed) Traffic Management** – integration of CCAM systems and services in fleet and traffic management **Development and demonstration of shared automated mobility solutions** and their integration in the transport system **Large-scale demonstration of highly automated passenger vehicles** and their integration in the transport system **Large-scale demonstration pilots of automated commercial/heavy duty vehicles** and their integration in the transport system **Societal needs analysis -** understand customer,

[8] Resulting from the R&I action areas and contributing to realising the strategic objectives

Overall objectives	Strategic objectives	Expected outcomes[8] by 2030	R&I action areas
	negating the positive effects on congestion or emissions. • Increased compliance with traffic, social and market rules		market and societal expectations, opportunities and acceptance **Socio-economic impact assessment,** including environmental impact assessment to better understand the potential for emission reduction, change in mobility demand, working condition, skills and jobs, etc.

Overall objectives	Strategic objectives	Expected outcomes[9] by 2030	R&I action areas
Increasing effectiveness of R&I contributing to maintaining and extending industrial leadership	• Better exchange and reuse of results from CCAM projects in the EU, improved common learning from experiences • More focused and long-term investments in R&I, development and pre-deployment of CCAM, in line	• Long-term framework for (coordination of) R&I and large-scale testing activities, involving all relevant public and private stakeholders from EU, national and regional levels • Common evaluation framework for R&I results	**Strategic European agenda for R&I and large-scale testing**, including links with other R&I areas/partnerships **European framework for testing on public roads** – all areas, all vehicles, ensure safe testing **Data exchange framework** in the context of cross-

[9] Resulting from the R&I action areas and contributing to realising the strategic objectives

Overall objectives	Strategic objectives	Expected outcomes[9] by 2030	R&I action areas
	with policy objectives and including better engagement of SMEs and start-ups • Strong synergies between the mobility sector and other sectors of the value chain • Decrease of risks linked to innovation, by better knowledge valorisation and handling of IPR and greater certainty in emerging business models • Robust standards framework supporting interoperable solutions for CCAM • Increased number of new professionals in CCAM	• EU-wide knowledge base and sharing platform for exchange of experiences in large-scale testing and R&I activities • 'standard model' of test data sharing • Improved synergies between public and private, vehicle and infrastructure, to achieve common goals and link R&I with (pre-) deployment.	border testing and learning **EU-wide knowledge base**, including common scenario database **Common evaluation framework and KPI's** - to allow comparability of results, complementing evaluations and meta-analysis over multiple evaluation studies **Data storage and sharing** - Data storage and sharing for improving/advancing CCAM **Workforce development** - Labour market effects of CCAM and push and pull measures to facilitate the transition of work force, skills and working conditions

Table 1: Overall objectives, strategic objectives, expected outcomes and linked R&I areas

4.1.3. *Necessity for a European Partnership*

Connected, cooperative and automated mobility is a complex ecosystem in which the vehicles the physical and digital infrastructure, technologies and human beings (traffic controllers, drivers, passengers, motorcyclists, cyclists, pedestrians) will need to interact.

The EU agenda follows a system level approach, which is vital, given the need to preserve and enhance interoperability across the EU network, and to ensure a critical mass of demand to allow industrialisation of innovation.

Meanwhile, EU support and calls for proposals for cooperative, connected and automated mobility have so far been looking mainly at specific technical solutions, their integration in specific use cases, and their impacts on the users. More recently, several large-scale pilots have been launched to test the robustness and reliability of automated driving technologies, systems and functions and to assess socio-economic impacts.

However, a lot of Research and Innovation challenges need to be addressed in an integrated way, to achieve a systematic breakthrough in line with EU policy objectives. These include, among others technologies at vehicle and infrastructure level and for data communication and processing, personal data protection, cyber-security, ethics, social acceptance, as well as impacts on labour and skills, road safety targets, emissions, land use, CCAM system validation and global competitiveness. In addition, a large number of actors (local and regional authorities, road operators, service providers, vehicle manufacturers, IT providers etc.) need to be involved in the development, large-scale testing and validation of solutions to address technical and non-technical challenges. Coordination at EU level is needed in order to develop harmonised solutions and to avoid fragmentation, duplication, inconsistencies and gaps.

Hence, in order to implement the R&I actions of the EU agenda in the most effective way, the EU needs a strong European R&I partnership in which all actors will pursue common objectives and clear deliverables in an aligned and coordinated manner.

4.2. Planned Implementation

4.2.1. Activities

The EU agenda includes R&I actions addressing all elements of the CCAM system (user, vehicle, its interaction with the surrounding environment, physical, digital and operational infrastructure, interfaces between the individual transport modes) and all technical and non-technical enablers.

CCAM mobility systems and services for 2030

The EU agenda for research and pre-deployment addresses all development paths of CCAM for the next decade that are relevant from a public policy perspective, a road operator, a user / consumer perspective and from an industry perspective. It will focus on those co-operative and automated mobility systems and services that can bring gains in terms of safety, efficiency and sustainability of the overall transport system.

The aim is to support the development and pre-deployment of innovative (shared) mobility and logistics services using fully connected and highly automated vehicles (SAE level 4) for passengers and freight. The EU agenda will follow an iterative approach based on experience gained during testing with the objective to continuously expand the operational design domain of highly automated vehicles. The table below shows the application areas for 2030 CCAM systems and services that will be targeted in the EU agenda for research, innovation and testing. Differences in terms of type and maturity of CCAM systems and services in the different geographical areas are to be expected. However, our overall goal and long-term ambition level for CCAM is the same for passengers and freight and in all application areas. Further detailing the CCAM systems and services, determining milestones, deliverables and specific timeframes is part of the follow-up work of WG1. The selection of use cases has to be impact driven. The ones most relevant to achieve the objectives identified in section 4.1.2 and with great potential for deployment in the short to medium term (market readiness, industrialisation) should be favoured. At the same time, it is important to remain open to consider other possible new mobility services / use cases being developed in the next coming years.

	Urban	Highway / nat. roads	Rural
Pax	Innovative, user-centric, inclusive (shared) mobility services using fully connected and highly automated vehicles (SAE level 4[10])		
Freight	Innovative, (shared) freight transportation and delivery services using fully connected and highly automated vehicles (SAE level 4) in real logistics operations		

Table 2: application areas for 2030 CCAM systems and services.

The long-term ambition level and detailed EU agenda developed in the CCAM platform shall also be the basis for the definition of concrete R&I actions of a future European Partnership on CCAM.

Type of R&I actions

We will address R&I actions of two types: pre-competitive research at lower TRL levels and demonstration actions in operational environments. As in the Horizon 2020 calls, the EU agenda for research, innovation and testing will focus on large-scale demonstrations to test the performance and safety of innovative highly automated driving systems for passenger and freight, in all environments. These large-scale demonstrations should prepare the way for the deployment of CCAM systems and services. The Connecting Europe Facility or European Investment Bank can support pre-deployment. Interaction with the mobility system, development of associated services and potential to create positive impact and business cases are examples of aspects that need to be accounted for in high-TRL actions.

Actions to provide inputs for standardisation and harmonisation of technologies and methodologies will also be included as well as the development of assessment and validation methods. Actions will develop technical specifications for interoperability making sure that investments at local, regional, national and EU level, both of public and private nature, are complementing each other towards a fully integrated European mobility system

The EU agenda for research and pre-deployment (and European partnership) will also include a number of actions to support the strategic planning, coordination and cooperation between EU and national R&I projects and programmes (following-up on the ongoing work of the CCAM Platform, e.g. well maintained and searchable knowledge base, data sharing framework, common scenario databases, etc.)

R&I action areas

Based on the action plan of the STRIA Roadmap on Connected and Automated Transport and the stakeholder discussions in WG1 of the CCAM platform, the following R&I action areas can be considered as priority areas for the EU agenda and for the European

[10] This does not exclude lower SAE levels from this roadmap, it means that our goal is to reach SAE level 4 as quickly as possible and priority should be given to activities that help achieve this objective.

partnership (see the earlier table for the link between the R&I action areas and the strategic objectives).

R&I action area	Description
Environment perception	Robust and accurate environment perception is essential for highly automated vehicles. To date systems are ready for partially automated driving in standard situations but not for complex driving conditions and demanding Operational Design Domains (ODDs). This will imply the need for: increased performance of perception systems (sensors), enhanced cognition using machine learning (AI), more powerful embedded in-vehicle systems, integration with infrastructure based perception systems to complete data fusion where internal systems are out of reach, and highly accurate and dependable localization systems. An incremental progress for highly automated driving in agreed ODDs to achieve less false detections for improved driver comfort and trust from all partners and road users of CCAM.
Cyber-secure Electronics	Systems for CCAM should be fail-operational and cyber-secure in their entire Operational Design Domains (ODD). In case of failure in subsystems or components, the CCAM system needs to remain safe, which requires advanced redundancy measures. Concepts are needed to identify tampering attempts and automated plausibility checks as part of the inherent safety concept along the entire lifetime and value chain, from production to operation to maintenance or repair (e.g. software updates, replacement of single components in a workshop).
Passive and active safety for CCAM	Active safety functions need to be adapted and advanced so that automated vehicles safely navigate in both, expected and un-expected scenarios. Therefore, systems need to be developed that aim to anticipate and minimize risks, avoiding collisions where possible and reducing the consequences of unavoidable crashes. Advanced passive safety systems protecting passengers in new, non-traditional seating positions will be a focal point of research as well as conditions for the use of such systems, e.g. in public shared automated vehicles. The development of automated driving functions will lead to new interior concepts that can significantly increase the comfort of the occupants and transform driving time into leisure or work time. As automated driving evolves, we can assume that crashes will continue to occur. Consistent methods and assessment tools are required to fully understand the safety impact of automated vehicles in mixed traffic and to derive safety requirements. Needs and potentials for the (conditional) adaptation of traffic rules should also be derived in this context. Progress in accidentology based on naturalistic driving data will be used to gain new insights on vehicle interaction with and for the protection of vulnerable road users. Moreover, research is needed on required reliability levels of in-vehicle systems and components as an element of active safety.

R&I action area	Description
On-board decision making	On-board safe, unambiguous, real-time decision-making for CCAM using complex in-vehicle systems-of-systems with advanced sensors, extensive computational power, reliable, dynamic high-definition digital maps. Focus on harsh and complex conditions where advanced capabilities such as pattern recognition, big data analysis and self-learning require high performance computing on- and off-board. Definition and EU-wide harmonisation of ODDs to ensure real-time decision-making for safe and secure CCAM for all types of traffic situations and roads.
Validation of CCAM systems	Higher level of automation, in particular in mixed traffic situations requires scenario-based validation and verification of the vehicle and its operation in the intended ODD to ensure safety, reliability and security. Within this context virtual, physical and hybrid approaches are needed allowing a cost-effective, reproducible and interchangeable validation of individual components and software as well as of the vehicle automation functions, including the underlying safety concept. Common methodologies and tools are needed to define the validation and verification requirements as well as the orchestration of the required tests including the derivation of representative scenarios and tests. This includes the development of a standardised, virtual simulation environment, dedicated hardware and physical infrastructure for testing. Attention needs to be given to the validation of self-learning systems as well, as their properties are principally dynamic and will change with time and with increasing experience on the road. Recommendations for a common framework for harmonisation, standardisation and homologation need to be elaborated on the basis of a common understanding of the required safety, reliability and security of CCAM.
Human-Machine interaction and interface design	Continue research and international standardization work on design strategies for in-vehicle input, in-vehicle interface with driver, output devices and actuators as well as on how to interact with surrounding road users (VRU, people in adjacent vehicles, police, etc). Consider different design strategies depending on road type, ODD, vehicle type etc. Ensure wider range of user groups (e.g. children, elderly, disabled people) especially when designing for mobility services. Ensure continued research and proof of concepts (PoC) on driver state assessment methods and technologies. Develop solutions to handle humans unfit to resume control. Develop training and information campaigns for users and general public which can complement intuitive vehicle designs. Continue work on developing proper HMI testing procedures, methods and tools which include both strict experimental set-ups as well as more naturalistic ones.
Remote operation and	When a CCAM vehicle is not able to continue operation without human intervention, remote operation and monitoring of related telematics can be useful to re-initiate safe operation. In this specific

R&I action area	Description
surveillance	situation safety, security and cybersecurity are critical. In addition, remote surveillance or user monitoring can be useful for safe system operation. This facilitates management of emergency situations, remote assistance for passengers, and supervision of the Quality Of Service. While enabling this functionality through connectivity, it is important not to change the safe system functioning and ensure minimal risk for users and other traffic participants. Therefore, the remote operation or surveillance should only be possible through the specific mode foreseen for this purpose by the manufacturer. This mode of operation should not alter any legal provisions and liability.
Physical and digital infrastructure (PDI)	Research and innovation on physical infrastructure (markings, road signs, layout, etc.) and digital infrastructure (digitised spatial network and regulations, communication technology, road-side sensors, HD maps integrating static and dynamic data, etc.) and operational (traffic management of the mobility network etc.) to support CCAM and ways to ensure how the transition can be made in the most efficient and cost-effective manner. Research on business and financing models, policy options and ways to increase competencies and resources for road authorities (and/or operators) to ensure, that the physical, digital and operational infrastructure remains fit for purpose. Achieve common understanding of the role of PDI for CCAM and specifications of required infrastructure.
Connectivity / cooperative systems	The main objective is to secure effective connectivity for the needs of CCAM. Ensure robustness and redundancy, availability of communication channels (network coverage) and a minimum quality of service (QoS) especially for higher levels of automation. For safety critical applications of CCAM, the performance and resilience of connectivity is essential. Create trust among the different entities exchanging information. Assess the performance from an end-to-end perspective in real-world driving conditions and in hybrid communication environments, safeguard fail-safe operation, appropriate degradation, privacy protection and end-to-end security. Ensure interoperability between all involved actors (vehicles, infrastructure, road users, road/fleet operators, public authorities, etc.), develop standardised C-ITS messages and message sets (e.g. for manoeuvres) and test EU-wide interoperability and compatibility.
Artificial Intelligence (AI)	Develop explainable concepts, techniques and models of Artificial Intelligence (AI) for CCAM. Huge amounts of in-vehicle and infrastructure-based sensor data together with other data sources will be used to 'train' AI algorithms. This development process is accelerated and supported through harmonization, availability, quality assurance, interoperability and exploitation of relevant data. However, a variety of challenges must be tackled: e.g. industrialisation, requirement-based development, continuous improvement of trained modules for application in safety critical domains and the verification

R&I action area	Description
	and certification of AI for automated driving functions.
Fleet and (mixed) Traffic Management	Integrate (shared) automated vehicle systems in existing traffic, with conventional vehicles and on existing roads. Integrate (shared) automated services in fleet and traffic management systems. This requires to reach agreements on targets and roles within the mobility system among multiple stakeholders, as well as research on a multitude of aspects, e.g. simulation and big data analysis, impacts on operations and users, total system effects, infrastructure needs, etc. Test new options and governance models to operate shared automated mobility systems as part of real-life fleet and traffic management systems. Guidance for authorities (e.g. local, regional, national, port, EU-wide) to prepare and plan for CCAM services.
Develop and demonstrate shared automated mobility solutions	Understand user acceptance and requirements of smart, shared, automated mobility solutions and foster the development of technologies and business models, in particular to encourage shared mobility, including proven and tested stimulation methods (like incentives, regulations and taxation schemes). This may include the design of a code of behaviour in driverless vehicles as well as widely acceptable access regulations. Provide appropriate living-labs to analyse public acceptance of CCAM in real-world conditions while offering stakeholders with the opportunity to innovate, propose, test, and improve high value mobility services for the benefit of the end-users and the overall community. Large-scale demonstrations shall increase the scalability of demonstrations of advanced shared automated mobility solutions to pre-deployment in more complex ODDs in urban, peri-urban and rural environments. Demonstrations will show efficient ways to integrate shared mobility solutions using CCAM vehicles into the transport system. Demonstrations will facilitate the uptake of new business models. They will demonstrate inclusive shared automated mobility solutions, in particular for users with special needs (such as disabled, elderly) and for Mobility White Spots, where other public transport is not economically viable.
Large-scale demonstration of highly automated passenger vehicles	Large-scale pilots and field operational trials (FOT) will ensure safety, provide valuable insights in the abilities of automated driving systems (ADS) and their current limitations. Large-scale pilots with prototype vehicles provide data for verifying and validating ADS ensuring safety and reliability before market introduction. Demonstrations with small series production passenger vehicles (i.e. FOTs) will raise user awareness, help assess the impact on society and accelerate implementation. For these FOTs, “Living Labs” provide the infrastructure (including connectivity), mixed dynamic traffic environments and user communities. The coordination of Living Labs for ADS is important to foster harmonization and interoperability and support cross-border functionality all over Europe. The network of large-scale pilots will boost knowledge acquisition through

R&I action area	Description
	harmonised data/scenario exchange. Improvements of operation efficiency in urban, sub-urban environment and smaller villages and for human-machine interaction will be assessed. Public and private stakeholder collaboration will be fostered to achieve common objectives and assess societal impact.
Large-scale demonstration pilots of automated commercial / freight vehicles	Large-scale demonstration pilots and pre-deployment (e.g. FOTs) activities will deliver evidence for quantifiable freight transport objectives such as increased freight transport efficiency, improved road infrastructure utilization, reduced energy consumption, increased safety, and improved working environment. Large-scale demonstration pilots will also prepare for deployment of connected automated commercial freight vehicles in mixed traffic with different type of vehicles of various automation levels. Early involvement of different freight logistics stakeholders such as; shippers, port, terminal, road infrastructure authorities, forwarders, truck OEMs, trailer and load-carrier manufacturers will identify opportunities and obstacles. New operational and business-models will be developed, tested and evaluated through logistics operational pilots in a "European logistics living lab" for integration into a global logistics context and to strengthen European competitiveness to pave the way for innovative concepts and new products and services.
Societal needs analysis	Analyse user requirements, expectations and concerns related to the use of connected, cooperative and automated driving technologies and systems in their broadest sense (e.g. interaction with the system, trust, liability, ethical issues, privacy concerns, security, minimum safety and performance standards, etc.). Particular attention will be given to the requirements of users in need of special attention (e.g. disabled, elderly people, children). Assess the impacts of higher degrees of automation and digitalisation in road transport on qualifications and licencing of the different actors involved in the mobility system. Examples include that vehicle drivers may turn more into operators, and traffic management may include more control tower elements. Analyse requirements for new competences and qualification principles. Develop updated education and licencing procedures and requirements, and define principles for their interaction with the new and fast changing framework conditions and technological evolutions of CCAM.
Socio-economic and environmental impact analysis	Assess the short, medium and long term impacts, benefits and costs of connected, cooperative and highly automated driving systems (in all areas) considering the full range of impacts including, but not limited to, driver behaviour, mobility behaviour, accessibility, safety, traffic efficiency, emissions, energy consumption, use of resources, impact on transport market, impact on employment and working conditions, required skills, infrastructure wear and land use. Conduct comprehensive cost / benefit analyses and projections of the overall

R&I action area	Description
	investment requirements, vehicle equipment costs, operating costs and environmental costs (including life cycle analyses of the systems) of large-scale CCAM deployment, in exchange for expected targets for road-safety, traffic efficiency, health and pollution, affordability for users, and inclusiveness, so as to direct development policies towards the most appropriate economic, social and environmental needs.
Strategic European agenda for R&I and large-scale testing	Develop and continuously update a clear long-term European agenda for research & innovation and large-scale testing activities, making sure that investments at European, national and local levels, both of public and private nature, are complementing each other towards systemic and interoperable solutions for a fully integrated European mobility system.
European frame-work for testing on public roads	Beyond validation and verification of the vehicle functions in confined areas, large scale testing on European level is needed to better understand the road user and driver behaviour as well as the ODD, including connectivity. Both are needed, on the one hand as input to the scenario-based vehicle validation, and on the other hand for evaluating the impact of CCAM in mix traffic scenarios (e.g. safety and energy consumption, reduction of congestions, environmental impact, etc.). To foster and enable such testing, a European framework to allow testing on public roads is needed, including different road categories, cross-border traffic and addressing all types of vehicles. It should allow to analyse and to demonstrate the performance, reliability, safety, security and robustness of CCAM including the fail-safe and fault-tolerant functioning in varying mixed traffic scenarios. Within the framework for testing, obligations on a common methodology for conducting and evaluating those field operational tests needs to be included as well as on a harmonised ontology for data handling and storage (taking privacy and cyber security aspects in account). The framework must ensure safe testing, before a comprehensive vehicle validation procedure is in place.
Data exchange framework	The effectiveness of large-scale testing in Europe can be largely increased by a more systematic exchange of experiences, test results and test data. Based on the work of the CCAM platform, the European partnership will establish a data exchange framework and a common evaluation methodology to improve cooperation and make better use of the results of all testing activities in Europe. Key objectives will be to ensure provision of high quality and well documented datasets, co-operate on a technical reference platform with other data sharing initiatives, encourage data re-use and establish win-win situations and keep the balance between privacy / IPR and availability.
EU-wide knowledge base, including	Establish and maintain the existing web-based Knowledge Base centralising information about stakeholders, R&I programmes and projects and testing activities in the field of CCAM in Europe and

R&I action area	Description
common scenario database	worldwide. Extend the Knowledge Base by providing more information about national, international CCAM activities, standards, testing methodologies, common scenario database, lessons learned.
Common evaluation framework	Develop and support coordinated and harmonised approaches to assess impacts of CCAM technologies and systems. Common evaluation framework for large-scale demonstration pilots in Europe to allow comparability of results, complementing evaluations and meta-analysis over multiple evaluation studies.
Data storage and sharing	*Develop a harmonised approach for data sharing based on open and interoperable programming interfaces (APIs) and access control by defined user rights. It shall focus on the data value chains, data storage needs and the related standards or data formats and related infrastructure. Provide a secure system architecture and comply with data security and cybersecurity requirements while allowing access to in-vehicle real-time data and resources (to be specified), as needed, to be exposed on-board and/or remotely, to all authorized service and application providers, in a context of innovation, open access, cross-industry interoperability, choice and portability of services for the user, price affordability, and competitiveness, while also allowing to third parties the maintenance, repair, and improvement of vehicles throughout their lifecycle. (to be finalised)*
Workforce development	Assess the impacts of higher degrees of automation and digitalisation in road transport on the future workforce (including job location, working environment, working times, needs for new skills, education and training). Analyse requirements for new workforce competences. Define policies for labour market incentives and ways to adapt workforce development and value chains to new and fast changing framework conditions and technological evolutions of CCAM.

WG 1 had its last meeting on 04 May 2020. Afterwards the CCAM Partnership took over to prepare the Strategic Research and Innovation Agenda with the goal to present a final draft in June 2020.

4.2.2. Partnership proposal (May 2020):

The proposed Partnership aims to harmonise European R&I efforts to accelerate the implementation of innovative CCAM technologies and services. It aims to exploit the full systemic benefits of new mobility solutions enabled by CCAM: increased safety, reduced environmental impacts, and inclusiveness. By bringing together the actors of the complex cross-sectoral value chain, the Partnership will work on a shared, coherent and long-term R&I agenda. It means that the European Partnership is open to all those stakeholders representing industry, public authorities, research and users and to international cooperation. The Vision of the Partnership is: “European leadership in safe and sustainable road transport through automation”.

The Partnership proposal described the portfolio of the Partnership. The R&I activities will be the value creating core of the Partnership activity portfolio, feeding into Deployment Readiness activities, leading to Large scale demonstrations for a new mobility system, but also for freight and conventional passenger mobility. Additionally, the portfolio will also deliver clear and objective-oriented coordination as well as systematic evaluation on social aspects and user acceptance. Moreover, the Partnership will support necessary activities outside the Partnership for a successful Deployment Readiness strategy, which are:

- Harmonisation and certification, which are key enablers for wide deployment and implementation of CCAM enabled mobility solutions;
- Technical standardisation to support European industrial leadership and highest possible efficiency of solutions.

For a better understanding of the envisioned portfolio of activities and its interactions, the Partnership is structured in seven CCAM Clusters:

Cluster 1: Large-scale demonstration
Cluster 2: In-vehicle technologies
Cluster 3: Validation
Cluster 4: Integrating the vehicle in the transport system
Cluster 5: Key enabling technologies
Cluster 6: Social aspects and user acceptance
Cluster 7: Coordination Each CCAM cluster provides the elements for the SRIA roadmap

Each CCAM cluster provides the elements for the SRIA roadmap with a brief description of the scope, the link and interface to other European Partnership activities as relevant for CCAM, and the actions towards standardisation, regulatory bodies or policy alignment.

A key part of this document is the definition of 7 clusters, the definition of related R&I actions, the link to other European partnerships. The SRIA is an important annex to the partnership proposal and identifies the foreseen portfolio of activities (outcomes, deliverables and milestones within a specific timeframe) of the partnership. The SRIA is a precondition to launch a European Partnership.

The proposal detailed also the necessary resources, the governance and the rules of openness and transparency.

The proposal should lead to a Memorandum of Understanding to be signed in Q2 2021 between the partners.

4.2.3. The Strategic Research and Innovation Agenda (June 2020)

Elaborating on the Partnership proposal, the draft proposal of the SRIA has been finalized in June and published 1st July 2020.

It focusses on:
- the further development of the framework of objectives and portfolio activities ventilated through the clusters to establish a logical link between the operational, specific and general objectives and to address the problem drivers for the CCAM deployment;
- and on the resources needed to achieve them, notably those from the side of the partners.

It also developed a proper monitoring framework that allows to monitor progress of (transformative) policy interventions towards the achievement of specific objectives, that also allows to anticipate changes. Implementation related aspects have been streamlined/ harmonised across initiatives to ensure comparability across initiatives and to simplify.

5. Detailed report of Working Group 2 "Coordination and Cooperation of R&I activities":

5.1. Scope and objectives

Testing of cooperative, connected and automated mobility is essential for further technology development, for assessing safety and performance of technologies, to anticipate user and customer expectations and to analyse the impact on society. Many diverse tests are ongoing across Europe and coordination is needed for synergies between tests.

Thus, WG2, coordination & cooperation of R&I and testing activities, had the following scope and objectives:

- Set up a **Knowledge Base** to gather and exchange experiences, best practices and knowledge on pilots, demonstrations and large-scale trials.
- Develop a **common evaluation methodology** to allow for comparison of results between tests. This includes establishing key performance indicators and a common framework for the assessments of impacts.
- Develop a common **test data sharing framework** for sharing of lessons learnt and test data arising in the context of large-scale demonstrations, taking into account already available approaches like the Data Sharing Framework made by the FOT-Net Data project.

WG2 met 8 times between June 2019 and December 2020. In addition, 4 expert workshops were held to prepare the discussions in the working group on the common evaluation methodology and the test data sharing framework.

The next sections will go deeper into these three topics and also describe the links between the topics, and the links between the work in WG2 and other WGs.

5.2. Knowledge base

5.2.1. Context and relevance of the Knowledge Base

Many R&I and testing activities have taken place over the last decades and many are on-going or in the planning stages. When coordinating such activities and setting up cooperations, it is important to be aware of what has already been done and what the results were of earlier testing activities. This is why a knowledge base has been developed, which is an instrument to gather and exchange experiences, best practices and knowledge on pilots, demonstrations and large-scale trials. The current CCAM Knowledge Base can be accessed at:

https://knowledge-base.connectedautomateddriving.eu/

5.2.2. Key challenges and actions regarding the Knowledge Base

The Knowledge Base comprises information that is categorised in several ways. Information can be found on several thematic areas (e.g. Policy and regulatory needs, European harmonisation; In-vehicle technology enablers) and R&I projects. There are sections on the FESTA Handbook and Guidelines and evaluation methodologies. There is a section on strategies and action plans and a section on data sharing. Also, a glossary can be found in the Knowledge Base, as well as a list of relevant events and FAQ. The key challenge for filling and maintaining the Knowledge Base is to organise that content is added and updated and that quality checks of the material are carried out, as the aim is to maintain the Knowledge Base for a long period, certainly beyond the time horizon of this WG.

Keywords have been added to the information in the Knowledge Base. It remains a challenge to use them in such a way that balance is maintained between too broad or too specific keywords, so that users can search for relevant information via those keywords. Having a good and user friendly search function is essential for the Knowledge Base.

5.2.3. Priorities and methods

The Knowledge Base has been set up by the Coordination & Support Action (CSA) ARCADE. In general, stakeholders need to add content, such as project information and keywords for projects, and give feedback on what is already available and on the structure of the Knowledge Base. The WG also discussed whether the Knowledge Base provides useful and appropriate information. Periodically, WG participants have been asked to provide specific input on what information is lacking or needs updating, on the keywords, on whether the right keywords have been assigned to projects, on whether all relevant roadmaps have been included.

5.3. Common evaluation methodology

5.3.1. Context and relevance of the common evaluation methodology

The desire for a common evaluation methodology stems from the need to be able to compare evaluation results from various tests and projects, allow for complementing evaluations and meta-analysis over multiple evaluation studies and assess impacts of deploying CCAM technologies and systems, including on the systems level. Several tried-and-tested methodologies are available – new projects should know about these and do not have to start from scratch. Therefore, it is valuable to make the current collective knowledge and experience available and accessible.

5.3.2. Key challenges and actions regarding the common evaluation methodology

The aim is to develop a common evaluation methodology. The WG has discussed the scope of this common evaluation methodology and agreed on what it will be used for, keeping in mind the underlying policy goals for implementing CCAM and what areas of evaluation these methods need to cover (e.g. which impacts, which geographical scale, which timescale, etc.). This depends on the scope of a project/test and should enable deriving conclusions on a systems level, taking into account the multiple cross effects at a local, national and international level, and the technical limitations of the systems.

There will always be a need to tailor the common evaluation methodology to the specific needs of a project or test. Following that, there will be a need for an approach for updating the common methodology according to the experiences gained and for feeding these updates into the Knowledge Base.

Other topics discussed include issues encountered with current evaluation methodologies or the lack of a common methodology, as well as issues expected regarding the way in which projects will be asked or encouraged to use the common evaluation methodology and if support is needed (from specific research support actions).

It will be very difficult to develop a methodology that is both all-encompassing, covering the complete spectrum of potential evaluation topics and sufficiently tailor-made for the specific project the evaluation is intended for. How to find the right balance between being complete and targeted will be a main challenge to develop a useful methodology.

Currently available methodologies

The Knowledge Base already has a dedicated section[11] covering the main methodologies (described below) as well as the most relevant project deliverables.

The **FESTA Handbook**, which provides methodologies to set up and execute Field Operational Test (FOT), applicable for also other type of field tests. The Knowledge Base includes a section called the Automated Driving Testing and Evaluation Materials Toolkit, which has links to documentation for each FESTA section.

Impact Assessment Frameworks for Connected and Automated Driving:

- The **Trilateral Impact Assessment Framework for Automation in Road Transportation** (EU–US–Japan cooperation). This a high-level framework to support harmonisation across the three regions. This framework includes recommendations and advice on the classification of evaluated systems or services, a description of 12 impact areas[12], impact mechanisms & paths, recommendations for experimental procedures and for data sharing, and commonly used KPIs.
- The **C-Roads evaluation plan**, which helps to harmonise evaluation activities related to C-ITS deployments.
- Practical methodologies have been developed in projects such as AdaptIVe, L3Pilot, Headstart, SAM and Levitate (see Figure 1) which provide additional insight in how the guidelines can be applied in specific contexts.

The FOT-Net Wiki and Catalogues, which give information on past Field Operational Tests and their tools and provides a common basis for evaluation and assessment of pilots.

5.3.3. Priorities and methods

WG2 organised two preparatory workshops on 16 and 31 March 2020 to get a comprehensive overview of evaluation initiatives that are available in the EU and prepare a first possible set-up for the European Common Evaluation Methodology (EU-CEM).

The objective of this first session was to discuss the possible scope of EU-CEM, potential strengths and weaknesses of such an approach, and gaps in knowledge/expertise for developing it. In the second session, the suitability of the current methodology pages and its contents were reviewed, and a first outline of EU-CEM was discussed, which was subsequently updated.

The envisioned EU-CEM consists of several elements (see figure 1):

1. Collective knowledge and experience

[11] https://knowledge-base.connectedautomateddriving.eu/methodology/

[12] These impact areas are: (1) user; (2) vehicle operations; (3) safety; (4) energy/environment; (5) personal mobility; (6) cost; (7) network efficiency; (8) travel behaviour; (9) asset management; (10) public health; (11) land use; (12) socio-economic impacts.

2. Lessons learned, relevant for evaluation
3. Guide for setting up new evaluations
4. Support team to help setting up new evaluations

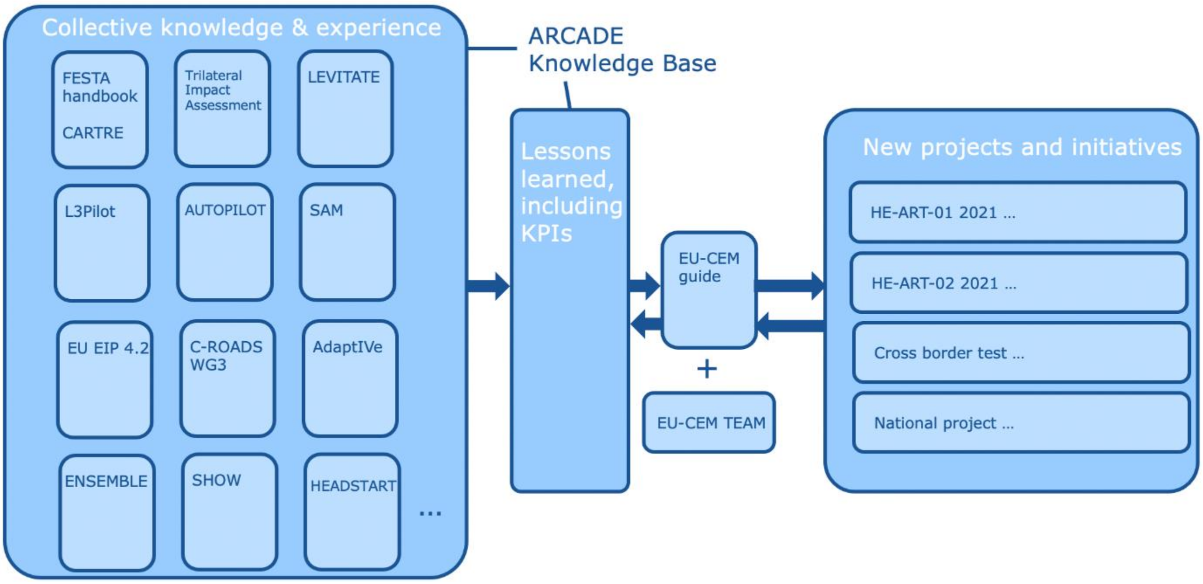


Figure 1: European Common Evaluation Methodology (EU-CEM)

Collective knowledge and experience from past and ongoing projects and initiatives is available and accessible at the Knowledge Base (as currently developed and maintained by ARCADE. This consists of a collection of specifically developed instruments (e.g. FESTA handbook, Trilateral Impact Assessment methodology) and deliverables from projects, describing evaluation approaches. The aim here is to be as complete and actual as possible and therefore it needs to be frequently updated.

When setting up an evaluation plan for a new or recently started project or initiative, it is useful to build upon such collective knowledge without having to go through all the deliverables to find out what's relevant for the project in mind. Therefore, a general collection of lessons learned (including what worked and what didn't work in projects completed) would be more practical to consult. Preferably these lessons learned are hosted at the same Knowledge Base and compiled (and updated after a project is finished) by a support team, to ensure expert knowledge and to lessen the burden on the project's capacity. However, due to the broad spectrum of projects and initiatives this could still amount to a large collection of information.

The central idea is to develop a set of guidelines to enable the setting up of an evaluation plan for new projects, initiatives or tests, whether they are EU projects in the new framework (Horizon Europe), or international or national tests or initiatives. This set of guidelines can be seen as a compact handbook that on the one hand takes full advantage of the (ever increasing) collective knowledge and experience that is available and on the other hand allows for the tailor-made approach that a specific project needs. Such a EU-CEM guide should be used for new EU funded projects.

By no means could the envisioned EU-CEM guide, in the hands of a novel user, substitute for the necessary knowledge and expertise to set up an adequate evaluation plan. Setting up an evaluation plan for a new project is time-consuming and requires specific knowhow which is not easy to acquire. Therefore it is deemed valuable to establish a support team that can facilitate this process, potentially funded as part of an action under Horizon Europe.

The described European Common Evaluation Methodology is not static and needs to be updated continuously. The frequency of doing this depends on the rhythm of relevant projects (methodology development takes place at the start, while deliverables and lessons learned become available at the end) rather than an annual or biannual cycle.

5.4. Test data sharing framework

5.4.1. Context and relevance of the test data sharing framework

Test data sharing is an important issue within and between projects. During the course of a project, large amounts of test data are collected, processed and analysed to arrive at information that is needed for policy making and investment decisions. How can large amounts of data be collected and stored securely, and under which conditions can the data be shared with others? These questions arise not only during a project, but are also relevant for the period after the project, when further analyses with the data are foreseen.

5.4.2. Key challenges and actions regarding the test data sharing framework

There are several key challenges regarding test data sharing:

- Test data sharing at the operational level: which data needs to be shared to ensure optimal working of a functionality?
- Data sharing for evaluation purposes: how to organise this in an efficient manner?
- How to deal with personal data (in particular video footage & exchange across organisations or borders) included in databases?
- Annotation of test data with metadata for future analyses: which metadata are needed?
- Size of the database needed: how to organize storage and usage during the project, how to keep the database up and running after the project ends, cost & ownership of the database, etc.
- Maintenance of the database: how to keep it up-to-date and accessible.

WG2 has worked towards a proposal for an open EU database with edge cases (starting with cases and data from current and recent EU-projects) with a common data format. The L3Pilot project common data format could be a good starting point for the common data format.

5.4.3. Priorities and methods

A pragmatic approach to come to a proposal for a European database of edge cases was proposed: hold workshops to discuss a possible common methodology to document these edge cases. This requires looking at it from different perspectives, from different stakeholders – OEMs, authorities, etc. To start up this process, a similar approach as for the Common Evaluation Methodology was used, that is to first have discussions in a small group. Two workshops were organised, on the 27th of May and 9th of June 2020, to discuss how to develop a European Test Data Sharing Framework including a Database of Edge Cases. The results were discussed in the WG.

In the first workshop, practical experiences from L3Pilot, SAFER and Vicomtech were shared, and a discussion was held, structured around three questions:

- What practical experience do you have in test data sharing?
- Which data needs to be shared? And which not?
- How could we set up an edge case database?

In the second workshop, it was discussed how to develop a European Test Data Sharing Framework (EU-TDSF). This concerned the possible scope of the EU-TDSF as well as a first outline of it.

Several trade-offs need to be addressed in the EU-TDSF:

- Level of detail; raw data vs aggregated data.
- Level of maintenance; amount of data vs costs.
- Level of sensitivity; closed / proprietary vs open / less sensitive.
- Level of anonymization.
- Level of accessibility; during and after project (scientific best practice).
- Level of purpose; directly linked to research questions (within project or test) vs reusability (for other research questions emerging during or after project or test or developing functions).

As was said during the discussions: “Data collection in general is not the issue, but hosting it with an adequate level of detail and keeping it accessible with the right amount of context is”

The envisioned EU-TDSF should contain several elements and consider various requirements:

- There needs to be a balance between having a strong relation between research questions and test data, versus a good reusability of test data for other research questions after the finish of the project or test.
- Also, a balance between usability of the test data and agreed upon aggregation level needs to be defined.
- The framework should use categories of data (e.g. linked to EU-CEM impact areas).
- The question of which level of context and (relevant) metadata, is needed, and whether a “context-person” is needed beyond available documentation should be addressed.
- The minimum level of test data sharing should be set, but the question is how and by whom can requirements be set?
- The question whether there should be a clause in the model contract to keep data for a specified time period needs to be addressed.

The EU-TDSF should clearly distinguish between sharing test data and sharing (operational) data for CCAM services. A (minimum) requirement on (new) projects could be set, and there could be a charter in the CCAM partnership for data sharing principles.

Also, it should be discussed how to keep data relevant and/or accessible after the completion of a project. This concerns for instance the difficulties that arise from the fact that different project participants hold the data, for different purposes, and it is difficult to reach the right people after completion of the project. Without proper explanation/guidance of the data there is a risk that data is reused/interpreted in an incorrect way.

Within a project there can be agreements on IPR and proper reuse of data. It is, however, difficult to foresee reuse after/outside the project or define a harmonized approach for this. Data quality standards and definitions (if possible based on existing standards) are needed to create trust in test data. A question that needs to be addressed is: Should there be requirements on projects? For instance, should it be mandatory to register data at the end of the project on data.europe.eu? Should the partnership agree on common principles for test data sharing?

It would be pragmatic and useful to collect edge cases, because they are rare (and a subset of a larger scenario database), and starting with edge cases was considered to have added value. The question is to what extent current and upcoming projects can contribute (e.g. L3Pilot, ENSEMBLE, SHOW, AWARD, Hi-Drive). It was proposed to have a trusted third party (or parties), to collect and build such an EU database with edge cases (EU-DEC).

The described elements and requirements for both the European Test Data Sharing Framework and Database of Edge Cases should lead to uniform versions that are not static and need to be updated continuously. The frequency of doing this depends on the rhythm of relevant projects rather than an annual or biannual cycle.

5.5. Recommendations

WG2 recommends that the work on the Knowledge Base, the Common Evaluation Methodology and the Test Data Sharing Framework is continued in a coordinated manner by the whole CCAM community. This is also reflected in the latest draft of the strategic research and innovation agenda of the **CCAM Partnership**[13], which brings all three topics together under **cluster 7: coordination**. This should lead to a common and comprehensive R&I action under the Horizon Europe Working Programme 2021.

To ensure effective coordination and data exchange between ongoing projects and all upcoming projects under the CCAM Partnership from the start, it is important to **ensure progress** is made on these topics before the launch of this new action. Therefore WG2 recommends that:

- **Work on the Knowledge Base is continued and intensified under the ARCADE CSA**, and strongly encourages stakeholders to contribute results from all relevant CCAM actions (also going beyond Horizon 2020) in a timely and proactive manner to the Knowledge Base.
- **Work on the Common Evaluation Methodology and the Test Data Sharing Framework is continued**, where feasible and relevant, under the current and upcoming demonstration projects under Horizon Europe (e.g. L3Pilot, ENSEMBLE, SHOW, AWARD, Hi-Drive).
- The outcomes of these actions are reflected in the further updates of the strategic research and innovation agenda, the proposals for research topics and the stakeholder engagement activities of the CCAM Partnership.

[13] Version 2 November 2020 : https://www.ertrac.org/uploads/images/CCAM%20Partnership%20SRIA%20v1.0%2002-11-2020.pdf

6. Detailed Report on Working Group 3 "Physical and Digital road Infrastrcuture":

6.1. Definition of the WG3 scope and goals (Road Infrastructure)

Road infrastructure can crucially enhance the performance and the availability of advanced driver assistance systems and connected driving use cases.

The main goal of WG3 was to identify how can physical infrastructure advancements support CCAM, and which are the improvements to road infrastructure that will be necessary to enable the above-mentioned mobility transformation, including meeting the requirements of the ODD, with a focus on SAE L4 Automated Vehicles (AV). This target will be achieved by reaching higher levels of Infrastructure Support for Automated Driving (ISAD), and in particular by identifying the appropriate levels to match the ODD of increasingly automated AV.

The support of infrastructure to CCAM must consider and include the following key dimensions:

- Physical infrastructure: characterised among others by road signs, road markings or communication interfaces that are a part of the physical world where vehicles operate;
- Digital infrastructure: comprising mostly, but not only, the static and dynamic digital representations of the physical world with which AVs interact and including additional types of information such as C-ITS, traffic rules, etc.

These dimensions play a central role in CCAM. For instance, an increasing digitalisation of road infrastructure shall help connected and automated vehicles to understand their surroundings and will connect them to dynamic traffic management procedures. At the same time, high-quality physical infrastructure will always be important to ensure that safety is safeguarded. All in all, vehicles should be able to use these dimensions in an integrated way, and there should be consistency among their contribution to CCAM solutions: for example, one can estimate that it will be necessary to maintain a high quality standard for the digital representation of the infrastructure (and, more broadly, of the traffic status), both in terms of accuracy and of timeliness of updates to that representation; one can also already consider that it will be necessary to have a communication infrastructure which supports infrastructure to vehicle (I2V) communication of live data.

It can also be expected that the interplay among those dimensions of road infrastructure, and between those and the vehicle, will enable new CCAM solutions, e.g. by extending the interaction between the autonomous vehicle and road infrastructure, allowing a more efficient traffic management and/or incident management, which in turn should lead to reduced fatalities, respectively increased road safety.

Developing such solutions will also require a closer collaboration between many public and private entities, including notably OEM, road authorities and operators.

6.2. The work of WG3

At the September and October 2019 meetings of WG3, participants started exploring the possibility of defining the contribution of road infrastructure to CCAM in terms of ISAD (Infrastructure Support to Automated Driving) levels.

To achieve this, it was decided to define the building blocks that contribute to each of those levels, and to bridge the perspective of stakeholders responsible for infrastructure with the one of stakeholders responsible for connected automated vehicles.

However, from an early state it was apparent that ISAD levels and SAE levels are not equivalent. Furthermore, despite the fact there was a broad recognition that PDI (Physical and Digital road Infrastructure) plays a key role in supporting CCAM, there was a variety of different views about which are exactly the PDI elements AVs really need to expand their ODD. All these elements posed challenges to building meaningful ISAD levels and, more fundamentally, to clarify (and reach an understanding on) which are the adjustments that might be needed to PDI to make it suitable, not only for automated driving, but more broadly to enable the realisation of CCAM.

In this context, it was decided within WG3 to start by addressing these information mismatches and to carry out an exercise where participants (road operators, OEM, NGOs focused on safety, local authorities, map providers, etc.) shared the lists of PDI elements (and their attributes) they take as a reference. Crossing those lists aimed at reaching a consolidated list comprising all relevant elements/attributes, ensuring not only that participants "speak the same language", but also that there is an agreed basis for further work. Most notably the list should serve following purposes:

- To assist in identifying potential areas for research and innovation in CCAM, and eventually in prioritising those (for instance, depending on whether they can more easily, quickly or unexpensively assist the extension or seamlessness of ODD).
- To assist in identifying policy actions other than R&I, and eventually in prioritising those as well (e.g., proposing standardisation and/or harmonisation, or using the list as a reference for exchanging best practices).
- More broadly, the list could also help better understand what is (or could be) the role of road infrastructure in supporting CCAM – which is the overarching mission of WG3.

6.3. The draft list of road infrastructure elements/features and their attributes

The first draft of a comprehensive list of road infrastructure elements/features and their attributes was presented at the January 2020 meeting of WG3. The exercise attempted at that time to establish a reliable catalogue of road infrastructure elements.

In building the list, we start by trying to answer the following question: when a vehicle is travelling in a given road segment, what elements of the road infrastructure are relevant for the vehicle? What functionalities or services does the infrastructure make available to the vehicle and/or its driver?

Naturally, the focus was on (the contribution of infrastructure to) realising CCAM, taking into account that different use cases, automation levels and models of mobility might require/dispense different infrastructure functionalities and services, and that it is not possible to foresee all configurations that co-operative mobility will have in the future.

6.3.1. *The methodology followed*

The approach consisted of the following:

- WG3 considered the basic structure for the list referred to the one of the physical (e.g. EuroRAP[14]) and digital infrastructure attributes from EU EIP[15] and MANTRA[16].
- WG3 looked "critically" into it, especially at the organisation of the various categories and their content. We further detailed some elements, while we discard others.
- WG3 tried to integrate all contributions received into that structure, even contributions containing lists of "what AVs expect". We tried to re-write those as functionalities that can be provided by the road infrastructure.
- WG3 tended to replace some terms with broader alternatives and to re-employ others with different meanings.
- The lists were completed and organised also taking into account some literature on the role of road infrastructure in CCAM.
- To the extent possible, WG3 tried to list groups of attributes according to some criteria: for example, the physical infrastructure elements were ranked in increasing detail (road-carriageway – lane – shoulder – etc…) and decreasing degree of "physicality" or "permanence" (road signs – road users – events and behaviours), and the digital and operational elements were listed in layers (positioning and the information system first, as these feed HD maps, and as HD maps can be a tool for traffic management, etc….)

6.3.2. *The outcome*

The preliminary outcome of this exercise was a list containing **physical** and **digital** elements of the road infrastructure. To these we added also the **"operational infrastructure"**, following the proposal contained in Amditis et al (2019)[17] and presented to WG3. One of the major advantages of including the operational infrastructure was that it works as a reminder that elements such as traffic management also characterise what kind of services/functionalities a vehicle can benefit from when circulating on a specific road segment. This means that, while the chapter on "digital and physical infrastructure" of the C-ITS Platform Phase II Final Report is a key reference to the work of WG3, the same should apply to the chapter dedicated to "Enhanced Traffic Management"[18].

---

[14] https://www.irap.org/methodology/

[15] Amelink, M. et al. (2020), Road map and action plan to facilitate automated driving on TEN road network – version 2020, EU EIP Sub-act. 4.2, Deliverable Task 3, www.its-platform.eu.

[16] Kulmala, R.. et al. (2020), Road map for developing road operator core business utilizing connectivity and automation, MANTRA Deliverable D5.2, https://www.cedr.eu/strategic-plan-tasks/research/call-2017/call-2017-automation/

[17] Amelink, M. et al. (2020), Road map and action plan to facilitate automated driving on TEN road network – version 2020, EU EIP Sub-act. 4.2, Deliverable Task 3, www.its-platform.eu.

[17] Kulmala, R.. et al. (2020), Road map for developing road operator core business utilising connectivity and automation, MANTRA Deliverable D5.2, https://www.cedr.eu/strategic-plan-tasks/research/call-2017/call-2017-automation/

[18] https://ec.europa.eu/transport/sites/transport/files/2017-09-c-its-platform-final-report.pdf. Also to be noted that the traffic management dimension is not an explicit attribution of other WGs within the CCAM Single Platform.

Some participants considered that there was no need to separate **physical and digital** elements. We have nevertheless kept them separated, even if we recognised that most elements can actually have a physical *and* a digital representation (e.g., infrastructure maintenance and traffic management (can) engage processes which are both), and even if there are some “indivisibilities” (e.g., some physical infrastructure elements exist to enable/support the digital part, and vice-versa). We proceeded this way for convenience – to have lists of a more manageable size – but also to trigger a discussion about whether the digital infrastructure is merely a mirror of the physical one. Ultimately, it could have been useful to check if all digital elements have (or should have) a physical correspondence (or vice-versa), and assess if it is recommended, necessary or even feasible to have such a bi-univocal correspondence between both dimensions.

As regards the **digital and operational** dimensions, we have chosen not to present them in separate sheets. Firstly, because there is a continuum between both – one which future R&I might even reinforce (e.g., HD maps assuming some functions or including some attributes “traditionally” expected from traffic management). Secondly, because there are multiple loops between both (for instance, we could imagine that the traffic management processes, which operates on the basis of what the information system provides, allows to produce historic data on traffic flows which will feed back into the information system).

Finally, the “overview” and the “digital and operational” lists include a reference to **electronic communications**. These have been included in the list (but in a separate sub-list) as they are part of the EU EIP – MANTRA contribution, and several other contributions received make reference to these as well. Despite this, the WG3 understands that identifying the electronic communication networks infrastructure, its characteristics and its roles in CCAM is not a priority matter for WG3, but for other WGs of the CCAM Platform.

The PDI attribute list is subject to update and improvement depending on the interpretation of the records themselves. For instance, some elements might show up in more than one of the sub-lists. Furthermore, some classifications of infrastructure elements might overlap. For example, lane markings can be categorised according to their quality (e.g. visibility and meeting requirements of existing standards) and characteristics (width, length, density of the paint, …) but they can also be categorised according to their readability, which in turn might depend on the kind of sensor used; while both perspectives should eventually converge, the decision-making by a road operator might be shaped in one way (the physical characteristics of a marking including also the quality) or another (one where the “demand side” dictates the action taken).

Below you can find a screenshot of the present status of the PDI attribute list.

List of road infrastructure elements/features and their attributes			
Physical road Infrastructure elements/features and their attributes	Road details and context, including road topology and geometry		
	Road type		
	Carriageways		
	Lanes		
	Other areas dedicated to automated vehicles (aside from lanes)		
	Pavement of road		
	Shoulder or kerb / roadside		
	Other road marking		
	Intersections and connections		
	Area		
	Traffic signs, including traffic lights		
	Road furniture		
	Road users, including vulnerable road users		
	Driving conditions, including traffic regulations		
	Environment/weather		
	Changes to the status of the road		
	Aggregate (higher-level) indicators or quality indicators		
	Infrastructure maintenance		
	Physical infrastructure elements assisting/enabling the digital infrastructure		
		Physical insfrastructure providing/supporting positioning, including satellite positioning	
		Physical insfrastructure supporting traffic management, information on traffic rules, ..	
Digital and operational infrastructure elements/features and their attributes	Positioning (digital elements)		
	Information system, covering static and dynamic elements		
		Information on the road network, its physical attributes, links...	
		Digital traffic rules and regulations	
		Availability of physical infrastructure	
		Real-time events, roadworks, incidents and other information of disturbances	
		Information on weather conditions	
		Geofencing information	
		Traffic performance status on road network (historic and/or real-time information)	
	HD map (covers/does not cover specific elements; quality and detail of the map)		
		Maps of the road environment	
		Visual representation of the real-time information on the traffic flows	
		Routing advice, including the timing of alternatives	
	Traffic management		
		Traffic management centre and processes	
		Management of road works, queues, other changes in infrastructure status	
			(1) providing information/warnings to Avs
			(2) reccomendations and instructions
		ODD management (management of factors affecting the ODDs of vehicles using the roads)	
	Fleet management and supervision		
		ODD management (management of factors affecting the ODDs of vehicles using the roads)	
		Fleet supervision: monitoring and supervision centres	
Electronic communications network infrastucture	Short-range V2I		
	Medium and long-range V2I		
	Broadcast communication (DAB, FM)		
	I2C		
	...		

6.4. Defining a matrix: methodology and main steps

After agreement was reached on a streamlined list of the various PDI elements/attributes (one which allows for filtering according to some criteria), this list should become useable to prioritise among elements/attributes and to identify R&I needs or other policy actions.

To reach this goal, it became clear that we first need to map the expectations from both infrastructure owners and vehicle manufacturers and get a better understanding of how the infrastructure really supports cooperative, connected and automated mobility. That means linking the PDI attributes with their support function, more particularly from a vehicle point of view.

After some work and reflection, WG3 concluded that prioritising PDI elements according to their support to specific use cases might not be the most appropriate way to proceed with the exercise, since no agreed list of use cases exists, nor is it possible to cover the wide variety in the Operational Design Domains, which depend on the local implementation of a specific use case.

On 29 June 2020 WG3 decided to continue developing the matrix idea in a subgroup with experts from the OEM and the infrastructure communities and then to converge to a common comprehension and definition of the priority matrix attributes. The subgroup met many times on an almost bi-monthly basis since then.

The criteria for **deciding which elements/attributes** should require priority, and which are the preferred actions/solutions relating to them, included the following:

- the relevance of the attribute in identified edge cases, i.e. the road sections where there are gaps in the ODD (example: concentrating on a specific type of intersection or on a given road geometry where incidents involving AV tend to occur more frequently, or where take over control (ToC) tends to be more frequent).

- the relative speed of development and implementation of such an improvement/innovation;

- whether the attribute has a direct link to road safety (i.e. whether improvements/innovations to it have proven benefits in terms of safety) and in particular crash modification factors (CMF)[19] whether the descriptive road attributes influence the likelihood and severity of the most common types of serious crashes for AV occupants and their relations to other users such as motorcyclists, pedestrians and bicyclists (i.e. whether improvements/innovations to it have proven benefits in terms of safety)[20]. The SLAIN CEF project will provide a current state of the art and future recommendations.

- whether the attribute is most likely to contribute to a co-operative model (e.g., enabling information flows in both directions between the infrastructure and the vehicles). This criterion embodies the vision of WG3 on CCAM – to explore not only what PDI can do for the AV, but also what the AV can "give back" to the PDI (e.g., data from AVs can contribute to real time traffic management (AVs can inform the traffic manager of abnormal traffic or weather situations, as if they were "mobile radars") and road maintenance.

The WG further decided to replace uses cases by generic driving tasks (Sensing & Perception, planning and actuation) and subtasks:

- Sensing & Perception
    - ego localisation
    - environmental awareness (object classification and incident detection)
    - enhanced perception (for limited visibility scenarios)
- Planning
    - (dynamic) information and regulations

[19] A crash modification factor (CMF) is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site http://www.cmfclearinghouse.org
[20] https://eurorap.org/slain-project/

  - safe and appropriate navigation plans
  - cooperative planning
- Actuation
  - Motion control (longitudinal and lateral)
  - Minimum Risk Manoeuvre

These driving tasks form the columns of the matrix and have been marked in yellow.

Driving tasks & ADS functions							
Sensing & Perception			Planning			Actuation	
Ego localisation	Environmental awareness (object classification & incident detection)	Enhanced perception (limited visibility scenarios)	(dynamic) information and regulations	Safe and appropriate navigation plans	Cooperative planning	Motion control (*longitudinal & lateral*)	**Minimum Risk Manoeuvre (ToC/MRM)** MRM save stop is ultima ratio and can happen anywhere

Physical and digital attributes form the rows of the matrix and have been marked in green. In the December 2020 meeting it was noted that the Matrix focussed primarily on the HD map and digital twins. For CCAM however, cooperation with the infrastructure is more than having access to a digital twin and particularly C-ITS is a key enabler.

To make this distinction clearer the group marked digital twins attributes in yellow and C-ITS services in blue. In several cases attributes could be classified as being both part of the digital twin and the subject of a C-ITS service. This should not come as a surprise as C-ITS is of course one of the means to deliver and update / maintain the digital twin. The reason it is highlighted in this table (compared to for example Variable Message Signs) is its ability to go beyond delivering the digital twin, more particularly its low latency and single trust domain allow a level of cooperation between the road users and infrastructure that is clearly beyond the digital twin and might not even have a related physical road infrastructure attribute. In the latter case it is marked blue, when C-ITS is only a means of delivery for the digital twin it is marked yellow and when C-ITS exists alongside the digital twin and provides more detailed or more timely information a yellow-blue gradient is used.

For this exercise the number of rows was reduced (compared to the full attribute list established earlier) as the goal was to better map its relations with basic driving tasks. For this it made sense to group attributes that have the same support function. Once support needs or priorities are well understood, one of course would go back to the exhaustive attribute list and evaluate the different options available for implementation, which will likely differ depending on local circumstances and were not part of the analysis in WG3.

Legend	digital twin of physical attribute
	C-ITS
Physical attribute (equivalent)	**Digital attribute (equivalent)**
RSU	Immediate collision warnings or Event, incident and other hazardous location information with C-ITS message (DENM)
Road Works (with possible RSU e.g. at road works trailer)	Roadworks information (stationary and mobile) with e.g. map information in HD map or C-ITS message (MAP) local warning with DENM about RWW. TPEG2-TEC dynamic data.

Next the matrix needed filling to capture the support function of the PDI. Through various iterations and discussions it was agreed to get to the essence of the support function, meaning that we needed to avoid repetition of a similar support function in the various columns corresponding to different driving tasks. When carefully considering we could often limit the support function to a specific (or at least very limited combination of) driving task(s).

Oversimplifying but useful for getting to grips with this exercise we can see that:

- The PDI mainly plays a role in the sensing and perception tasks of CCAM vehicles. An accurate and timely updated digital twin can offer major support to understanding the vehicle surroundings and traffic situation. C-ITS can further enhance this, by directly linking the PDI and CCAM vehicles in real-time, offering information otherwise not available (e.g. line of sight limitations of vehicle-based sensors) or not part of the traditional digital twin (e.g. collective perception messages based on roadside radars).

- The PDI also plays a big role in the planning part, CCAM vehicles can plan upfront based on known limitations of certain routes but also need to adapt to dynamically changing situations. In the latter case C-ITS can play a major role (e.g. dynamically changing direction of travel) and evolve to cooperative planning (e.g. adapting driving speed to traffic light information).

- The PDI has little to no role in the actuation task of the CCAM vehicle. This is of course related to the fact that vehicles need to function safely at all times. That means they need to be able to take all relevant decisions themselves (contrary to for example automated metro lines). Remote operation could be an exception but even that is today not considered to intervene in the actuation task but in the planning task (e.g. remote approving of a vehicle-planned manoeuvre or temporary violation of traffic rules).

Furthermore, for each attribute, the WG decided to define, when possible, recommendations in terms of investments (priority, nature, frequency, pertinence), taking into account two types of priority actions:

- **Maintenance** or **upgrading (Road sections)** of the physical and/or digital road infrastructure elements/attributes, which are key to support CCAM, **by using currently available technologies** (e.g. improving geo-fencing or using extra lanes or dedicated lanes during rush hour might facilitate the introduction of AVs without implying R&I).
- **Additional research and innovation** in certain cases to reach a specific level of performance of the PDI elements, enable new functionalities, and/or to develop new services.

Choices in upgrading or innovating in existing road sections can follow different criteria than investing in new roads or road sections: indeed, even when changes to existing physical infrastructure might be costly, the construction and design of new roads could consider suitability for CCAM from the start.

Following different criteria can point towards different choices between investing in physical elements and attributes or in digital/operational ones: for example, while in general digital and operational infrastructure might be updated and harmonised more easily than the physical one, an optimised mix of both kinds of elements/attributes will be most suitable to support CCAM solutions, as interactions between them are strong.

Finally, it is worth stressing again that some redundancy (and hence investing in multiple road elements at the same time) might be needed to maximise road safety when increasing levels of automation and an increased complexity of the interplay among vehicles, and between these and infrastructure.

The WG also analysed the pertinence of each attribute according to relevant circumstances and environment. It appears that it is not necessarily useful to have all attributes everywhere and for all kind of road or vehicles.

Finally the Group decided to point out **which added value and usefulness each attribute could bring to automated vehicles and to human operated vehicles and general traffic safety.**

		red: my notes 29.3.		Added value and usefulness to	
Physical attribute (equivalent)	Digital attribute (equivalent)	recommendation for investments:	relevant circumstances / environments	Automated vehicles	Human-operated vehicles / general traffic safety
	ODD/ISAD management information, element in HD map like (dynamic) geofences or archieved trought active transmission of C-ITS messages	To be deployed only when main stakehodlers (OEMs, ADS developers and road operators) agree on the matter	To be agreed by the major stakeholders	Essential for management of AV fleets	Not very useful
	Vehicle and fleet supervision with operator in control center	Deployment or purchase of service where and when appropriate; low priority in general but high priority for specific services when deployed	likely needed for robot taxi and shuttle services	Essential for the safe management of AV fleets and MRMs	Not very useful
	non-road elements in HD Map	in addition to digital twin of the physical road network: digital waypoint map (same level of information as in C-ITS MAP), AD vehicles require add. Info compared to digital twin on HD	~~emergency stop bay, road construction ramps, unclear exits~~	Essential for sensing and planning, reliable navigation, differentiate position of VRU's to be in conflicting	Useful in enabling various services, reliable navigation, differentiate position of VRU's to conflicting or

6.5. First results and recommendations

The matrix (cf. Annex) now consists of a streamlined list of attributes reduced to 29 elements, 19 of them being considered digital twins, 6 coming under C-ITS and 4 being a mix. Though the group believes the current matrix can be a useful tool in further advancing understanding on how PDI and vehicles can work together, thus guiding towards the most efficient ways to enable highly automated mobility services, it is also recognized that more work is needed. Nevertheless, several recommendations linked to the matrix can be formulated, often building on and confirming past conclusions. Notably the recommendations can be split into more general aspects of the PDI investments and those that play a key role in addressing specific and challenging traffic situations. The latter confirming the strategy of focussing on edge cases as a way to link easier sections into larger operational design domains.

In terms of general recommendations about digital support for CCAM, WG3 proposes the following:

- Investments in digital and operational infrastructure should increasingly complement and strengthen investments in physical infrastructure. In the long term this might even reduce the necessary investments in physical infrastructure. This should not be seen as an alternative or plea for reduced investments in physical infrastructure, quite the contrary, investments in high-quality transport infrastructure are very much needed, both to increase road safety and address the negative impact of congestion. The recommendation is that **within an overall**

increase of investments for transport infrastructure the share of digital and operational increases as well.

- The former is particularly true for investments in new infrastructure. Completing the digital infrastructure, as in a high-quality digital twin of all infrastructure, complemented by cooperative intelligent transport systems in relevant areas, will take time. Setting up the necessary process to keep it up-to-date will too. There are today however no reasons why investments in new infrastructure would not be accompanied by the matching digital infrastructure. In other words, **investments in new transport infrastructure should always include the relevant digital components.**

- As the transition phase will be long, mixed traffic will exist for multiple decades, infrastructure improvements that also benefit other road users will make for a much better return on investment. Hence, to make tangible progress early on, as well as prepare for a rapid deployment of automated mobility services, one should **prioritize investments that benefit both human driven and automated vehicles**.
- Digital infrastructure already enables dynamic traffic management today. For example, variable message signs are used for dynamic setting of speed limits or direction of travel. When available, **this information should be replicated in the digital twin (e.g. via a National Access Point)**, making it available for HD maps, **as well as being shared through C-ITS messages**, reducing latency and creating redundancy. **The relevant public authority (local, regional or national) should take responsibility for all representations of PDI data in equal manner**.
- To maximise its potential in supporting CCAM, the digital and operational infrastructure needs to be reliable, up to date, trusted and secure. Though particularly for C-ITS some of these elements are already addressed the recommendation remains that **digital infrastructure needs to fully embrace functional safety**.

The WG also formulated recommendations related to specific and challenging situations. A common element in all of them is the use of connectivity and particularly C-ITS to enhance cooperation between infrastructure and vehicle, helping the latter deal with the challenge efficiently.

- **Road works remain a major challenge**. During construction reduced speed limits and alternative lanes, often with reduced width and mixed with normal lane marking, pose great difficulty to automated vehicles (as well as human drivers). Guiding automated vehicles through road works zones requires accurate representation of these areas in the PDI. For stationary road works that means they are available in the HD map and through both C-ITS and legacy systems (DAB broadcast, TPEG, FM broadcast, VMS). For mobile road works C-ITS systems are particularly useful, alongside legacy systems, and moving roadworks should be equipped with C-ITS communication. Such **digital investments for road works will not only address a key edge case for CCAM but also improve safety of road workers and human drivers**.

- **Complex intersections and crossings pose another major challenge**. An obstructed view of traffic lights or Vulnerable Road Users (VRU), or the presence of emergency vehicles could further complicate the situation. Both CCAM and human-driven vehicles would benefit greatly from C-ITS, which can address all challenges in such situations. C-ITS removes the line-of-sight problem and creates redundancy (e.g. signal phases being available visually and digitally). Existing C-ITS SPaT and MAP based services can be expanded with Collective Perception. In other words, **complex intersections should be equipped with C-ITS, supporting and improving safety of all road users, including CCAM vehicles, human-driven vehicles and vulnerable road users**.

- **Some areas** pose particular challenges to ego-localisation, such as **underground parkings or urban canyons**, or to bridging locations with limited availability of GNSS signals, such as tunnels. **Investments in digital infrastructure can help to establish an initial position or maintain accurate positioning when GNSS signals cannot be received**.

6.6. What comes next

The work of the WG3 for phase one will end with the proposed PDI attribute matrix and the formulated recommendations. Participants of WG3 are welcome to participate to the upcoming CCAM Partnership and especially to the work of Cluster 4. The research and innovation projects in this Cluster will advance the physical and digital infrastructure support for CCAM vehicles and improve connectivity and cooperation between actors, which will support the integration of CCAM vehicles in the overall transport system so that fleet and traffic management systems can be enhanced. First calls will be launched in June 2021.

7. DETAILED REPORT ON WORKING GROUP 4 "ROAD SAFETY":

7.1. Definition of the WG4 scope and goals

The main goals of WG4 was to answer following questions:

1. **What are the recent or current activities on road testing and pre-deployment relating to road safety?**
   a. How can the results of these activities be used to identify best practices for the safe transition to higher levels of automation (mixed traffic, interaction with other road users, platooning)?
   b. What were the lessons learnt with these road testing and pre-deployment activities that could be useful towards a common safety assessment methodology for CAVs and road infrastructure that take into account acceptable behaviour (especially in mixed traffic)?
   c. Which gaps were identified with these road testing and pre-deployment activities?

2. **Which road safety gaps would benefit from testing and large-scale testing activities, e.g. which pre-normative activities, standards or technical road safety specifications?**

For instance, testing and pre-deployment could be used to identify the need for reviewing relevant road safety-related legislation or international traffic conventions (e.g. legislation on driving licences, roadworthiness, training of professional drivers and driving times).

3. **Which road safety legal issues are affecting the road testing and pre-deployment of CCAM, such as national traffic rules and/or vehicle legislation?**
   a. How could these be addressed in the context of projects?
   b. For example, by coordinating or harmonizing the safety rules to facilitate cross-border testing in Europe?

These questions are relevant in establishing road exemption procedures for CCAM testing and for developing regulation or certification to allow pre-deployment of CCAM.

The group focus on safety elements related to the vehicle itself, improvement to safety linked to the infrastructure and to the connectivity were shared with (respectively) working group 3 and working group 5 (or 6).

7.2. CCAM Platform WG4 Member Consultation

Road safety is achieved by a proper combination of factors that include adequate CCAM technologies, traffic regulations, type approval process, public education, driver training, among others. This means that different stakeholders need to be involved, which has been the purpose of WG4 Road Safety.

The following list of stakeholders have been identified.

Large scale CCAM safety testing stakeholders	Safe insertion of automated vehicles in mixed traffic stakeholders	Stimulating testing and pre-deployment of CCAMs stakeholders
Road-side system owners, landowners	Road infrastructure operators	National, regional and city government
Back-office owners	Road type approval agencies	Private actors
Traffic management centers	Road infrastructure operators	Road authorities, road operators
OEMs, TIERs	Road authorities	
CCAM service providers	Service providers	
Road-exception authorities	Insurers	
Cities, municipalities, regions	Entities in charge of driver training and assessment	
Road operators	Research community	
Research community	Cities	
Emergency services	Public transport operators	
Enforcement agencies (e.g., the police)		
The public		
CCAM-related ICT providers		
Legislative bodies		
Road-side system owners, landowners		

7.2.1. Scope of the testing activities targeted by the recommendation

It is a major challenge to define how to assess the safety of CCAM given the number of vehicle systems, operational driving domain, interaction with other road users and impact on traffic they can have.

Based on the ERTRAC and STRIA roadmaps, the results from GEAR 2030 and the Guidelines for the EU approval of autonomous vehicles, combined with the discussions in the WG4 meetings, key challenges were identified considering both the system components and their interaction with the users. Annexe (**Error! Reference source not found.**) presents a parallel approach of participants of the WG4, tightly linked on ERTRAC work highlighting lesson learnt and research needs.

On this basis, three main use cases for CCAM were identified by the WG4 partners:

- Motorway applications
- Shuttles applications in urban environments
- Platooning applications

The assurance of safe testing during pre-deployment poses different challenges. For *testing during the R&D stage* it is assumed that the vehicles on public roads are operated by expert drivers that have to meet specific requirements, while in *the stage of pre-deployment* non-expert drivers would be involved. In this phase simulators play an important role since they enable involvement of non-experienced drivers without compromising safety. This means that the safety requirements of pre-deployment are different from those from R&D testing.

7.2.2. *WG4 statement on "What has been learnt?" and "what are the safety gap identified"*

From the question presented for the scope and goals of WG4, the group came to the following conclusions:

What has been learnt?

Although there are many research projects, **most of them are still going on** (InteractiVe, AdaptIVe, SCOOP, C-ROAD, SLAIN, SAM, L3Pilot, Ensemble).

- They are being run with different vehicles (cars, truck platooning, automated/buses and shuttles, small urban goods delivery vehicle robots; and
- covers different ODD (highway, parking lots, urban settings, building sites, confined areas).

There is a strong **research focus on**

- Technology: functionality of AD systems/AV, interactions AVs and other road users,
- Driver behaviour, (safety) driver readiness, HMI. Adaptation/acceptance, trust.
- Impact assessment on road safety, efficiency, connectivity issues, testing methodology.
- More focus on automation than on connected; and even less focus on cooperative. More focus on vehicles than "Mobility".

Examples of lessons learnt

- The impact of CCAM on traffic safety occurs through a diversity of complex mechanisms; (no "one-fit-all" simple answer);
- Infrastructure can be an enabler for AVs, but for a large ODD it is necessary for the AV to coexist with the existing infrastructure;
- The use case selection orients the whole project;
- The methodology to study acceptability of autonomous vehicles;
- Cumulated experience with identifying and handling safety and risk stations for automation shuttles and specific hazard for low speed automated buses/shuttles;
- Initial assessment methodology for safety performance for select AV functions;
- Each ODD may need different requirements for open road testing;

Road safety for R&I and testing

WG4 aligned with the conclusion from WG1 and by extension supported the initiative for the topic of road safety in the CCAM partnership under Horizon Europe

Research gaps on technology

Following gaps have been identified:

Safety and reliability of AD functions.

- Further define acceptable risk levels (ex: safety assurance, validation) and assessment methods
- Definition/determination of "safe behaviour" for an automated driving system (in expected and unexpected scenarios).
- Tests in real conditions to develop roadworthiness and system reliability (AI, sensors, etc… especially in adverse environmental conditions)
- Connectivity/road infrastructure support/limits for AD.
- Review crash worthiness needs for AD

Interaction with the driver:

- Measurement of situational awareness. Trust in the AD system vs overreliance
- What is the preferred state and how can drivers be kept in this state? Do drivers need training on AD systems?
- Competences and performance needed: ex. appropriate transition demand time
- Potential degradation of driver capabilities, Driver training, public education

Interaction with passengers:

- Monitoring of passengers needed?
- Need for access rules and regulations for the use of driverless vehicles?

Interaction with other road users:

- Non-automated vehicles, Vulnerable users, Emergency services: Each type may require specific AV behaviour.
- Handling extreme dangerous behaviour (ex. crossing suddenly in front an AV)
- External HMI (only for the police?), is it needed? To signal what? Automated mode?
- Acceptability of AVs by other road users and society in general.
- How will automation affect scenarios related to safety? (Anticipation based on pre-deployment activities).
- Adaptation of traffic rules and regulations
- Adapt the current road infrastructure to support CCAMs (ex. traffic signs/rules, infrastructure sensors, V2X definitions as discussed in WG3),
- Raise knowledge and awareness build-up in municipalities, cities, regions through testing to encourage policy driven demand of CCAM solutions.
- Develop through testing harmonized pan-EU standards for V2I, I2V, and safety-related communications to support CCAMs and ensure interoperability. (WG3 and WG6)
- Develop through testing pan-EN catalogue of road markings, etc. for testing. (Pan-EU standards seem very ambitious.) (WG3)
- Determine how to assign liability.
- Effects of modal split in traffic safety

These recommendations have fueled the discussion on the priorities for research in the next Horizon Europe programme and its possible future CCAM partnership.

7.2.3. *Recommendations concerning on the legal framework for on road experimentations*

One of the main concerns among the WG4 partners was the establishment of actions to support the safe introduction of CCAVs for testing and pre-deployment activities.

The current situation is that there is a large variety in regulations between EU member states, as well as the requirements for road experimentations. An overview of the current regulation for on-road experimentations can be found on the website of connected and automate driving that has been established by EU project ARCADE[21]. The national regulations generally have in common that the following information should be provided:

- The applicant (e.g. contacts, insurance).
- The driver / steward (e.g. understanding of the system).
- The vehicle (e.g. description, meeting applicable standards).
- The infrastructure / Operational Domain (e.g. needed for the test).
- Behaviour (e.g. what driving tasks are automated and need to be tested).
- Documentation (e.g. Function description, Hazard analysis & Risk assessment, Electro-Magnetic Compatibility (EMC)).
- Results of admittance testing (e.g. safe operation, including stress testing).
- Results of the field operational tests (e.g. logbooks, evaluation).

The way this information needs to be provided is not harmonised between member states.

From the discussions with the stakeholders it can be concluded that the reuse and acceptance of documentation and test results from one member state in other member states would be first the step towards EU wide approval of automated vehicle trials. This would support the request from stakeholders simplify admittance procedures for trials with automated vehicles across Europe.

Regarding the registration process, WG4 has collected and compared the registration process in the different Member States and neighbour Countries, this work will is still in progress.

➢ For the registration, a distinction may be made between early testing on research prototype vehicles, large-scale testing of near-to-market vehicles and pre-deployment trials. Early research prototypes usually involve several improvement cycles between tests, and hence registration processes can result in considerable overhead. In order to assure the possibility to develop and test innovative CCAM functionalities within the framework of R&D projects, the registration process for research prototypes should be flexible to allow testing of specific scenarios in controlled conditions and having safety driver.

[21] https://knowledge-base.connectedautomateddriving.eu/regulation-and-policies/national-level/eu/

To reach this objective various recommendations are derived from the discussions, they are presented by topics.

The **function description** is always required in Europe, with many common features already shared between all countries:

- A description of what function is intended to be tested (and why necessarily on public road)
- A description of the modifications to the vehicle (if based on type-approved vehicle)

Questionnaire are used in Sweden and France. WG4 proposes to use or combine the questionnaires to create a template for any function description for testing in EU:

- Will the vehicle be modified in relation to the approval rules for this category? (if so, describe these changes.)
- Does the vehicle have specific warning devices or specific lights?
  - In the case of a modified approved vehicle, specify whether the vehicle will have specific warning devices;
  - In the case of an unapproved vehicle, a description of the audible warning devices which it will have at its disposal;
  - In the case of an electric vehicle, specify whether it will have a courtesy call in order to signal its presence
- In what form(s) does the term vehicle(s) with partial or total delegation of driving appear in the vehicle? (specify location, size, format, etc.)

The **open road experimentation description** is always required in Europe, with many common features already shared between all countries:

- trip – area
- Number of vehicle
- What is tested (precisely)
- Description / Declaration / interview (NL) of: Type of road to be used (urban area / motorway / …)
- Any specific infrastructure requirements that are considered necessary within the framework of the tests, including traffic signals, will need to be put in place as agreed with the road authority/authorities
- Duration
- other relevant information

The agreement of local authorities of where the experimentation is taking place is needed. Information is provided to road managers. Only elements that are described in the documentation form are part of the authorisation.

The **risk analysis** is always required in Europe, with many common features already shared between all countries:

- Relevant risk have been identified (e.g. fits with the planned ODD for experimentation)
- Measures are taken to minimise the risk during the on-road test
- The vehicles goes into a safe state in case of error
- Electro Magnetic Compatibility (EMC) and Cybersecurity risks. Compliance to International standards/regulation can be used for this purpose (not mandatory).

A questionnaire can be used for template. WG4 proposed to consider the questionnaire from France:

- How did you analyse the safety/cyber security risks? (specify the method used)
- Has the risk analysis been carried out by a certified body? (if yes, please specify)
- What are the main risks associated with this experiment? (list and describe)
- What measures have been put in place to limit these risks? (list and describe)
- What are the procedures for detecting, analysing and handling incidents? (type of corrective measures in place, etc.)
- What system of registration of safety/security events, as well as continuous improvement strategy, have you implemented? (specify)
- Standards can be used for this purpose (e.g.: Failure Modes and Effects Analysis (FMEA) or the functional safety standard ISO 26262) – not Mandatory

Transition of control / activation and de-activation: The current situation is varied and is still evolving. In Denmark and France the responsibility of the autonomous function is on the safety driver, and turn off button are often required (FR, NL, DK, FI, BE) and/or override possibility (SE, ES, FI). Transition demand and/or minimum risk manoeuvre are required in the Netherlands and in Denmark. Requirement for the system to turn-off itself can be required to be described (DK, FI) or let to the operator's responsibility (AT). WG4 recommends to develop methods for objective assessment of driver-vehicle interaction considering transition of control driver override or intervention, activation/de-activation principles etc.

- It can be optional with a safety driver (it is the human responsibility);
- Every member states require a turn off button and/or an override strategy;
- If available, describe the transition demand and minimum risk manoeuver strategy of the vehicle – keep in mind to provide an intuitive HMI and focus on minimising risks.

Remote control operation is currently extremely rare in Europe, it is not possible in many countries (HU, DE, BE, AT), limited to safety driver in line of sight (SE) and authorised with safety driver out of sight of the test vehicle in Denmark and for a few exceptions (DE-Stuttgart, FR-Chateauroux and NL-Rotterdam).

Data recorder is required for accident reconstruction, but also may be asked to record specific KPIs (for example in US the intervention by the safety driver).

- For accident reconstruction:
  - The recommendation from the EU guidelines (from 23 to 27), are recommended – installation, liability, resistance for fire and high acceleration.
  - The recording time should be at least 5 minutes before the crash(base on France requirement, but it can be higher in Hungary it is 1 hour before and 1 minute after)
  - The minimum dataset is recommended to be: speed, relative position of the vehicle, level of automation, takeover time and time limit (based on requirement from France).
- Other events:
  - WG4 does not recommend (yet) other event to be recorded.
  - Reporting requirement may directly influence the data to be recorded, it can be case by case and used to demonstrate what has been learned during the test.

Authorities check / Third Party check:

- Documentation
  - The check is based on the risk analysis (derived from the documentation provided by the manufacturer)
  - A similar dossier is asked in every Member States, WG4 harmonised template is available in Annexe (separated document from this report). The annex is complimentary to the national document required.
- Test track
  - Can be done by the manufacturer or the authority (NL)
  - Particularly to demonstrate that safety critical risks are managed.
  - (ex: if safety driver necessary, it shall ensure that a test driver or test manager can take manual control of the vehicle from the automated driving mode in order to ensure the necessary safety during testing)
  - Can test of subcategories of ODD (e.g roundabout, crossing, etc)
- Local elements
  - There is always an on-road testing for trip approval (with local authorities).
  - For shuttles (possibly robotaxi) we recommend a test on-trip without passengers before 1st operation

The **operational conditions** collected in Europe are already aligned, as follow:

- The vehicle shall be insured
- Contact details of the applicants shall be provided.
- Ownership information of the vehicle shall identify all parties liable
- A trained driver/supervisor with experience in handling risky situation is required.
- The test vehicle shall meet the local rules
- The vehicle shall meet local rules for identification (licence plate, test plate, AV indicators)
- The vehicle shall not cause crashes

The **reporting** elements are aligned in principle but not clearly listed throughout Europe. WG4 proposes the following list of reporting elements:

- Reporting on the results of the experimentation shall be made at the end of the experimentation (ex: errors encountered, software update)
- Purpose of the reporting must be clarified.
- (ex: overall performance of the vehicle? Handling liability issues? …)
- Any accident shall be reported
- A log must saved (duration TBD) and available upon request

A strong follow-up recommended will be to prepare a common layout to be used in Europe

Traffic rules: All countries in Europe require compliance to traffic rules and local/implicit traffic rules. To assess it, it is needed to develop tests/methods based the target location considering the safety of automated driving trials that will be used to demonstrate the compliance to general traffic rules and local traffic rules.

- Propositions: Extend the concept of Operational Driving Domain (ODD) by considering local traffic rules and expected interaction with other road users, e.g. categorised for different road environments (urban, motorway, etc.), or road sections (e.g. roundabout, crossing, etc).
- This recommendation is suited for track test and simulation
- Local traffic rules are always confirmed locally during the road test of the trip
- Please note that a safety driver is always required

Build-in self tests are indicators implemented for the purpose of reporting, they will be used to demonstrate the absence of failure (or adapted intervention, and correct software or hardware update following the incident). They are currently required by few countries (HU, FR) and required (in HU) to give information when the test driver shall act (in case of failure with visual and audio warnings) when testing with road traffic

7.2.4. Recommendation implementation – national experts suggestions

Sweden national expert recommend that technical regulations should be written in a neutral form, be general and functional and not detailed.
However, Sweden also recognize the use of specific and detailed technical and functional rules when needed from a safety perspective, especially when technical solutions should be an enabler of the desired and decided functionality of the automated vehicle and when the functionality need to be described in metrics e.g. meters, seconds, speed, retardation etc.

Sweden has a restrictive stance of policy towards specific rules and regulations towards automated vehicles, they support to use rules that are common both for conventional and automated vehicles, acknowledging that automated vehicles will need some special rules but minimise the use of these.

Finally, future EU regulatory effort in this area must correspond to what will be decided within UNECE WP.1 and WP.29.

In Spain, since 2015, a specific allowance is offered for AVs applications already approved in another Member States. It is expressed as follow:

> 1 - REQUIREMENTS FOR OBTAINING AUTHORIZATION TO UNDERTAKE AUTOMATED VEHICLE TESTING.
> […]
> Requirements for the automated vehicle:
> […]
>
> - To ensure the maturity, safety and reliability of the automated driving systems, the automated vehicle owner must prove:
>   […]
>   2- That the competent authority of another Member State of the European Union has issued, through an equivalent prior control procedure, authorization to conduct tests on roads open to general traffic to automated vehicles with technologies and configurations of the same nature.

This text means that the technical assessment is not necessary (as long as a certificate is delivered by the Member State and deemed equivalent), but the administrative part is still required to allow testing in Spain.

In the Netherlands, the “Assessment framework” (version 03.07.2017 – 1.4 EN) also include a similar entry on foreign exemption, in part “3.2. Safety”:

> - **Vehicle with a foreign exemption**
>   A previously granted licence in other countries can be used to demonstrate safety. This on the condition of applicability to the application document of the test application and clear and qualitative documentation.

7.2.5. Horizontal cross WG issues

Safety assessment should be done on the whole system, not only the vehicle (or vehicle group in case of a platooning) but also the infrastructure (WG3) and communication & services (WG6). The cyber aspects (WG5) are relevant for vehicle integrity and overall safety of the system and should also be considered.

The developments within this working group will provide input to the research and innovation agenda of WG2. The deployment agenda of WG1 will furthermore set the timing of the needed developments, as well as define the stakeholder partnerships needed.

7.2.6. CCAM partnership topics

The CCAM partnership, under Horizon Europe, refers directly to the conclusions from different groups of the CCAM platform.

- The gap analysis recommendations will contribute to the topic of "Reliable vehicle technologies ensuring the safety of highly automated vehicles"; and

The legal framework recommendation will contribute to the *"Harmonised conditions and processes for tests of CCAM systems on public roads, including criteria for a mutual recognition of procedures*" for the topic of "Coordination of CCAM demonstrations in Europe".

8. DETAILED REPORT OF WORKING GROUP 5 “ACCESS TO AND EXCHANGE OF DATA & CYBERSECURITY”

8.1. Definition of the WG5 theme

The focus of WG5 was on how testing and pre-deployment activities can be used to develop cybersecurity and access to in-vehicle data, without prejudice to regulatory activities, in particular in the field of vehicle type approval, road worthiness and ITS. WG5 aimed at promoting collaboration between the various actors to ensure high quality standards and accuracy of data, and compliance with the General Data protection Regulation and the Regulation on Free flow of Non-personal Data.

WG5’s task was to identify how testing and pre-deployment activities can be used to:

- identify **learnings to ensure security** of cooperative connected and automated vehicles against cyber threats for car manufacturers and other actors of the smart mobility ecosystem by taking into account the vulnerabilities and technology robustness level of partially or/and fully automated and connected systems, as well as procedures for reporting cyber incidents.
- identify **how secure access to, and secure exchange of, vehicle and infrastructure data (including instructions) have been and may be facilitated** over the full lifecycle of the components of the ecosystem through testing and pre-deployment activities.
- to find a **common understanding for addressing technical and legal issues that are relevant for the access, transfer, sharing, use and storage of data**, including the use of data by artificial intelligence solutions
- WG5 focusses on V(=automotive vehicles)to X(anything)[22].

To ease the discussion on cybersecurity and data access for CCAM, the following definitions for the concept of connected mobility, cooperative mobility and automated mobility have been used:

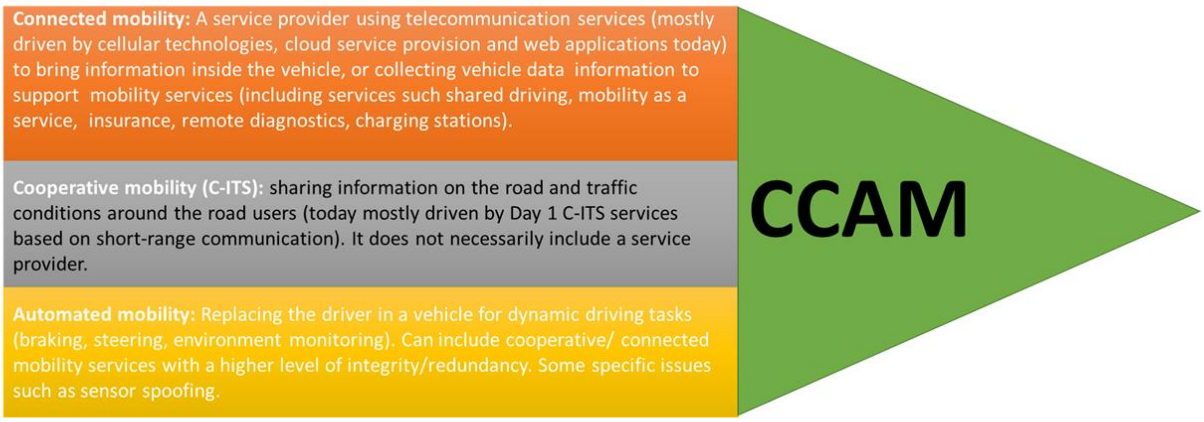


Figure 1 short summary of CCAM

[22] We focus on public roads. It is worthwhile to evaluate the “private road domain’’ for additional learnings.

8.2. The process followed by WG5

From November 2019 to December 2020 several WG5 meetings were held to discuss intermediate results with the members. Next to these joint WG5 meeting a small preparatory group of WG5 volunteers prepared the materials that were discussed at the WG5 meetings. Together with the preparatory group the contractor made an inventory of relative actions and projects addressing CCAM that were active in March 2020. Also the outline of the scoping report was presented to WG5 Plenary Meeting on the 24th of June 2020. The feedback and comments were consequently used for producing the draft scoping paper that was elucidated in the Plenary Meeting on October 15, 2020. The comments on the scoping paper from that meeting were used to create this document.

8.3. Gap analysis

Based on the project inventory of running CCAM projects and operational systems, selected by the EU, the learnings in the field cybersecurity were extracted on the basis of the reference models described in figure 1 above. We observe that:

- Solutions have to be compliant with applicable national and European regulations including ePrivacy, GDPR and telecom regulations. In addition vehicles will have to be protected against cyberattacks from July 2022 in accordance with Regulation (EU) 2019/2144 on Vehicle general safety and UN/ECE Regulation No. 155 on cybersecurity. The UN/ECE Regulation does not prescribe any technical solutions and does not include in its scope data access rights or interoperability issues. Standards have also been developed (cybersecurity[23], extended vehicle concept[24], C-ITS, etc.).
- In the Connected Mobility Domain, most of the solutions deployed on the EU market consist of vehicle/driver data collected remotely and combined with external cloud services (managed by vehicle manufacturers or a third party) and a web interface for aftersales services. Rules to make systems operational and cybersecurity reliable are identified and have been successfully implemented in experiments. Typical examples include the *extended vehicle* (ExVe) cloud services provided by several vehicle manufacturers. Another example concerns on-board telematics platforms for fleet management implemented by independent Telematics Service Providers using security standards, such as those that apply for C-ITS.
- In the Cooperative Mobility Domain (aka C-ITS) the TRL is high for C-ITS Day 1 and Day 2 services: security standards are developed and implemented. Day 3 services are under development. Yet the actual deployment of C-ITS has been limited.
- In the Automated and autonomous Mobility Domain the focus at this stage has been on the development of primary services. An additional security risk identified is sensor spoofing where the sensors (e.g. cameras) of the vehicles are being manipulated which can lead to serious consequences in case of automated driving.

[23] SO/SAE 21434

[24] ISO 20078 on IT Security Evaluation, C-ITS

- Although the European member states regard the infrastructures for mobility as critical, national agencies are not yet actively (or not visibly) involved in its cybersecurity.

WG5 noted that much attention had been devoted to the technical development of IT components in the primary service chain, e.g. between servers and the car, the ITS-services for cars and trucks. But it might be fruitful to also pay attention in some domains to the collaboration of different entities at the institutional level, the system level and the individual components, as well as legal and enforcement aspects.

The common reference model in figure 2 below has been used, to identify gaps.

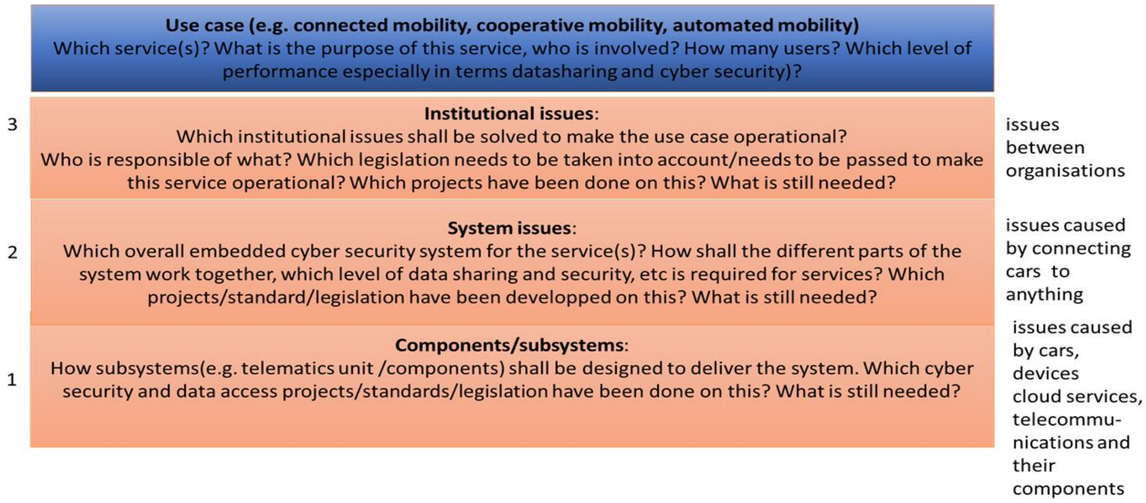


Figure 2 The common reference model, developed by WG5 distinguishing the institutional level, the system level and the individual components

The common reference model helped WG5 to review the whole technical system level and institutional deployment issues that are relevant for CCAM. The maturity of pre-deployment activities at all of the levels in the common reference model, have been rated in accordance with the next section.

8.3.1. Cyber Security Maturity Criteria (CSMC) for the gap-analysis for deployment

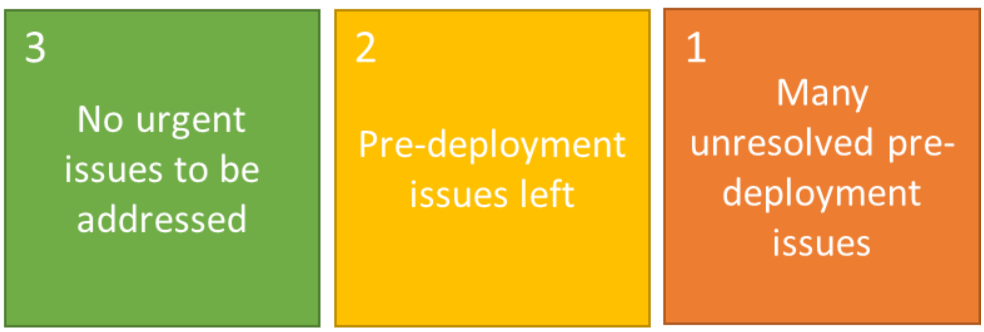


Figure 3 The Maturity Criteria, as developed by WG5, expressed in colours and numbers. E.g. for C-ITS Day 2, services at the institution level of the reference model, the yellow code indicates that formal institutional collaboration is still in development.

Table 3 describes the maturity criteria used for the gap analysis for deployment. The highest maturity level (3) issues are addressed in a structured and formalised way where the roles of all organizations involved are explicitly covered and embedded in explicit norms. The preparatory group first looked at the activities of R&D consortia and commercial activities that were reported by the EU in a table (named "the Matrix"). If an activity has addressed issues falling in one of the three levels of the common reference model, the maturity was evaluated concordant to that level following the criteria in Table 3. Then a number is assigned to the activity, 3 is the highest and 1 the lowest maturity level. For a given CCAM domain, the group evaluated all the attributed numbers for a given level, and determined a sort an average maturity. This can be used to identify if there is a potential for pre-deployment projects. This potential is indicated by the colours of Figure 3. (green, yellow and orange).

Table 3 Maturity criteria that will be applied to projects that address issues attributed to the institutional, system and technical level of the common reference model.

Institutional	
3	if all relevant stakeholders' roles, duties, liabilities and responsibilities are described and collaboration and orchestration are formalized (law, CSMS) and ready for implementation
2	addressed, yet some stakeholders are missing (e.g. in the field of monitoring/enforcement)
1	if ignored
System	
3	if system security is formally addressed for components of all stakeholders, e.g. in a CSMS (e.g. the ExVe or the OTP and the car, the cellular network, data-sharing)
2	if system security is addressed for a subset of system components
1	if one or more components are not certified
Technical	
3	if some components are certified and a CSMS exists
2	if standards exist, are made, components have been tested, used
1	if not adhering to standards, legal demands and other requirements
Other	
X	All of the projects/technologies of "the Matrix" we have plotted on the common reference model. Some of them did not address any cyber security issues directly, this was indicated by 'X'.

The gap analysis requires to express, in terms of the common reference model, the difference of the current CCAM state that follows from the project analysis and compare it with an ideal situation. Although the maturity criteria and the distinguished levels of the common reference model do not form an exact canvas on the state of affairs, it has served the members of the preparatory group to characterize what has been done and compare that with a mature "target situation". This target situation is described in the next section and gives context and relevance to the gap analysis and the pre-deployment activities that are based on the analysis.

8.4. Context and relevance

Connected and automated vehicles are generating, storing and using increasing quantities of data. At the same time, wireless connectivity is making it easier to share these data with various actors. This connectivity[25] fuels the idea that a large variety of cyberattacks on any part of a vehicle can be launched by any hacker on the internet, possibly having catastrophic results;

Some of the responsibility and liability issues that arise are the following: Is the cybersecurity of a car the sole responsibility of its manufacturer? Of the authorities responsible for public safety? Responsibility of the workshop that maintains the vehicle? What are the parties that contribute to the cybersecurity of a vehicle?

In the target situation, all technologies of all parties that contribute to the cybersecurity of a vehicle shall cooperate to achieve a system that mitigates weaknesses of its parts. All parties have therefore shared liability in terms of how and when they influence the vehicle's safety/security/ performance. But influence of one entity is the sole responsibility of that entity. This collaboration is formalised in norms (e.g. contracts, laws, regulations, type approval) and requires monitoring and enforcement to be effectuated.

8.4.1. State of the art

WG5 captured the state of the art for each of the mobility domains and the results are given in the subsections below.

Connected Mobility.

The Connected Mobility Domain has fairly mature services, as Figure 4 depicts. Opened points relate to the type of access to in-vehicle data and HMI and data sharing by the different CCAM actors and security protocols needed for this access/sharing. WG5 recognized that the quality of aftersales services that can be provided is dependent on the quality of the data collected (e.g. data scope, sample frequency), on limited board computing , connectivity performance (e.g. latency), the cloud service as well as the access to the Human machine interface of the vehicle. Finally it is yet unknown to what extent the authorities, that have a role in safeguarding critical infrastructures, should be involved.

[25] https://techcrunch.com/2016/08/25/the-biggest-threat-facing-connected-autonomous-vehicles-is-cybersecurity/

	Connected services Purpose: bring data to vehicles, retrieve data from vehicles, handhelds in the vehicle and other terminals and vice versa. Potentially indefinite service providers connecting to the vehicle. (user to move from A to B)	
3	**Institutional issues**: existing and missing mechanisms to monitor compliancy to rules and regulations, enforcement, agreements for collaboration with CSIRTs, NCSAs. Potentially indefinite service providers connecting to the vehicle.	Deployed. Rely mostly on systems developed by manufacturers UN Regulation on cyber security adopted (mostly rely on OEM cybersecurity management system) The role of the EU Cybersecurity Act (nothing specific on Connected mobility at this stage) and the implementation of the NIS Directive (coordination at EU level and implementation at the Member State level) has to be clarified. Remote diagnosis and OBD access is regulated by EU vehicle approval legislation
2	**System issues**: covered by edpb_guidelines_202001_connectedvehicles (about ePrivacy, GDPR, telecommunications, cloud computing, …) ISO Extended Vehicle (https://www.iso.org/ics/43.040.15/x/) , ENISA smart cars 2019	Systems designs and cybersecurity are proprietary and deployed Systems for in-car data access to vehicles are proprietary and deployed
1	**Components/subsystems**: access to OBD, Telematics unit.	Systems are proprietary, protected and deployed. DDOS Service attacks cannot be dealt with

Figure 4 State of affairs of Connected Mobility for the three levels of the common reference model.

Cooperative Mobility (C-ITS)

WG 5 has concluded that C-ITS Day 1 services are well developed from the pre-deployment point of view, whilst Day 2 and especially Day 3 services still have pre-deployment issues to be solved such as issues linked to automated driving (e.g. automated decision based on the information broadcasted).

	C-ITS services Purpose: broadcasting trustful local traffic information to the road user (e.g. traffic jam ahead).			
3	**Institutional issues**: Draft delegated act on C-ITS : Format of messages based on standardisation work, authentication of messages managed by JRC, no mandatory C-ITS services imposed self certification for the C-ITS stations based on listed standardised communication profiles, etc.	No urgent isses to be addressed Day 1	some Pre-deployment issues left Day 2	Many unresolved pre-deployment issues Day 3 and beyond
2	**System issues**: Which overall system for the services? C-ITS interoperability done with CRoad projects. Technical standard (ETSI, CEN/CENElec) profiled by C2C-CC and C-Roads Day 1,2,3 as defined in the C-ITS platform report.	No urgent isses to be addressed Day 1	some Pre-deployment issues left Day 2, e.g. multi connectivity cyber security	Many unresolved pre-deployment issues Day 3 and beyond
1	**Components/subsystems**: Services and C-ITS stations covered by EN/ETSI standards? For subsystems (communication unit?) /components ? How shall they be standardized to deliver the system. Which projects/standard/legislation have been done on this? What is still needed? Responsibility for PKI central elements CPOC/TLM/ECTL by JRC	No urgent isses to be addressed Day 1	some Pre-deployment issues left Day 2 (Most of the standards are ready)	Many unresolved pre-deployment issues Day 3 and beyond

Figure 5 Summarization of the state of affairs for Coordinated Mobility, aka C-ITS Day 1, 2 and 3.

Automated Mobility.

Automated mobility is still very much in its infancy stage. Cybersecurity has a new dimension here as sensors and AI can be manipulated (e.g. person holding a cardboard stop-sign) with unpredictable and potentially undesirable consequences. Threat analysis can be used as basis for cooperation of OEMs with road authorities (e.g. the spoofing threat is reduced if one knows where the traffic signs are placed). Safety and security co-engineering as already foreseen in the new ISO_TR_4804_2020 will help to better understand the implications of cyber-threats against the AD systems intended functionality (Safety Of The Intended Functionality analysis-‘SOTIF’).

	Automated mobility: example of automated cars, trucks and buses Purpose: automated decision making based on sensor, traffic and cloud service information that includes assessment of possible information manipulations and the cyber threats the vehicle/machine is currently exposed to	
3	**Institutional issues** UNECE regulation on cybersecurity and automation(mostly rely on OEM cybersecurity management system) ISO work	In the process of being addressed.
2	**System issues**: UNECE activities for automation. Specific cyber security issues for automation, ENISA Threats and Measures 2019.	Relies on the systems developed by vehicle manufacturers
1	**Components/subsystems**: cyber security issues not unlike connected and cooperative mobility	Ex: dealing with sensor spoofing, fake information

Figure 6 Developers of Automated and autonomous Mobility face many new challenges, amongst others they have to deal with the manipulation of sensors and sensor information. This field of cybersecurity is considered in the right side of the table.

8.4.2. CS maturity CS & evaluation of projects ("Matrix")

Figure 7 Summary of the Cybersecurity of R&D projects and deployed systems in the field of CCAM plotted on the canvas of the common reference model and rated (with 3,2,1,X) according to the maturity criteria in Table 3.

Figure 7 summarizes the level of maturity per CCAM domain. The evaluation comprises:

1. the CCAM domain
2. the level (component, system, institutional) in the common reference model
3. the maturity level (as in Table 3).

As a conclusion, the Connected Mobility domain is quite mature at the system and technical levels. At the institutional level the operational systems are rated with the maturity 2 mainly because it is unknown whether arrangements exist with national security agencies that safeguard critical infrastructures. A broad range of services are already deployed by vehicle manufacturers as well as independent Telematics Service Providers for fleet management (trucks are covered by J1939 standard). Access to Vehicle Maintenance repair data is also already regulated by EU law since 2007. However the market for in-vehicle data is not yet as far advanced as desired by some stakeholders (such as available data, sampling frequency, communication latency, on board computation capabilities and access to HMI). Two initiatives mentioned at the system level of Connected Mobility in the Development column, were rated at maturity level 1 at system level as an alternative/complement to vehicle manufacturer solutions. In particular technologies developed for C-ITS services (on board telematics platform and Secure Vehicle Interface) present opportunities to facilitate in-vehicle access to data in the Connected Mobility domain (data scope, sample frequency, on board computing, HMI access, communication latency, …).

The maturity of the technologies and regulations in the C-ITS domain is high. This is understandable as the interconnection needed between vehicles of various brands and with other ITS stations requires technical and institutional cooperation between OEMs and with authorities. Yet, this high level of technical maturity has not pushed C-ITS deployment much. It is one thing to design technology, another is to create market demand. Also, governments still need to take up their roles as certificate authorities as well as to implement their activities to protect of critical infrastructures. Governments would be greatly helped by blue prints for institutional design and the operational policies of those institutions. One of the attendants of the WG5 webinar on June 29th 2020 remarked “we should have pre-deployment activities that involve governments”.

8.4.3. Triangulation with ENISA Threat taxonomy

The WG5 findings on threat taxonomy can be compared with the results of ENISA 2019-publication[26] on the “good practices for the security of smart cars”. In that publication ENISA categorizes the practices in three areas: policies, organisational practices and technical practices. We cite from Section 4 in this document

- On policies: *“this first category of security measures encompasses the different policies and procedures to be established within organizations to ensure an appropriate cybersecurity level.”*
- On organisational practices: *“Organisational and governance processes are of utmost importance to ensure smart cars security. In what follows, a set of organisational rules and best practices are detailed. They cover several aspects such as relationships with suppliers, employees training, incident management, etc.”*
- On technical practices: *”a set of technical security measures should be implemented to protect both smart cars and the associated back-end systems. Hereinafter, we provide an overview of these technical practices which covers several aspects such as software security, cloud security, detection, access control and so on.”*

Figure 8 reproduces the ENISAs summarization of the practises associated to these categories.

[26] https://www.enisa.europa.eu/publications/smart-cars

Figure 8 Cybersecurity Good Practices Overview from ENISA[26]

This threat taxonomy and mitigation measures was considered as a good basis by the WG5. WG5 also recalled the general safety vehicle regulation (EU) 2144/2019 which will mandate cyber security type approval according to UN Regulation 155[27] (including a list of threat to be addressed) and the European type approval framework regulation EU 2018/858 to require type approval according to the UN Regulation 156[28] on software updates. The Type Approval Regulations focus on cyber security risk management implemented by the vehicle manufacturer, and does not prescribe any technical requirements for components. The legal system is less clear for the cybersecurity of the transport system as a whole (e.g. multiple eyes principle and separation of duties) and institutional aspects related to monitoring and enforcement activities, e.g. by governments

8.4.4. Future challenges

From the gap analysis WG5 sees that the maturity of activities at the system and institutional level leave room for improvement:

1. The governmental agencies responsible for cybersecurity of critical infrastructures should be stimulated to participate actively in CCAM at a technical and institutional level.
2. Governments should setup certificate authorities for C-ITS[29].
3. In the Connected Mobility domain, pre deployment activities could facilitate collaboration on solutions enabling a fair access to in-car data in and foster innovation.
4. Cybersecurity pre-deployment activities should take care of development in the Automated and autonomous Mobility Domain.

---

[27] http://www.unece.org/fileadmin/DAM/trans/doc/2020/wp29grva/ECE-TRANS-WP29-2020-079-Revised.pdf

[28] https://undocs.org/ECE/TRANS/WP.29/2020/80

[29] The extension of the scope of Article 61 of EU Regulation 2018/858 for the purpose of accreditation could also be considered.

8.5. Major actions and core issues limiting deployment (How, Who and When)

8.5.1. Ations needed (How)

This section describes solutions to the challenges defined in the previous section. The future challenges in the field of cybersecurity have one common deployment issue: This is the need to improve the common know-how of governmental agencies and the collaboration with companies that deploy CCAM services. Hence the actions needed for each of the CCAM domains is to investigate the practical multi-organisation cybersecurity issues and organise activities that address them, specifically:

- EU guidance is needed to ensure that Member States implement specific legal and technical frameworks on cybersecurity for testing in a consistent manner:
- The Connected Mobility Domain requires the governmental agencies of the member states to further collaborate with stakeholders to improve CCAM data exchange and cybersecurity mechanisms;
- The Coordinated Mobility Domain would benefit if governmental agencies are supported to set-up national trust networks, e.g. organisations involved with the establishment of Public Key Infrastructure, managing cyber incidents;
- The Automated and autonomous Mobility domain introduces new (e.g. self-learning) technologies should be considered by governmental agencies.

8.5.2. Stakeholders involved (who)

Stakeholders are all organisations who run a service or have a governance task in any part of the organisational ecosystem that jointly contribute to the cybersecurity of a CCAM domain. Hence the collaboration that executes pre-deployment activities must be a representative part of the eco-system for a given CCAM domain.

8.5.3. Time line for implementation (when)

The development of CCAM technologies – even for the Automated and autonomous Domain – has evolved far enough to, from now on, and should involve governmental agencies in the early stage of pre-deployment activities.

8.6. Horizontal Cross WG issues

Issues in the field of cybersecurity differ for the CCAM domains. Yet, there is almost always a link with the deployment of the CCAM service in a given domain and deployment issues are also present in other WGs.

9. DETAILED REPORT ON WORKING GROUP 6 "CONNECTIVITY AND DIGITAL INFRASTRUCTURE":

9.1. Definition of the WG6 theme - Connectivity and digital infrastructure for cooperative, connected and automated mobility

Connectivity is vital for cooperative and automated vehicles, other road users, road side systems and cloud services to realise the vision of CCAM. The digital infrastructure is the communication infrastructure that connects all devices and systems in CCAM. This needs to be done through hybrid communication, i.e. alternative communication technologies operating in parallel for the same or complementary services. WG6 addresses the infrastructure based and/or infrastructure-less short-range, long-range and broadcast communication infrastructure from technological perspectives, in order to establish further needs for co-existence and interoperability testing. WG6 does not look at the advantages and inconveniences of any specific technology.

WG6 addresses how to increase competitiveness of European ecosystems that develop, deploy and operate the digital infrastructure. Better focused and harmonised investments are needed to keep a leading position on communication technology.

Focus of WG6 was to identify:

- parameters of good quality projects as basis for future investments, testing and pre-deployment;
- the eco-system of stakeholders, their roles and investments needed to boost developments, testing and pre-deployments, and to increase the competitiveness;
- cross-segment and co-existence requirements;
- architecture, standards and communication issues to be resolved;
- spectrum requirements.

Needs and requirements on connectivity and the digital infrastructure were formulated in other working groups, e.g. on vehicle automation and infrastructure supported automated driving (WG3), safety (WG4), and cyber-security (WG5).

9.2. Context and relevance (why)

Europe has made significant investments in the digital infrastructure for the development and (pre)deployment of short and long range communication. Given the forthcoming increase in demands for connected and automated mobility services, significant investments will be needed in the digital infrastructure in order to support a successful deployment in the EU. In this regard, new communication technologies with increased performance and quality of service are needed. The automotive and mobility ecosystems will interact stronger with the telecom ecosystems.

The main objective for WG6 was to offer secure and adequate connectivity for the needs of CCAM. Specific goals were to:

- ensure robustness, redundancy, predictability and availability of communication channels (network coverage) and a minimum quality of service (QoS) especially for higher levels of automation.
    - For safety-relevant applications of CCAM, the performance and resilience of connectivity is essential.

  - Connectivity should improve safety of automated mobility at different safety levels.
  - Vehicles must always behave safely even without connectivity.

- provide through digital infrastructure the means for implementing the security mechanisms, e.g. as defined in WG5.
- provide clarity on the liability of the different actors.
- assess the performance in hybrid communication environments from an end-to-end perspective in real-world driving conditions; safeguard robust operation; appropriate degradation; privacy protection; and, end-to-end security.
- ensure interoperability between all involved actors (vehicles, infrastructure, (vulnerable) road users, road/fleet operators, authorities and supporting industry, etc.); help develop standardised C-ITS messages and message sets (e.g. for manoeuvres); and, test EU-wide interoperability and compatibility using different solutions.
- explore cost effectiveness, including costs and benefits on EU and national scale for all stakeholders.
- shape a fact-based scenario on relevant use cases and the role of connectivity.

9.3. Key challenges and actions (what)

9.3.1. State of the Art

The state of the art is that various communication technologies are available for CCAM:

- Short-range communication: ITS-G5, LTE-V2X (PC5), NR-v2x (PC5), Bluetooth and infrared, ultra-wide band and visible light.
- Long-range communication: 4G, 5G.
- Satellite.
- Broadcast communication: RDS, DAB+.

These types of communication technologies are used in different digital infrastructures, architectures and protocols. Short range communication typically requires direct communication between devices of road users for example, while long-range and broadcast communication require network-based communication and back-end services for data provisioning and CCAM functions.

Europe has adopted a ‘hybrid’ communication approach for CCAM based on the principle of technology neutrality. In the hybrid approach, various communication technologies are combined for several reasons, for example:

- to make CCAM deployment independent of specific technologies;
- to improve the quality of service in terms of redundancy, resilience, robustness and coverage; and
- to enable alternative business models and deployment strategies.

The Member States, regions and projects in the EU develop standards and profiles for Day1 C-ITS and automated driving services, use cases and scenarios, using a multitude of communication architectures, technologies, standards and profiles. Significant harmonisation efforts are needed to align these into a harmonised European standard and profile in a bottom-up approach.

The state-of-the-art for CCAM becomes even more diverse if other mobility services are considered, such as for electronic tolling, traffic information, public transport, freight transport, protection of vulnerable road users, and rail, all using different communication frequencies (spectrum), protocols, standards and technologies.

The ARCADE knowledge base[30] was used to assess existing projects and technologies, and was extended for the purpose of WG6 and CCAM.

On the state of the art in pre-deployment, the following general observations can be made:

- Regarding communication technologies, although Europe has strengths that should be leveraged, there are some challenges to be tackled in order to keep the leadership in CCAM.
- Europe has developed many research, demonstration, pilot and (pre)deployment projects over the last decade on CCAM. These investments are scattered, nonhomogeneous and implement national, regional or project specific solutions, and the potential to scale-up for (pre)deployment is limited.
- This limits the potential for developing new business and services, and for investing in R&D for new technology.

9.3.2. Future Challenges

Following future challenges were identified:

How to support CCAM, including advanced use cases and scenarios (e.g. SAE L4, ISAD)?

- Different requirements, e.g. from functional safety, QoS for services, use cases, scenarios:
    - communication latency and reliability, time criticality;
    - ensure resilient and robust communication in all environments, thus ensuring functional safety (ISO26262) of CAD systems (STRIA RoadMap E4 – 5.8) as well as with other road user systems such as ebikes (ISO 13849);
    - availability and coverage of communication;
    - provide the means for implementing the security mechanisms; and,
    - inter-working between network operators;
- Technology lifecycle:
    - evolutions and revolutions of communication technologies;

[30] ARCADE knowledge base on https://knowledge-base.connectedautomateddriving.eu/

    - obsolescence, support for older technologies and seamless upgrades to new technologies;
    - over-the-air (OTA) updates – security and functional safety; and,
    - hybrid communication – as a requirement and solution.
- AI technologies, communication demands (larger / big data volumes, lower latencies, …
- Data sharing and storage for different service and use cases.
- New communication technologies (e.g. IEEE 802.11bd).

How to improve the penetration rate of equipment of road users including those connected to the digital infrastructure.

How to improve the competitiveness of the EU ecosystems:

- Improve the quality of projects including the scale and scope of tests, predeployments and business take-up;
- Level playing field;
- Technology independence versus decisions on standards, profiles and reference architectures;

Challenges for (pre)deployment of communication technologies:

- Harmonise architectures, standards and profiles and ensure coordination between the SDOs involved;
- Focus needed on development, testing and pre-deployment;
- Necessary investments by the relevant stakeholders for large-scale testing and pre-deployment needed to realise the goals on traffic safety and efficiency, mobility, …

Cybersecurity challenges:

- Integrate PKI for automobile into internet;
- Quantum-resistance;
- Trust chain

Several landmark services are considered from ETSI, ISO and CEN, C2C-CC, 5GAA, Data for Road Safety (previously the Data Task Force), and C-ROADS as representative examples of current and future priority services for which connectivity will play a key role as a fundamental enabler. In this regard, analysis is made upon the following criteria:

- Whether a service can only be provided through in-vehicle sensors or can also make use of communication.
- The options for communication technologies (broadcasting, cellular mobile network, direct short range communication).
- Clarify testing needs on interoperability, spectrum and coexistence, with a view to ensure future-proof solutions.
- How the penetration rate – for all services – evolves.
- Whether aftermarket devices can improve penetration.

Emergency Braking / dangerous situations / for traffic jams:

- From a vehicle centric point of view, the use case is being (partly) addressed by proven vehicle solutions such as Forward Collision Warning (FCW) with or without Automated Emergency Braking (AEB) as well as Adaptive Cruise Control (ACC). Communication complements these solutions with detection and dissemination beyond the range of vehicle sensors and driver awareness, and contributes to predict the exact geolocation of hard braking and can prepare vehicle functions to a possible braking action. Centralised and decentralised approaches exist. Day1 services like Traffic Jam or End-of-Queue Warning and Emergency Electronic Brake Lights (EEBL) can predict braking actions up to 20 sec ahead of the end-of-queue. Centralised approaches via traffic management centres help to moderate and gradually decrease speeds of vehicles between 30 sec and 3 min ahead of a traffic jam. By having a large data sampling and a wider dissemination, this use case eventually helps the traffic manager to control efficiently the traffic flow and avoid traffic instabilities. A special case for the centralised approach is the interoperability between mobile network operators.
- Traditionally broadcasting and connected services are used to disseminate this information. It can also be done via short range communication (V2I or V2V).
- The major challenge is the penetration rate of equipped vehicles. Hence the centralised and decentralised approaches will both be needed. It is important to invest short-term in back-end solutions while keeping a long-term impact strategy with short-range communication.

Vulnerable Road Users and pedestrian crossing in cities:

- The General Safety Regulation (GSR) will mandate safety measures in vehicles to detect and protect VRUs, and to warn or activate emergency braking systems. Connectivity could play an important role in increasing time and distance for users' reaction as well as tackling some of the limitations and constraints of in-vehicle and road side measures.
- Given the high penetration of smartphones among VRUs, vehicle users and in-vehicle systems, the approach should utilize widely used communication technologies available in the smartphones.
- The major challenge may be the need for dedicated apps. Diversity of apps may constrain scalability and interoperability. Another challenge is the high density of users in cities and congestion of the safety-related band.
- Intermodal communicating sensor based for collective perception from Vehicle and Infrastructure can get an acceptable result for protecting Vulnerable Road User .

Lane merging on highways as an example of cooperative driving in which coordination of manoeuvres among vehicles will take place through functionalities enabled by connectivity.

Platooning, namely, a group of two or more automated cooperative vehicles in line, maintaining a close distance using wireless communication (V2V), requires cooperative automation on different hierarchical levels, based on reliable short-range vehicle-to-vehicle and vehicle-to-smart-infrastructure communications (V2X), and long-range back-office communications. Main issues for the successful deployment of multiband and interoperable solutions relate to latency requirements, allocation of protected spectrum bands and bandwidth needs. In the future, various models for providing redundancy within the radio spectrum might be necessary.

And advantage of a ground proved technology would be that the basic principles could be extended for any vehicle platooning, e.g. other commercial vehicles, passenger cars, agricultural vehicles, or public transport vehicles such as buses or automated taxis/shuttles.

Teleoperation of vehicles, as a flagship use case where connectivity and communications technologies can play a major role. The use explores the need for requirements and a framework of communication technologies and connectivity supporting ToV to help frame and boost this mobility solution. It also analyses the advantages of multi-purpose wireless networks deployment with defined requirements (coverage or QoS alongside roads), and how cellular communication (particularly 5G) will be key in enabling the deployment of this solution.

The main challenges may relate to sufficient network infrastructure and spectrum allocation and protection for such services.

Multimodal journey, communication systems and digital technologies can help contribute to the materialization of multimodality in a seamless way in the EU. The involvement of different actors (from service providers to public authorities) along with standardization and interconnection of platforms might play an essential role. For this purpose, the analysis focuses on a typical daily commuting journey and how connectivity will enable a sustainable and efficient multimodal trip. In this regard, as a conclusion, the use of a common, fast and reliable communication technology will greatly improve and facilitate the materialization of a truly multimodal journey, hence using connectivity as a federating power to enable multimodality. Main challenges are network availability and infrastructure deployment.

9.3.3. What needs to be done

Benchmark Test and pre-deployment sites:

- Inventory of existing sites:
    - Tests and (pre)deployments of short- and long-range communication in the EU, China, USA, Japan.
    - Identify good quality projects and sites
- Develop benchmark sites for future projects:
    - Reuse and mature test sites – towards leading test environments.
    - Evolve technology and services, also communication technology.
    - Compare/evaluate alternative (old/new) technologies and solutions, and their impact on CCAM. This includes evaluation of compatibility and interoperability of new systems and technologies with existing ones. Develop sites into benchmarks for further (pre)deployment across the EU.

Map/classify CCAM use cases, services and scenarios, functional safety levels to requirements on communication QoS, in a generic manner for current and new use cases / scenarios.

9.4. Major actions and core issues limiting deployment (How, Who and When)

9.4.1. Priorities and methods (how)

First, we need good quality projects. Good quality projects for development, testing and pre-deployment of communication technologies are essential to improve the competitiveness of the EU ecosystem. A separate working paper in annex defines the details how to select and evaluate CCAM connectivity and digital infrastructure pre-deployment projects.

- Characteristics are distinguished for the project evaluation criteria and indicators:
- Ex-ante and ex-post criteria (achieved objectives);
- Input, intermediary or output criteria;
- Quantitative, factual or qualitative criteria;
- Intrinsic achievement criteria vs impact criteria;
- A/B testing.

Pre-requisites are conditions that must be met before pre-deployment:

- live from subsidies vs. industry take-up;
- all components should be off-the-shelf;
- component wear and obsolescence should be factored in.

Criteria to evaluate the scale and scope of pre-deployments projects:

- size/complexity of the road environment;
- complexity of the member state environment;
- complexity of border environment;
- complexity of the communication environment;
- number and proportion of new vehicles;
- number and proportions of retrofitted vehicles;
- number and proportions of pedestrians;
- duration and circumstances of observation;
- breath of CCAM services deployed;
- number of CCAM / C-ITS messages

Validation criteria of project results:

- Communication performance;
- Number of lives saved/injuries avoided/collisions avoided;
- Less traffic congestion and greater transport efficiency;
- Mobility and service reliability;
- Reduced energy used;

- Fewer negative environmental impacts;
- Support for economic development;
- Robustness of the business model proposed for deployment;
- Intercontinental benchmarking (competitiveness);
- Contribution to completeness of deployment toolkit.

Quantifying the criteria: Out of the 31 criteria identified, 18 are supposed to be totally or partially quantitative. Ex ante quantification of benefits is not an exact science. Multiple methodological approaches to quantifying the same benefits can improve the level of confidence in the results of the quantification exercise.

Requirements on connectivity and the digital infrastructure. Future challenges on connectivity and the digital infrastructure arise from the requirements from future CCAM and priority road transport services. In a separate working paper[31], an analysis is made on the ballpark communication requirements aiming at determining how connectivity and digital technologies can contribute to the efficient provision of services (from the simplest to the most advanced "day-X" services). That paper covers, among others, the following aspects:

- The role of communication technologies in those services and their link with other existing solutions in vehicles or on infrastructure.
- Type of communication (cellular mobile network, direct short range technologies, broadcasting) for the provision of services.
- Testing needs on interoperability, spectrum and coexistence, with a view to ensuring future-proof solutions.

9.4.2. Stakeholders involved (who)

- Road infrastructure managers
- Traffic management companies
- Third party in-vehicle services providers
- Original Equipment Manufacturers (OEM) such as vehicle manufacturers, including cars, trucks, motorcycles, e-bikes, …
- Telecom industry companies such as Mobile Network Operators
- Supply companies
- Organisations representing road users including mobility clubs
- Legislators and regulators
- Public Transport Operators
- Security providers (PKI)

[31] https://circabc.europa.eu/ui/group/2fae7ed4-1333-485d-a9fb-055f4ad85275/library/46fa65a3-06f1-447b-8fe0-72f8056c0240/details

9.4.3. *Recommendations*

Use cases as they are presently described in WG6 may not include all the elements to help build quantified targets. The WG6 subgroup on use cases may consider this aspect if they continue their effort. For instance, CCAM use cases could specify the class of cooperation they address (Class A: Status-sharing – Here I am and what I see; Class B: Intent-Sharing – This is what I plan to do; Class C: Agreement-seeking – Let's do this together; Class D: Prescription – I will do as directed).

Regarding communication technologies, use case testing requirements should focus on the robustness of the solution. Extreme usage conditions should be investigated. Tests should focus on how fast does the performance decrease with the increase of subscribers. This is never linear, as per the Erlang formula. Use case testing environments must be specific to the Technology Readiness Level (TRL)4 of the experiment. The higher the TRL, the more realistic the testing environment should be. Most tests of CCAM services require a higher TRL for the communication infrastructure than for the CCAM service itself. However, the use case is the system, and the TRL of the system is the TRL of its least mature component. In the higher TRLs, we should also define which business relations should be established (e.g. between MNOs if we need a given latency between two vehicles served by two different MNOs).

10. CONCLUSION:

The CCAM platform was created in June 2019 with the goal to provide advice and support to the Commission in the field of testing and pre-deployment activities for Cooperative, Connected, Automated and Autonomous Mobility (CCAM).

The platform gathered almost 400 experts from the public and private sector and structured its activities around six thematic Working groups to cover the main relevant topics.

After two years of activities and many meetings, the different working groups delivered their contributions and conclusions. Many aspects of the work can be developed further and deepened.

However, it is now time for the platform to close its activities and to pass the baton to the CCAM Co-programmed Partnership under Horizon Europe, which was officially launched on 23 June 2021. €162 million are planned in the Work Programme 2021-2022. Six calls are planned for 2021 for a total amount of €74 million and five calls for 2022 for a total of €88 million.

The calls in 2021 will cover topics such as:

1. More powerful and reliable on-board perception and decision-making technologies addressing complex environmental conditions;
2. Common approaches for the safety validation of CCAM systems;
3. Physical and Digital Infrastructure (PDI), connectivity and cooperation enabling and supporting CCAM;
4. Cyber secure and resilient CCAM;
5. Analysis of socio-economic and environmental impacts and assessment of societal, citizen and user aspects for needs based CCAM solutions;
6. Framework for better coordination of large-scale demonstration pilots in Europe and EU-wide knowledge base.

The calls in 2022 will cover topics such as:

1. European demonstrators for integrated shared automated mobility solutions for people and goods;
2. Reliable occupant protection technologies and HMI solutions to ensure the safety of highly automated vehicles;
3. Human behavioural model to assess the performance of CCAM solutions compared to human driven vehicles;
4. Integrate CCAM services in fleet and traffic management systems;
5. Artificial Intelligence (AI): Explainable and trustworthy concepts, techniques and models for CCAM.

The members of the CCAM platform are invited to participate to these calls and to pursue the work initiated by the platform.

11. ANNEX:

11.1. WG3: PDI attributes Matrix

Due to the length and complexity of the Matrix, a specific Excel document has been created and will separately accompany this report.

11.2. WG4: annexes

There are two annexes from WG4. The first annexe is presented below. The second annex is a template for application. It is an interactive document, which separately accompany this report, to be completed by the applicant and does not replace the official document required by Members States.

11.2.1. Results of CCAM Platform WG4 Member sub-group Consultation

The analysis on input from WG4 is done by relating it to the ERTRAC's roadmap on Safe Road Transport and their roadmap on Connected Automated Transport, in order to summarize how topics relevant for road safety have been addressed. Additionally, the STRIA Roadmap on Connected and Automated Transport is considered.

Section 5.1 contains an overview of lessons learnt from projects regarding road safety of automated vehicles, in Section 5.2 recommendations are made on R&I actions for road safety, and Section 5.3 addresses recommendation for research related to admittance procedures. Within the CCAM platform there are topics discussed in working groups that focus on other aspects of CCAM deployment that have links with road safety. The issues that are common in the various working groups are presented in Section 5.4.

11.2.1.1. Lessons learnt from projects regarding Road Safety automated vehicles

Many previous and existing initiatives lead to insights into the challenges of road safety and automated vehicles. Previous projects dealing with the topics and results that were addressed in WG4 are to a large extent documented in ERTRAC's roadmap on safe road transport[1] and the ERTRAC roadmap on Connected Automated Driving[2]. As Figure 1 shows, H2020 has provided wide support for CCAM development.

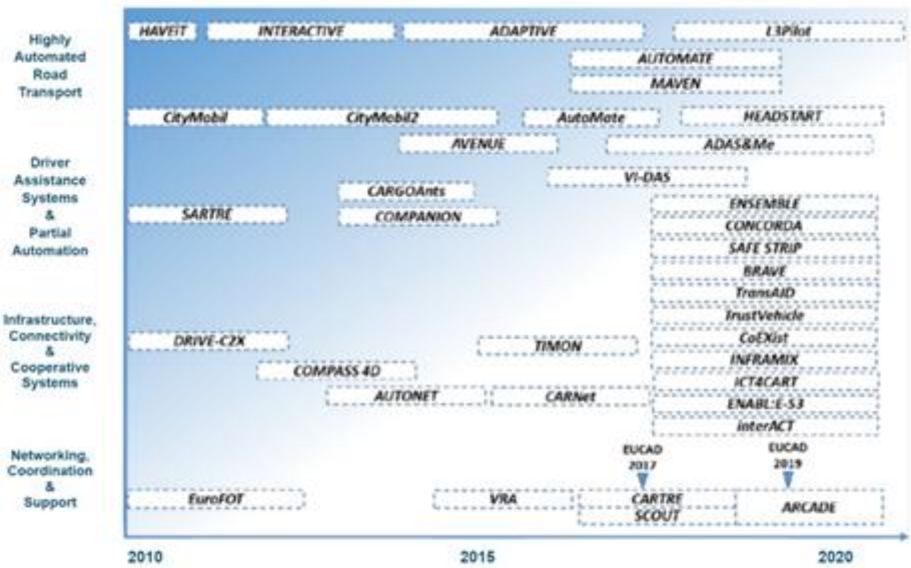


Figure 1: Overview of EC funded projects dedicated to road safety (bottom) and dedicated to automated driving development (top). Source: https://www.ertrac.org/uploads/documentsearch/id57/ERTRAC-CAD-Roadmap-2019.pdf.

An overview on road safety topics addressed in H2020 projects is shown in Figure 2.

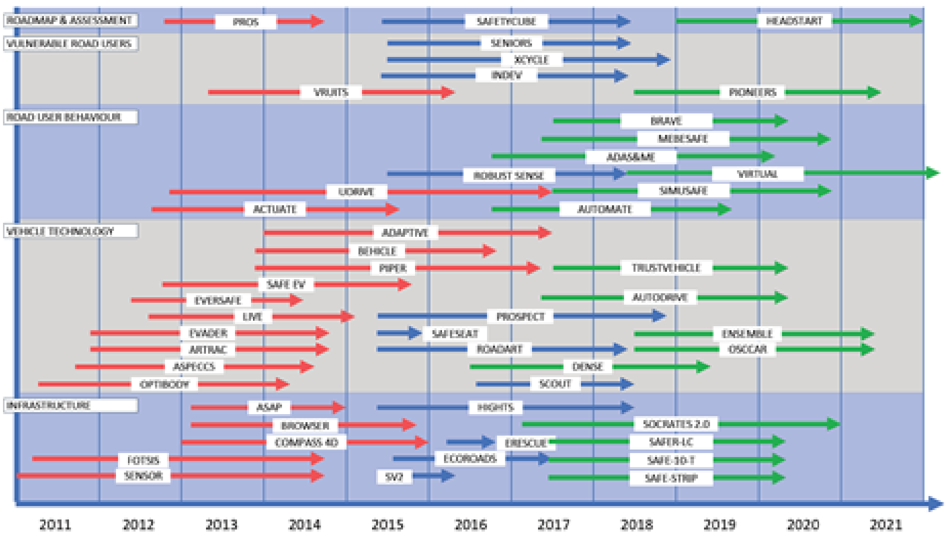


Figure 2: Road safety topics in H2020 projects (Source: https://www.ertrac.org/uploads/documentsearch/id58/ERTRAC-Road-Safety-Roadmap-2019.pdf)

Several types of vehicles have been considered by these projects, including passenger cars, (platoons of) trucks, automated buses, automated shuttles, mining vehicles, personal mobility urban vehicles, service vehicles, (unmanned) small goods delivery vehicles/robots, etc.

These projects also took into account a variety of Operational Design Domains (ODDs) such as motorway, parking lots, urban settings, working environments, building sites, confined areas, etc. The research was focused on developing automated driving functions and systems, understanding the interactions between automated vehicles and other road users, driver behaviour and readiness, HMI, assessment of impact on road safety, connectivity issues, and testing methodologies.

From the overview in Figure 2 it can be seen that driver-vehicle interaction has not been recognized as a separate topic, while in WG4 it was one of the key topics discussed. An ongoing study executed for the European Commission “Study on the effects of automation on road user behaviour and performance” provides an overview of which challenges exist on human interaction with automated vehicles, considering driver-vehicle interaction and interactions of automated vehicles with other road users, also in relation to traffic rules.

ERTRAC identifies 11 research needs (RNs) on road safety, 6 of which encompass the majority of the R&I actions proposed by WG4 (see Table 1).

These 6 research needs can be related to 5 topics addressed the context of WG4:

- Assessment methods for CCAM capabilities
- Human interaction with CCAM
- Safe CCAM integration with traffic and road users
- Reliability assurance of CCAM systems and infrastructure
- Traffic safety assessment and safety validation

The ERTRAC research needs are listed in Table 1, together with their recommended priority level (expressed by their recommended time period). Each research need addresses a specific challenge and has an expected impact. This information is summarized in Table 2.

Table 1: Research needs from the ERTRAC Road Safety roadmap compatible with the R&I actions identified by WG4. The priority level of each need is given by its recommended time period.

Research Need		Time Period		
		2021-2022	2023-2024	2025-2027
RN3	Assessment of road user capabilities in future scenarios of road transport		x	
RN4	Safe human-technology interaction in the digital traffic system	x		
RN5	Safe inclusion of new means of transport into the traffic system	x		
RN6	Safety of highly and fully automated vehicles			x
RN9	Infrastructure safety		x	
RN10	Predictive safety assessment and validation framework	x		

Table 2: Specific challenges and expected impact for each research need listed in Table 1 (from the ERTRAC Road Safety roadmap).

	Specific Challenge	Expected Impact
RN3	Investigate new driver skills needed due to vehicle automation and the changes on interactions between road users and automated vehicles	Input for future training of road users ensuring today's high level of driver capabilities to future contexts of automated and electrified mobility HMIs can be designed according to the future road users' skills and capabilities.
RN4	In the future, humans will become co-operators of the transport systems, providing only partial input to the control systems. Hence, adaptive systems have to be explored, to allow for safe human-technology interaction in road transport. Such systems should consider long-term mental and physical capacity as well as instantaneous limitations in capabilities (drunkenness, drowsiness, etc.). Another challenge is the potential information overload that might lead to increased driver, rider and pedestrian distraction.	Methods to handle road user distraction and to inform them unobtrusively about the distribution of control roles and expected actions at any time. Safe mobility even for users who show impaired mental and physical capacity. Homologation and testing/validation processes adopt the adaptability of new vehicle systems. System models implement the human as an integral part of control systems, thus providing necessary background for design and management guidelines of adaptive automated systems.
RN5	Automated vehicles will interact with non-automated, non-connected and unprotected road users. They will have to cope efficiently and co-operatively with multiple traffic situations, while humans would have to be trained to cooperate with them.	Concepts and systems for safeguarding unprotected and non-connected users' safety in mixed traffic Training and educational schemes for of all stakeholders involved in mixed traffic

RN6	Development of a code of behaviour for highly and fully automated vehicles. Access regulations to driverless vehicles should be analysed from a road safety perspective. Increasing levels of automation demand higher reliability of critical vehicle systems. For highly connected automated and remotely controlled vehicles, it is necessary to provide fail-operational critical in-vehicle systems. In addition, the extent of the potential benefits of V2x communication for safety should be established. Situations will arise where which disobeying a traffic rule might be safer for vehicle occupants (or other road users) or avoid traffic breakdowns Relevant situations and corresponding needs for adaptations of existing rules should be analysed in detail.	Increased acceptance of highly and fully automated vehicles Reduced human suffering and burden for the health care system, while making best possible use of the potential safety benefits of road automation.
RN9	It is essential to understand how to adapt and upgrade the infrastructure network to make it compatible with all road users and in particular with automated vehicles at different levels of automation. Advanced monitoring, warning and maintenance techniques need to be developed in order to guarantee a timely assessment of the operating conditions of road structures and furniture.	Enhanced safety level of the infrastructure by enabling a prompt reaction to potentially unsafe conditions. Infrastructure characteristics that enable connected automated vehicles to travel under safe conditions
RN10	Future transportation systems will present new scenarios relevant for safety, which are not yet captured in accident databases. Traditional analysis methods and road studies cannot predict the impact of new developments and new measures on road safety in such cases. The number of scenarios which have to be considered in future safety assessments is expected to increase drastically. Safety assessment methods should be extended to potential future scenarios. This requires appropriate simulation environments and realistic models of all elements of the transport system (most notably, human behaviour), which need to be validated by physical testing and harmonised to make them available for regulatory and consumer assessment.	Harmonization of a prospective assessment and validation framework for road safety solutions will allow all stakeholders to compare different measures for decision making. New methods to efficiently predict the effects of road safety improvements by technology, infrastructure or behavioural changes up to the level of socio-economic benefits. Test scenarios using less critical but more frequent events than collisions

Recommendations for research on road safety

The WG4 partners, together with an external pan-European panel of experts, have identified a number of knowledge gaps on CCAM aspects, which would lead to recommendations for testing and research. It appears that the topic of Human Factors has been addressed insufficiently in earlier research. On the one hand, human driving behaviour can be considered to be an unpredictable risk factor for automated vehicles. On the other hand, as most typical human driving behaviour is collision-free, it should be considered as a reference to develop safe automated driving functions (specially under mixed traffic conditions). Secondly the human in the vehicle may no longer be a driver; the role of the human can be monitoring in order to take control when requested, or simply be a passenger. Within WG4 most of the research topics mentioned can be related to humans, in summary:

- Detection of VRU in exceptional configurations(e.g. recumbent bicycle, child on scooter, parent pushing child in buggy)
- Safe human driving behaviour, and driving behaviour in emergency situations
- User acceptance and social acceptance in relation to AV capabilities (which are restricted by safety requirements)
- Reactions of humans and traffic to automated (and minimum risk) manoeuvres
- Human capabilities in tele-operation and remote operation; and occupant dependent manoeuvring
- Driver interaction with automated vehicles in shared responsibility, transition of control schemes
- Safe insertion of automated vehicles in traffic (specific traffic rules, external HMI on AVs, 'driver education, etc.), such as addressed on a recent study[3]
- Occupants in (new) positions and activities enabled by CCAM, and humans under remote or automated operation (e.g. "the platooned driver").

Many of the gaps on Human Factors and CCAM technology are addressed in an R&I action in the STRIA Roadmap on Connected and Automated Transport[4]. The STRIA roadmap distributes these actions across multiple clusters so they cannot be one on one related to the needs for road safety research. Tables 3-5 present the identified actions and relates them to mentioned ERTRAC's research needs.

Table 3: WG4 recommended R&I action on Human factors

Human Factors		ERTRAC Research Needs					
		RN3	RN4	RN5	RN6	RN9	RN10
HF1	Assessment of driver situational awareness (and its variation) during driving	X					
HF2	The preferred driver state/condition during driving, and methods to keep them in that state		X				
HF3	Methods to prevent driver over reliance on vehicle automation			X			
HF4	Methods to (re-)educate drivers to handle automated vehicles and keep them responsible for the driving task as automation levels increase			X			
HF5	Knowledge on the competences and performance of drivers and different driver types in the context of CCAM	X					
HF6	Interactions between the police or emergency services in general and AVs		X		X		
HF7	Knowledge and data on interactions between CCAVs, their users, their surrounding VRUs and other (non-automated) road users			X			
HF8	Knowledge on CCAV occupancy: sitting positions, effects on passenger during collisions, occupancy monitoring, etc.						
HF9	Definitions of safe, human-like interactions of CCAVs with non-automated vehicles an VRU’s in mixed traffic			X			X
HF10	Human reference driver model as a basis for CCAV behaviour in mixed traffic			X			X

Table 4: WG4 recommended R&I action on CCAM technology

CCAM Technology		**ERTRAC Research Needs**					
		RN3	RN4	RN5	RN6	RN9	RN10
CT1	Impact of quality-of-service and other communication factors on CCAM safety/reliability					X	
CT2	Liability assignment and determination of acceptable risk levels for CCAV operation				X		
CT3	Safety assurance and reliability of CCAVs and their embedded AI functions						X
CT4	Sensor reliability, especially under adverse weather conditions						X
CT5	Safe remote CCAV operations					X	

Table 5: Other WG4 recommended R&I actions.

Miscellaneous		**ERTRAC Research Needs**					
		RN3	RN4	RN5	RN6	RN9	RN10
M1	CCAV behaviour in scenarios outside ODD or unexpected scenarios within ODD, when approaching limits of ODD						X
M2	Possible adaptions of current road infrastructure for CCAM					X	
M3	Limiting factors of deployment in specific ODDs						X
M4	Changes in traffic system (and its safety) due increased automation				X		X
M5	Knowledge and awareness build-up in municipalities, cities, regions to encourage policy driven demand of CCAM solutions.					X	
M6	A standard, common set of safety evaluation criteria to support a common safety assessment methodology framework						X
M7	A pan-European catalogue of road markings, traffic rules, etc. for cross border testing.					X	
M8	Interaction of CCAM with road-side and traffic management systems and optimizing services					X	

[1] Safe Road Transport Roadmap, 28.02.2019, ERTRAC Working Group: Road Transport Safety & Security, https://www.ertrac.org/uploads/documentsearch/id58/ERTRAC-Road-Safety-Roadmap-2019.pdf
[2] Connected Automated Driving Roadmap, 08.03.2019, ERTRAC Working Group "Connectivity and Automated Driving", https://www.ertrac.org/uploads/documentsearch/id57/ERTRAC-CAD-Roadmap-2019.pdf
[3] Study on the effects of automation on road user behaviour and performance, EU DG MOVE, October 2020, downloadable via https://op.europa.eu/s/omMB

[4] STRIA Roadmap on Connected and Automated Transport, EU DG R&I, April 2019: https://trimis.ec.europa.eu/sites/default/files/roadmaps/stria_roadmap_2019-connected_and_automated_transport.pdf

11.3. WG6 annex:

11.3.1. WG6: uses cases

ANALYSIS OF PRIORITY TRANSPORT SERVICES.
SCOPE & RATIONALE
WG6 CCAM, Connectivity and Digital Infra.

May, 8th 2020
Rev3
DGCNECT-H5

I. BACKGROUND

(1) The scoping paper of the working group WG6 of the CCAM Platform sets out as two of the main objectives to identify:

(i) cross-segment and co-existence requirements; and
(ii) architecture, standards and communication issues to be resolved.

(2) In particular, one of the working group´s targets is to analyze and ascertain the needs for further and future coexistence and interoperability testing.

(3) The document on criteria for projects on CCAM, as part of the deliverables of the WG6, also consider the quality and complexity of the communication environment, their performance capabilities, their overall efficiency, the evolution of technology, or the impact on different actors as some of the elements to be assessed.

(4) In order to determine the need for further action the group should first establish common facts. This means that it is relevant to see which communication technology is, can be or will be used for which service.

(5) In the originally proposed table the priority services under examination, definitions and categorization (day 1, day 1.5, etc… services) were taken from the conclusions and reports of the C-ITS Platform. In addition, the work of Standardization Organizations (SDOs) such ETSI, and from relevant documents of some organizations and associations such as C2C-CC, 5GAA, the Data Task Force, or C-ROADS, are also considered.

(6) The Working Group suggested that it would be more appropriate to first determine the need for a full-fledged analysis of a wide sample of existing and future services. For this purpose it was decided to develop an in-depth study of some landmark services.

II. SCOPE OF THIS ANALYSIS

(7) In order to help achieve the objectives of the working group, this analysis aims at determining the specific issues and actions for future test projects regarding cooperative, connected and automated mobility.

(8) In this respect, this exercise takes a representative example of current and future priority services (and their related uses cases) for which connectivity will play a key role as a fundamental enabler.

(9) The specific goals of the analysis are the following:

(i) to determine whether a certain service can only be provided through in-vehicle sensors (and automation features), or can also make use of communications. Capabilities and functionalities of the different technologies;
(ii) to point out within the connectivity-based solutions which options for technology exist (cellular mobile network, direct short range technologies);
(iii) to help clarify further testing needs on interoperability, spectrum and coexistence, with a view to ensuring future-proof solutions;

III. APPROACH (OTHER FACTS WORTH CONSIDERING)

(10) For the purposes of this analysis, a representative example of priority services and their derived uses cases are listed in the annexed table (see rows). They include day 1, day 1.5, day 2, etc.

(11) That table also shows the most significant technical features and attributes that are the inputs for the analysis. This includes the same services with different levels of urgency.

(12) Of that (non-exhaustive) list of services, the following ones are selected for a more substantial examination, which is the basis of this analysis:

(i) Emergency braking traffic jam.
(ii) Vulnerable road user: pedestrians in urban environment (jaywalking/Xsing)
(iii) Lane merging on highways (automated vehicles).

(13) For each of the above use cases, one pager is attached containing a short definition, the assessment of the different features, and a reflection on possible conflicts and issues where more consolidated results are necessary.

(14) Building on this analysis, WG6 can identify and recommend actions where future testing activities should focus on.

ANALYSIS OF ADVANCED TRANSPORT SERVICES:

Jan, 22nd 2020
Rev3
DGCNECT-H5

Use Case: MULTIMODAL DAILY COMMUTING
WG6 CCAM, Connectivity and Digital Infra.

I. KEY OBJECTIVE OF THE USE CASE (MAIN POLICY ASPECTS)

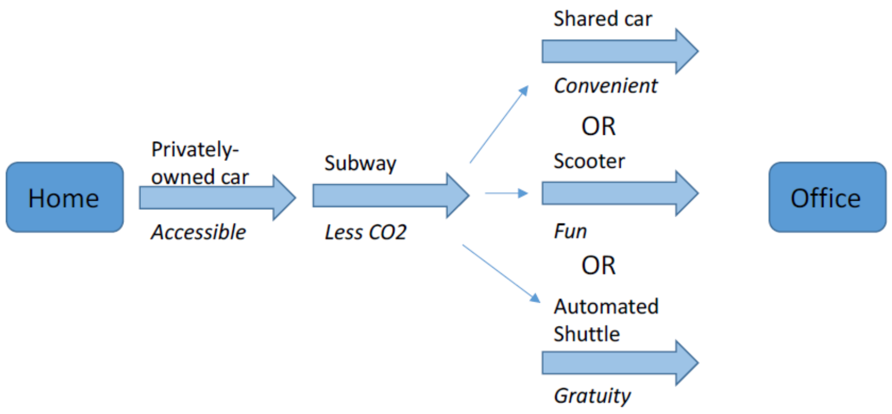
"Multimodality" in the transport sector, or "multimodal transport" refers to the use of different modes (or means) of transport on a given OD (Origin-Destination) *trip*. In particular, a *journey* is made of one mode (e.g. a rail journey), while a *trip* is a travel for a given purpose between one (physical) origin and one (physical) destination through a travel chain of journeys. Multimodality takes advantage of the strengths of the different modes and in combination, can offer more efficient transport solutions. Key barriers to increased multimodality, in particular for passengers, can be overcome by solutions offered by digitalization and communication technologies, shifting towards a better knowledge of potential transport options combining existing and new (e.g. *Mobility as a Service)* transport services. In particular, a relevant field for **multimodality** refers to **daily commuting**: a person leaves her home by private car or a car share and drives to the nearest railway station, parks the car, takes the train, arrives at another station and then takes another public transport mode, or a shared personal mobility vehicle or an automated shuttle to get to the office.

During a commuting trip, the availability and use of digital systems or platforms with communication technologies (with long range cellular or satellite and/or short range communication) in support of mobility will be key to enhance the operation of the system. In addition, during the time of transport from [place of]"Home" to [place of]"Work" additional possibilities can be offered to utilize the time for working through better connectivity. If appropriate, an additional *offer* in multi-modal transport would be the **remote workplace**. This option would happen mostly simultaneously with the sequence of existing modes (car, train, end trip mode(s)), influencing the multi-modal travel chain scheduling. The concepts of **Digital Twin** may also help improve the multimodal approach.

Key Objective: to determine how communication systems and digital technologies can help contribute to the materialization of multimodality in a seamless way in the EU. The involvement of different actors (from service providers to public authorities) along with standardization and interconnection of platforms might play an essential role. For this purpose, the analysis focuses on a typical daily commuting journey.

II. CURRENT STATE OF THE ART. LIMITATIONS

Definition of Multimodal daily commuting: *definition*.
Definition of Digital Twin: *definition*.



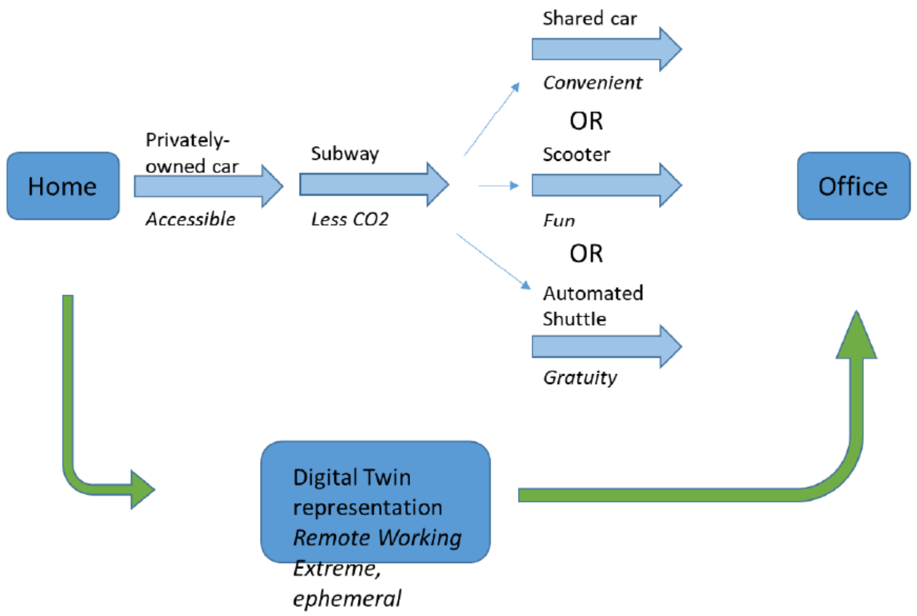
State-of the art on multi-modal transportation:

- Multi-modal transport planning tools for the end-user (customer, traveler, passenger). A *customer* may plan a trip for someone else, who would be the traveler. A *traveler* may call on her OD trip for services which are not pure transport – e.g. hotel reservation – and becomes a *passenger* when s/he boards a vehicle. Such tools are e.g. in the Ile-de-France Region: "Directions" on Google Maps, RATP App or SNCF App or "vianavigo" app, and some others. For a customer who plans a trip for someone else an example multi-modal planning tool is traveldoo.com.
- EU projects having built multimodal transport tools: for example, project Instant Mobility in FP7 in year 2011.
- A multimodal transportation use-case that might relate to digitalization concepts (and potentially lead to the use of Digital Twin) is mentioned in a new use-case for multi-modal delivery of goods (not transport of persons); this 'Socialized Internet of Things' (SIoT) use-case is described in the document titled "Network 2030 – Additional representative use cases and key network requirements for Network 2030" which is the result of the Focus Group FG-NET2030 and was issued in 2020, see URL https://www.itu.int/dms_pub/itu-t/opb/fg/T-FG-NET2030-2020-2-PDF-E.pdf)
- The multimodal transportation mode is mentioned in the draft Horizon Europe's Cluster5 as "Multimodal and sustainable transport systems for passengers and goods". See the document titled "Draft Work Programme 2021-2022, Cluster 5 ('Climate, Energy and Mobility'), version of 26 November 2020. The document is available via a National Contact Point (NCP) for the domain.

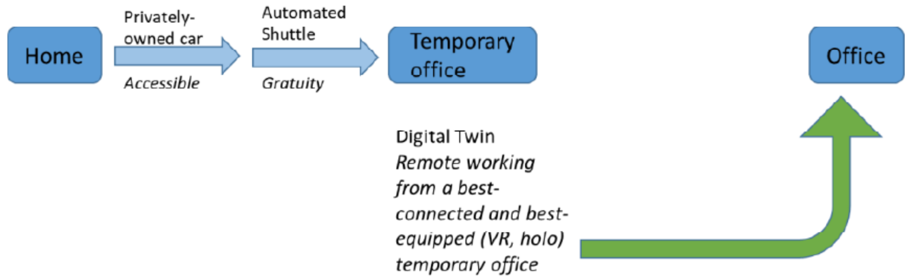
There are two distinct ways for considering Digital Twin concepts in multimodality:

- The digital twin representation of data and orchestrated in the cloud. For each vehicle and for each user there is a corresponding digital twin in the cloud. The planning of a trip comes down to orchestrating these representations, reasoning over their sequence and suggesting a result that best matches the requirements (e.g. user A must take her car first, then get off at station X, and finally take an automated shuttle to the Office).
- The digital twin representation of the workplace as a projection that could offer an alternative to the actual office. For this latter case, the multimodal transport planning must take into account the transmission of much more data and with more stringent requirements. The benefit of this lies in the significant reduction of non-necessary travel segments (journeys) of the trip, that are accompanied by potentially large gains in generated CO2 reductions, together with improved connected working conditions at the final physical destination replacing the office.

In the case of daily commuting trip the digital twin can help to reduce the number of modes. However, the path planning should take into consideration stronger connectivity requirements that might be needed for the use of a Digital Twin alternate path. The figure below shows an extreme case where the end user does not travel to the *office* but to a *remote smart workplace* (maybe with a doublerobotics.com device, or other VR devices). If this might work for a remote working office kind of activity, it is obviously not applicable on all cases (go to cinema, theatre, shopping, tourism). However, new activities such as Virtual Tourism, Virtual Concert, Virtual Airport do pertain to such kind of travel: physically travel to a place where VR equipment is available and from there virtually project to a virtual place. The relevant virtual remote smart place attributes would need to be specified for each of the trip purposes (work, leisure, culture…). Similarly the pricing conditions for the original O-D trip options and for the alternative O-*(better connected)* D trip options should be presented in a harmonized way to the potential customer.



A more probable multimodal way of transportation with the involvement of Digital Twin representations is illustrated below:



III. CONNECTIVITY ROLE. TECHNOLOGY

- Connectivity to the end user is essential to the realization of multi-modal transportation. That connectivity should be continuous (always be connected, regardless of where in the journey the end user is situated: in the street, in the underground, in a plane.) That connectivity should also be a connectivity to the Internet-at-large, not just connectivity to a local service provider, because in multi-modal transportation a variety of providers are involved and they are all connected to the Internet. Finally, the end user should use that connectivity on a portable device that s/he carries permanently during the entire travel. The portable device is most often a smartphone but several possibilities exist: a laptop, a smart wristband or watch, glasses for VR and more.
- The service providers and authorities that are involved in multimodal commuting must be connected to the Internet and must offer schemes of sharing the data with other providers.
- The technologies used in Connectivity should be mainly wireless links: cellular systems (3G, 4G, 5G and 6G in the future); V2X and ITS-G5, WiFi hotspots and ad-hoc networks. In certain cases wired technologies such as Gigabit Ethernet must be used, for example in waiting areas (lobby, lounge, bench, platforms, and more).
- However, the use of a common, fast and reliable communication technology such as 5G, will greatly improve and facilitate the materialization of a truly multimodal journey, hence using connectivity as a federating power to enable multimodality.
- Advanced webservice technologies should be used for sharing and aggregating data between service providers such as to offer a single common and homogeneous interface to the end user, despite the fact that data might be represented differently at each provider.
- For the Digital Twin aspects, the connectivity role requires particularly important characteristics: high bandwidth for sending 3D videos and holograms, low latency to allow remote actuation and realistic feedback, haptic and tactile.

IV. ISSUES

The characteristics of the current communication systems are likely not able to accommodate enormous data traffic that might be necessary in the realistic representation of numerous and dynamically interacting Digital Twins in support of multi-modal transportation. Holoportation and similar use-cases still are a remotely considered use-case, for example in 6G.

V. EXPECTED EVOLUTION OF DEVELOPMENT

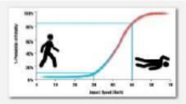
It is expected in the near future that remote presence, rather than travelling, will become a stronger necessity. However, travelling is still an important mobility activity that is highly desirable. To achieve the universal travelling one is used to prior to COVID situation, it is expected that digitalization technologies will be used extensively. Under the current rate of evolution of bandwidth and latency requirements (e.g. the linear and timed evolution of 2G..5G) the classical technology will probably be doubled by other means of significantly increase bandwidth and reduce latency. These means include, but are not limited to: extensive use of simultaneous communication media, quantum networking and more.

Further 5G (and 6G in the future) infrastructure deployment to significantly contribute to overcoming current issues and enabling multimodal mobility services.

I. KEY OBJECTIVE OF THE USE CASE (MAIN POLICY ASPECTS)

Nearly 21% of all traffic fatalities in the EU are pedestrians. Most fatalities, severe and slight injuries to pedestrians and cyclists occur in urban areas. Motor vehicles (cars, lorries, and buses) account for over 80% of vehicles striking pedestrians. Crashes involving pedestrians and cyclists occur frequently at facilities designed for pedestrians and cyclists such as pedestrian crossings, cycle tracks, and cycle lanes. This means that these facilities are not necessarily good enough to prevent crashes. However, pedestrian crossings might also be the location at which roads are most often crossed.

It is been widely demonstrated that the probability of death and serious injury in pedestrians accidents increases exponentially with the vehicle speed.



Key Objective: to reduce and mitigate the potential points of conflict where crashes involving pedestrians usually occur in cities. Determine the role of communication technologies and digital, detection and positioning technologies to contribute to the reduction of these accidents. For this purpose, the analysis focuses on pedestrians in cities in general and accidents in pedestrian-crossings and jaywalking.

Use case 1: pedestrian warning in vehicle by a warning to the driver on functional safety QM level, e.g. done by acustic/visual warning to the driver.

a) at pedestrian crossing
b) anywhere

Use case 2: vehicle´s active intervention (braking/steering) to avoid a pedestrian´s accident involving functional safety level A-D[1]

a) at pedestrian crossing
b) anywhere

Use case 3: vehicle´s presence warning received on the pedestrian´s mobile device.

The overall public road safety is lying in the sovereign responsibility of public authorities. In our case the pedestrian safety on urban roads is in the responsibility of the cities road authorities.

II. CURRENT STATE OF THE ART. LIMITATIONS

Currently, actions for solving run-over pedestrian accidents mainly focused on measures on the physical infrastructure, such as those derived from road traffic calming, enhancement of visibility in spaces of interaction, or increasing awareness of the presence of pedestrian to drivers by means of illumination. Given the use of smartphones by pedestrians when crossing a street (jaywalking or smartphone zombies), latest implementations[2] aim at alerting them in the proximity of points of conflict or ped crossings.

From the point of view of the systems installed in vehicles, as of 2022 new safety features conceived for further protection and detection of pedestrians will be mandatory for new vehicles (General Safety Regulation EU 2019/2144, GSR). Among others: (i) head impact zone enlargement for pedestrians and cyclists -safety glass in case of crash (cars and vans); (ii) vulnerable road user detection and warning on front and side of vehicle (trucks and buses); and, (iii) vulnerable road user improved direct vision from driver's position (trucks and buses).

More relevant is the prevision provided for in the GSR to mandate advanced emergency braking for pedestrian and cyclist in new cars and vans by 2024. Such systems employ in-vehicle perception sensors like automotive radar, camera, LiDAR to monitor the proximity of the pedestrian in front and detect situations where the relative speed and distance between the vehicle and the pedestrian suggest that a collision is imminent. In such situation, if the driver does not react to the system's warning alerts, emergency braking will automatically be applied to avoid the collision or at least to mitigate its effects. As stated in the UNECE technical regulation, there are some restrictions for the

functioning of the system, mainly regarding environmental conditions (light, rain, etc…), and up to a vehicle speed of 60 km/h.
According to European project PROSPECT in-vehicle perception ADAS can address 55% of vehicle vs VRU crashes[3]. Therefore, some limitations of in-vehicle sensors and systems can be concluded:

- scenarios in non-line-of-sight conditions
- harsh weather conditions;

[1] According to functional safety concepts SOTIF ISO 21448:2019 and in-vehicle functional safety levels QM, A-D according to ISO 26262

[2] https://www.reuters.com/article/us-southkorea-smartphones-crossing/south-korea-radar-and-thermal-camera-system-warns-smartphone-zombies-of-traffic-idUSKCN1R0029

[3] European H2020 research project PROSPECT, PROactive Safety for PEdestrians and CyclisTs, analyse and tested in-vehicle perception ADAS to protect VRUs, finalized 2018. Deliverable D2.3 can be found here: https://ec.europa.eu/inea/en/horizon-2020/projects/H2020-Transport/Safety/PROSPECT

- vehicle speed relative to distance between vehicle and pedestrian;
- Participant intention not detected or misinterpreted lack of physical measures.

III. CONNECTIVITY ROLE. TECHNOLOGY

Communication technologies could play an important role in increasing time and distance for users´ reaction, as well as tackling some of the limitations and constraints of other technologies and physical measures. Many of the current (and likely future) issues relate to the use of smartphones by pedestrians while walking roads or crossing streets. Although this behavior clearly imposes a risk on road safety (users distraction), it also poses an advantage since these communication devices can be a mean to address conflicts.

In this regard, some **research studies**, for example Bagheri et al (2014)[4], concluded that, since smartphones do not support the IEEE 802.11p amendment (which is customized for vehicular networking), the approach should utilize cellular technologies, 3G and LTE. Hussein et al (2016)[56] proposed an application using broadcasting to exchange data among VRU and vehicles. Anaya et al (2014)[7], carried out demonstrations making use of dedicated Wi-Fi networks. ETSI is also working in VRU ITS applications related to awareness, definition of use cases, and definition of Functional Architecture and Requirements (in particular Technical Reports TR 103 300-1 and ETSI TR 103 300-2[8]).

VRUITS EU funded project pointed out some challenges for VRU devices: power consumption, context sensitivity, channel congestion, standardization and security of messages.

The above studies are based on concepts were the pedestrian´s mobile phone place an active role. This assumes the pedestrian carries a mobile phone and that the necessary consent regarding GDPR is given to activate the service.

An alternative approach is to use the collective perception service. This is a service based on infrastructure and vehicles sharing their observations of all objects including VRUs/pedestrian by broadcasting detected objects with Collective Perception Messages (CPM), e.g. see ETSI TR 103 562[9]. CPM is tested and implemented in prototype vehicles of different OEM in project IMAGinE[10]. Advantages of this concept are good pedestrian´s localization by vehicles and optimal positioning of the pedestrians by smart infrastructure, interoperable solutions for different OEM, opportunity to achieve higher levels of functional safety, short service level latency, reliable pedestrian detection in Non-Line-of-Sight conditions by multiple sources like by different vehicles and infrastructure independent of each other.
Such a CPM based service is expected to support use case 1,2,3. CPM based pedestrian protection solves two major shortcomings of sensor based ADAS. First is the unknown pedestrian intention, the second are obstructed pedestrians. When looking at the pedestrian from a different angle than the vehicle that might have a collision with this pedestrian helps solve these two problems.

Some **real tests** have been carried out during the last year. In Australia, Cohda Wireless trialed its vehicle-topedestrian (V2P) technology on city streets for the first time leveraging cellular mobile networks[11]. In Spain, a privatepublic app[12] was launched in 2015 aiming at connecting VRU with vehicles, mostly in interurban roads, so as to send alerts to both users and mitigate potential crashes using cellular mobile networks. More than 50.000 warnings in real traffic conditions have been transmitted with an average latency of less than 200 msec.

More recently, 5GAA has conducted some tests using C-V2X technology, successfully concluding the possibility of connecting VRU and vehicles through PC5 enabled smartphones. Main findings are related to the need of accurate position (0.1m) and path prediction for reliability and avoidance of false warnings. Localization technologies to improve positioning: Ultra Wide Band UWB technology, combination of dynamic sensors and GNSS in vehicles by sensor fusion, infrastructure based positioning.

4 Bagheri, Mehrdad & Siekkinen, Matti & Nurminen, Jukka. (2014). Cellular-based Vehicle to Pedestrian (V2P) Adaptive Communication for Collision Avoidance. 10.1109/ICCVE.2014.85.

5 Hussein, Ahmed & Garcia, Fernando & Armingol, J.M. & Olaverri Monreal, Cristina. (2016). P2V and V2P Communication for Pedestrian Warning on the basis of Autonomous Vehicles.
6 .1109/ITSC.2016.7795885.

7 Anaya, José & Merdrignac, Pierre & Shagdar, Oyunchimeg & Nashashibi, Fawzi. (2014). Vehicle to Pedestrian Communications for Protection of Vulnerable road Users. IEEE Intelligent Vehicles Symposium, Proceedings. 1037-1042. 10.1109/IVS.2014.6856553.

8 https://www.etsi.org/deliver/etsi_tr/103300_103399/10330001/02.01.01_60/tr_10330001v020101p.pdf &

9 Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Analysis of the Collective Perception Service (CPS); Release 2

10 See https://imagine-online.de/home/

11 https://www.spatialsource.com.au/unmanned/mobile-technology-boost-pedestrian-safety

12 Comobity: http://www.dgt.es/es/prensa/notas-de-prensa/2015/20151112-App-Comobity-DGT.shtml

IV. COMMUNICATION INTEROPERABILITY, SPECTRUM AND COEXISTENCE ISSUES

- Market penetration: how to obtain the pedestrian´s data: position and intention.
  - In case of using mobile devices e.g. smart phone
    - _the need of dedicated apps. This may constraint scalability and interoperability (at the high level with different apps in different cities and different mobile network operators MNO), especially on the pedestrian usage and acceptance. However, many pedestrians may currently use existing mobility apps while walking, which can be used to reach them and enlarge penetration rates.
    - Availability of short range technology in mobile devices.
  - In case of CPM based services, the service and short range communication technology would need to be implemented in vehicles and/or road infrastructure.
- Interoperability:
  - In case of using smart phone: from the VRU point of view, it can only be reached either by enabling a short range ad hoc network for which the pedestrian mobile phone should have the necessary security credentials and enroll, or via the cellular mobile network. Since smartphones use the former by default, it would be more efficient to leverage this network to exchange data and information, hence future projects might focus on how to overcome this point.
  - In case of using CPM in vehicles and / or road infrastructure and short range ad hoc network: security credentials are available if already other V2V, V2I services are supported. The service is designed to run over short range ad hoc communication. However, no fundamental restrictions exist to use it over other types of communication, e.g. long range (cellular) communication. In the latter case, the same interoperability issues as mentioned for the case using smart phones apply here.
- From the vehicle side, the transmission of messages could be done using short range technologies or cellular ones, and considering how to reach the pedestrian´s involvement and the use of smartphones and their communication technologies. However, the advantage of vehicles compared to mobile devices is the improved positioning in using the in-vehicle dynamic sensors and GNNS compared to mobile devices. In addition, digital developments and applications in cities, namely 5G or edge computing, might bring improvements and benefits in the short-term. A critical point is to avoid false warnings / false positives as a service will not be accepted otherwise. On top for higher levels of automated driving the performance requirement increases, e.g. as unnecessary hard braking can be a safety risk itself.
- For use case 1 and 2, requirements on service level latency including the communication latency are high and around 100ms in case a collision risk should be mitigated.
- The GNNS (Gallileo, GPS, GLONAS, BeiDou) location/positioning approaches may contribute to safety issues in critical situations, limited due to its intrinsic error. For an information GNSS alone is enough. For warnings and avoidance of critical situations an accurate positioning may be needed. State of the art GNNS has positioning issues in some urban environments.
- On spectrum aspects, the high density of users in cities might imply a congestion of the safety-related band in detriment of quality of service, or even affecting other applications using that band in case pedestrian´s mobile device send e.g. VAM[13]. Some actions on channel load reduction (clustering) might therefore be needed.
- For CPM service spectrum needs of 20 MHz to 30 MHz in 5.9 GHz[14] depending on the environment are foreseen if one short range communication technology is used.
- Spectrum considerations should be included in pre-deployment projects.

The difficulty in reaching all users in all situations may determine the supplementary role of communication technologies for this use case, since it may not successfully be used in every situation, especially in critical conflicts. An optimal approach might build on communication technologies for warning and distant alerts using cellular mobile networks like use case 3, while relying in a good combination of physical measures, sensors in vehicles plus Collective Perception by vehicles or road infrastructure and/or detection sensors for critical points (i.e. ped crossings). It may be more efficient to alert drivers (connectivity as an additional sensor) according to use case 1 rather to pedestrians according to use case 3, especially in high-dense scenarios like cities.

Interoperability solutions meeting the use case 1, 2, 3 requirements should be examined.

[13] VRU Awareness Message (VAM) according to , ETSI TR 103 300-1 Ver. 2.1.1, TS 103 300-2 Ver. 2.1.1, TS 103 300-3 Ver. 2.1.1
[14] See CAR 2 CAR Communicatin Consortium (car-2-car.org) "Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Cooperative Automated Driving"

V. EXPECTED EVOLUTION OF TECHNOLOGY

- V2X as an additional sensor integrated in in-vehicle perception sensors as primary source in points of conflict/critical points building C-ITS enhanced ADAS → pedestrian in urban environment
- Deployment of physical measures using digital technologies and connectivity in critical points/sections of streets and roads (crossings). A preference for sending messages to vehicles rather to pedestrians.
- Some points to be taken into account in future developments:
  - Different needs and categories depending on the road scenario: Rural roads vs. cities
  - Combinations of solutions (fusion of information and collective perception):
    a. sensor detected the ped → no connectivity is needed → improved by collective perception
    b. sensor no detects/fails → connectivity role → how to reach peds
       i. Modification on the hardware of the phone and position accuracy target reached with phones?→ V2X tech on phones sending VRU Awareness Message (VAM)
       ii. Edge computing, AI, MEC,…
       iii. Collective perception (fusion of info + short range comm) for vehicles and / or for smart road infrastructure
       iv. Alerting vehicles vs alerting pedestrians (related to road scenario)
       v. Active intervention in vehicle dynamics to protect pedestrians with V2X enhanced ADAS

The cities road authorities need to be included in pre-deployment projets.

Quantified objectives for projects addressing these use cases	1. Scale: Number and proportions of Vulnerable Road Users, which could be covered with project if deployed massively. 2. Number of pedestrian´s life's saved/number of severe accidents avoided/ number of accidents avoided with use case "VRU. Pedestrian protection in urban areas" if project would be deployed en mass. 3. Quantified radio spectrum needs with selected communication technology for this use case if deployed en mass. 4. Quantified communication performance: measured performance in end to end latency/bandwidth/reliability compared with use case requirements.

ANALYSIS OF PRIORITY TRANSPORT SERVICES 04/03/2020
USE CASE: Emergency braking-dangerous situation-traffic jam Rev05
WG6 CCAM, Connectivity and Digital Infra.

I. KEY OBJECTIVE OF THE USE CASE (MAIN POLICY ASPECTS)

[source: EuroNCAP] "Many accidents are caused by no braking, late braking and/or braking with insufficient force. A driver may brake too late for several reasons: he is distracted or inattentive; visibility is poor, for instance when driving towards a low sun; or a situation may be very difficult to predict because the driver ahead is braking unexpectedly or a pedestrian crosses the street without paying attention. Most people are not used to dealing with such critical situations and do not apply enough braking force to avoid a crash or do not brake at all because there is not sufficient time to react." However, when traffic instabilities are detected, there is much to gain to inform driver ahead of time to avoid any hard braking maneuvers.

High level objectives: Avoid risks associated with hard braking of the preceding vehicles:

1. **Safety**: reduce sudden hard braking due to obstacle or/and due to traffic jam build up
2. **Congestion**: mitigate or damp shockwaves caused by traffic flow instabilities
3. **Environment**: smoothen traffic flow to avoid unnecessary acceleration/deceleration

II. CURRENT STATE OF THE ART. LIMITATIONS.

The use case "Emergency braking-dangerous situation-traffic jam" combines well known highway situations during which traffic manager can observe and even predict traffic flow disruption but individually drivers do not see them until very late (having sight on only up to five cars ahead). The use case is mostly triggered in dense traffic situations presenting vehicle flow instabilities; which are well-studied from a traffic management point of view.

From a vehicle centric point of view, the use case is being (partly) addressed by proven vehicle solutions such as Forward Collision Warning with or without Automated Emergency Braking (AEB) as well as Adaptive Cruise control (ACC).

AEB uses vehicle sensors to identify potential risks in front of the car. This information is combined car sensors such as speed and trajectory to determine whether or not a critical situation is developing[1]. FCW alone and FCW with AEB reduced rear-end striking crash involvement rates by 23% and 39%, respectively[2]. FCW and AEB is part of the GSR and will be installed on all new vehicles as of 2022.

Euro NCAP describes three different driving scenarios: (i) driving towards a stationary vehicle (30-80 km/h), (ii) closing in at a slower vehicle in front (30-80 km/h) and (iii) following a car in front which suddenly starts braking (50 km/h, gentle and harsh braking). Other scenarios are linked to unpredictable events such as sudden crossing of animals, children, or fallen objects, etc. which we will keep out of the scope of this description. Current AEB shows limitations with regard to the high-level objectives above: AEB triggers are not particularly suited to address highway traffic jam situations. Indeed, AEB is seen as a last resort function used in emergency situations; when possible, vehicles should not break the flow of traffic but rather smoothen traffic up to the end-of-queue position.

Beyond AEB, Adaptive Cruise control (ACC) is particularly well suited to handle higher speed scenarios on highways helping drivers to respond smoothly to speed variation.

III. CONNECTIVITY ROLE. TECHNOLOGY

Connectivity role in the "Emergency braking-dangerous situation-traffic jam" use case is mainly introduced with Day-1 use cases "Traffic Jam warning", "End-of-Queue warning" and/or "Emergency Electronic Brake Lights (EEBL)". There are two complementary "detection and dissemination" approaches: Centralised or Decentralised. In both cases, a traffic disruption is detected thanks to road sensors, vehicle sensors and/or smart devices. If present, road sensors are directly relaying this information to the traffic manager. If equipped with a radio, vehicles can also notify electronically a hard-braking maneuver or sudden variation of speed and slower traffic. Vehicles can report both via short range or via the vehicle back-end (digital twin).

Short range data is sent to neighboring vehicles which complements efficiently FCW/AEB and ACC as

[1] Source: EuroNCAP

[2] Source: IIHS https://orfe.princeton.edu/~alaink/SmartDrivingCars/Papers/IIHS-CicchinoEffectivenessOfCWS-Jan2016.pdf

an extra set of data. It contributes to predict the exact geolocation of hard braking and can prepare the vehicle functions to a possible braking actuation up to 20 sec ahead of the end-of-queue. On the other hand, back-end data is promptly analyzed and communicated to oncoming vehicles on the road and to the relevant traffic manager.

At the traffic management center (or other similar service providers), data gathered from multiple vehicles are used to track and predict the traffic flow and the evolution of the end-of-queue geolocation.

Warnings sent to oncoming vehicles (by the traffic manager or other similar service providers) help to moderate and gradually decrease the speed of vehicles between 30 sec to 3 min ahead of the traffic jam. In this case, the original EEBL warning rather contributes to an (automated) speed advice use case ahead of the traffic disturbance.

The information is traditionally disseminated to vehicles via broadcasting (e.g. RDS-TMC/ DAB/ Satellite/ MBMS/ etc.) and/or via connected services (operated by the OEM, traffic managers or other parties). It can also be done directly via a Road-side unit (RSU) equipment (V2I), if present on that part of the road.

By having a large data sampling and a wider dissemination, this use case eventually helps the traffic manager to control efficiently the traffic flow and avoid traffic instabilities[3].

IV. COMMUNICATION INTEROPERABILITY, SPECTRUM AND COEXISTENCE ISSUES

The "Emergency braking-dangerous situation-traffic jam" Use Case comes with on major challenge challenge: penetration rate: on the detection side, the accuracy of the position of the end-of-queue is highly dependent on the penetration rate of equipped vehicles. Fortunately, traffic managers (or third party services) can, out of several data points, predict the evolution of the position of the end-of-queue. On the other hand, EEBL messages will need to wait for V2V penetration rates above a certain threshold to start making an impact[4].

The above shows the importance to invest short-term in the back-end solutions while keeping a long-term impact strategy with the short-range technology. Investment in the back-end solutions would also address the interoperability challenge at service level while acknowledging that LTE-V2X (PC5) and 802.11p are not interoperable at radio level and will co-exist in the 5.9GHz band[5].

From a mobile network point of view, data traffic generated from and to connected vehicles would be negligible even with current state-of-the-art mobile networks.

V. EXPECTED EVOLUTION OF DEVELOPMENT

There is a clear evolution of the technology related to the use case. The roadmap may possibly fork between V2N and V2I based services depending on the roadside investment or/and the public-private agreement between road and mobile operators:

- **Sensor based**: AEB/FCW/ACC
- **Map based**: intelligent ACC
- **V2V-based communication**: EEBL/CACC
- **LTE-V2N & Cloud-based**: End-of-queue warning, Traffic Management monitoring, Traffic

smoothing, Advanced speed advise, shock wave damping, etc.

- **V2I-based communication (if RSU network is present)**: Dynamic Speed Harmonisation, Advanced ramp metering, HOV lanes,
- **5G-V2N & MEC-based**: Low latency for cloud services above, Highway group start, etc..

The additional benefit of 5G V2N is essentially guaranteed QoS along with low latency.

---

[3] Traffic flow fundamental diagram https://en.wikipedia.org/wiki/Fundamental_diagram_of_traffic_flow

[4] Y. Liu, W. Zhang, Z. Wang and C. Chan, "DSRC-based end of queue warning system," 2017 IEEE Intelligent Vehicles Symposium (IV), Los Angeles, CA, 2017, pp. 993-998. / Typical vehicle inter-distance on a dense highway is 50m, 10% penetration rate would represent a typically inter-distance of 500m between sender and receiver at the time of the EEBL and around 100m end-of-queue uncertainty.

[5] See https://5gaa.org/news/an-assessment-of-lte-v2x-pc5-and-802-11p-direct-communications-technologies-for-improved-road-safety-in-the-eu/

I. KEY OBJECTIVE OF THE USE CASE (MAIN POLICY ASPECTS)

Merging lanes is the single situation where drivers needs to be attentive of intersecting traffic in a highway environment. Which is why this situation is subject to similar types of problems that otherwise is common in non-highway intersections. According to DOT HS 811366[1] the most common critical reasons for intersection related crashes are recognition and decision errors. These types of human errors are probably the same in the merging lanes on highway scenario.

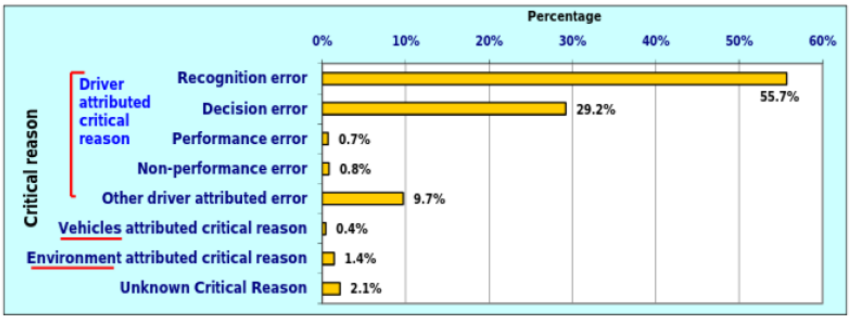


Figure 6: Distribution of critical reasons for intersection-related crashes
Data Source: NMVCCS 2005-2007

It is expected that further developed Advanced Driver Assistance Systems (ADAS) and eventually highly automated driving, will continue to increase traffic safety by reducing the impact of human errors[2] such as the ones above. Merging into traffic when highway lanes merge is a maneuver which will definitely be subject for ADAS evolution as well as being a target for automation.

Driver support and automation also has the potential to improve traffic efficiency and reduce environmental impact by reducing the disturbances and congestion created by the situations that arise due to the recognition and decision errors of the human drivers.

II. CURRENT STATE OF THE ART. LIMITATIONS.

This use-case will be from the start in most cases be implemented using in-vehicle sensors to solve the millisecond safety critical decisions, for the foreseeable future at least.

The limitations of this solution are:

- Decisions are based on visually observable knowledge of the current traffic situation only. It will not be able to handle other vehicles intentions that have not yet been implemented into action.
- It is limited to line of sight for the vehicle sensors, even though sensor technology is evolving at a rapid pace there are physical limitations which will be hard to come around.

III. CONNECTIVITY ROLE. TECHNOLOGY

Adding connectivity to the use-case could in the short term help increase traffic efficiency by affecting the tactical planning of a vehicle heading into a lane merge, adapting speed to fit into the overall traffic flow. There is also a cumulative effect in that even with quite low vehicle penetration, the equipped vehicles behaviour will affect surrounding road users.

For connectivity to add to the safety aspect is seen as a much more long-term objective. Vehicles will rely on in-vehicle sensors to take the millisecond decisions in a lane-merge situation for the foreseeable future.

Connectivity can be added in several different possible variations leveraging both long-range cellular and short-range ad-hoc communication methods both in isolation and combined as a hybrid. Some possible configurations are:

1. Vehicles exchanges state information (CAM) directly V2V to determine a suitable speed into the merge.
2. Central traffic management supplies a guiding speed to vehicles over a cellular network and/or a road-side unit well ahead of the merge.
3. Road-side units acts a bouncers for CAM to extend line of sight for vehicles.
4. Road-side units aggregates CAM to determine and distribute guiding speeds to vehicles further back.

Even in the case of introducing road side equipment it can selectively be rolled out on selected locations and provide return on investment as soon as properly equipped vehicles starts using it. This will enable a staged introduction where the locations with the most problematic lane merging setups can be targeted first.

IV. COMMUNICATION INTEROPERABILITY, SPECTRUM AND COEXISTENCE ISSUES

Based on our knowledge the following areas could need further work:

- Communication standards for intercommunication between road-side units, including spectrum and co-existance.
- Communication standards and interoperability for “bouncing” C-ITS messages.

V. EXPECTED EVOLUTION OF DEVELOPMENT

In-vehicle sensor technology will continue to evolve becoming more powerful and intelligent, which will push the boundaries of the ability of vehicles to solve this use-case.

Connectivity will add a new dimension of input to the vehicle navigating through the use-case which makes functional safety aspects on external data and communication important.

As penetration rate of automated vehicles increase more control can possibly be handled over to central traffic management. End to end redundancy in communication technology could then become an important tool to address functional safety.

1. NHTSA DOT HS 811 366 “Crash Factors in Intersection-Related Crashes: An On-Scene Perspective”
2. J. Nilsson, J. Silvlin, M. Brannstrom, E. Coelingh, and J. Fredriksson, “If, when, and how to perform lane change maneuvers on highways, ”IEEE Intelligent Transportation Systems Magazine, vol. 8, no. 4, pp.68–78, October 2016.

ANALYSIS OF ADVANCED TRANSPORT SERVICES:

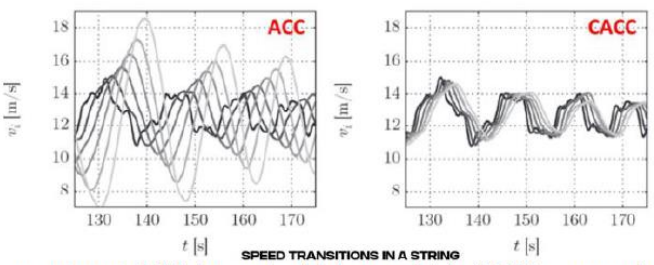
March,4th 2021
Rev5
DGCNECT-H5

Use Case: Platooning
WG6 CCAM, Connectivity and Digital Infra.

I. KEY OBJECTIVE OF THE USE CASE (MAIN POLICY ASPECTS)

Platooning = a group of two or more automated cooperative vehicles are in line, maintaining a close distance using wireless communication (V2V), typically such a distance to reduce fuel consumption by air drag, to increase traffic safety by use of additional ADAS-technology, and to improve traffic throughput because vehicles are driving closer together and take up less space on the road.
Platooning requires cooperative automation on different hierarchical levels, encompassing automation of strategic, tactical, as well as operational functionalities, based on reliable short-range vehicle-to-vehicle and vehicle-to-smart-infrastructure communications (V2X), and long-range back-office communications.
Aiming for Europe-wide deployment of platooning, ‘multi-brand’ solutions are paramount. It will enable a single truck to form a platoon with any other truck. In a next phase, any 4 wheel vehicle can form a platoon with other 4 wheel vehicle.

- Interoperable platooning — when forming a scalable, multi-brand convoy – the vehicles must be compatible to ensure correct and safe operation.
- Safe Platooning —designing fail-safe and fault tolerant mechanisms is a priority to include safe interaction both within the platoon and with other road users using secure wireless communication. E.g. ENSEMBLE will approach the road authorities to jointly define road approval requirements taking into account the impact of platoons on the road and infrastructure.
- To enhance safety and efficiency, see speed improvements through speed harmonization of cooperative ACC (C-ACC) compared to ACC of following vehicles. C-ACC is based on vehicle-to-vehicle communication able of building convoys with non-automated vehicles. Platooning is a subclass of C-ACC applications with higher requirements on communication and safety as well as security.



SPEED TRANSITIONS IN A STRING

- Platooning depends on automated driving and vehicle-to-vehicle (V2V) communication combined to cooperative automated driving.
- As platoons are connected to a backend it is connected and cooperative automated driving.

II. CURRENT STATE OF THE ART. LIMITATIONS

- Truck platooning was demonstrated in 2016 with the European Truck Platooning Challenge[1] for single brand truck platooning using ITS-G5 short-range communication by six truck OEMs[2].
- Multi brand truck platooning is in research and standardization process. EU H2020 "Ensemble" Six European truck OEM implement dense truck platooning with multiple brands in a field test in 2020. In 2021 the multi-brand platooning will be demonstrated in a public demo. In Ensemble DSRC (ITS-G5) communication is used for direct V2V communication in 5.9 GHz safety spectrum band.
- Convoys of constantly distanced automobiles based on direct message exchanges on IP (not via RSU, not V2X, but on TCP with RTMAPS; not based on camera video images, nor on lidar) were demonstrated in 2019 and 2020 at end of EU project "AUTOPILOT", with 3 self-driving communicating Renault Twizies. https://youtu.be/QI6OhF9w93o?t=144

- Public transport trials with convoys deliver additional experiences.
- For interoperability the V2X messages needs to be standardized and the short range communication technology aligned with a harmonized communication profile and standards.
- https://platooningensemble.eu/
- The safety functions in Platooning requires short-range ad hoc communication with short latency.

[1] European Truck Platooning Challenge - Connected Automated Driving Europe

[2] OEM original equipment manufacturer of vehicles

- Platooning is in standardization in ETSI TR 103 298 "Intelligent Transport Systems (ITS); Platooning; Pre-standardization study"
- After Ensemble ends in 2021, ETSI Standardization needs to be finalized.
- In case of interference into the direct ad hoc short range communication by e.g. jamming, problems can occur and such problems needs to be taken into account during the safety assessment

III. CONNECTIVITY ROLE. TECHNOLOGY

- The direct short range communication of e.g. sudden braking of the first truck with all other platooning trucks as well as any truck in the platoon to the others of its capabilities e.g. max deceleration, is the key to solve delays of the following vehicles whenever a change of vehicle dynamic is necessary. This enables to drive with shorter distance to each other.
- Very short communication latency of 5ms max is required.[3]
- For Platooning V2X is integral part of the Functional Safety Assessment. Hazard Analysis and Risk Assessment study resulted in ASIL C level on V2X communication. https://platooningensemble.eu/storage/uploads/documents/2019/10/04/ENSEMBLE-D2.11-Fist-version-Hazard-Analysis-and-Risk-Assessment-and-Functional-Safety-Concept_Under-approval-by-EC.pdf
  Spectrum considerations should be included in pre-deployment projects.
- Platooning as a use-case for V2V networking is also described in Section 3.1 "V2V" of the work in progress draft-ietf-ipwave-vehicular-networking-19, publicly available.

IV. ISSUES

- A certain minimum distance between platooning vehicles needs to be ensured to solve the platoon in case of safety issue.
- As other vehicles have issues to exit or enter a highway if a platoon is present, the platoon might has to solve for highway exists or entrances.
- The short-range communication for platooning needs to be reliable and is part of the functional safety evaluation. Reliability can be enhanced by e.g.

- Exclusive usage of one radio channel. To reach higher reliability the radio channel used for platooning might need additional protection measures e.g. separate channel for platooning, protection from adjacent channel interference.
    - Retransmission of communication messages can increase reliability.
    - With a redundant spectrum for short range communication (at least 500 MHz apart from 5.9 GHz) the reliability in sense of functional safety could be increased so that the minimum distance between platooning vehicles can be reduced further.
  - A second safety short range communication technology in combination with a second radio spectrum could enhance functional safety level.
- Sufficient spectrum:
    - Spectrum needs study[4] recognize the minimum need for 10 MHz of spectrum in 5.9 GHz in case a few platoons are in communication distance to each other.
- Higher bandwidth: Some needs of communication between vehicles might be related to using a higher bandwidth. Currently, operating 802.11 in OCB mode (.11p) on single channels of 10MHz width offers approx. 16Mbit/s bandwidth. This is way too low for transmitting between cars richer data, such as a raw lidar data. It might be that in a convoy only the lead vehicle be equipped with an expensive lidar, and transmit that data to the other vehicles in the convoy which might not have a lidar. Other than the lidar data, there might be other needs of higher than 16mbit/s flows between the cars. The group at IEEE that develops the 802.11bd protocol considers these needs. It might be appropriate to consider the use of 802.11bd (an evolution of 802.11p for higher bandwidth) in a convoy.
- EU project "Autopilot" considers following issues:
    - One of the limitations is related to the demonstrated size of platoon in EU project "Autopilot": only 3 vehicles were involved. The communication system (IP hop-by-hop routing, and not single subnet V2X) might scale up to hundreds of vehicles, but only 3 were tested. A need is to test more vehicles; ideally a demonstrator should exceed the typical radio range of ITS-G5 (e.g. exceed 1km), such as to expose the fact that even when the Lead vehicle the last vehicle are not in range they can still communicate.

[3]

[4] See CAR 2 CAR Communicatin Consortium (car-2-car.org) "Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Cooperative Automated Driving"

    - Other limitations relate to the risks exposed during extensive testing: some times some vehicle might leave the convoy. It was not immediately clear who was the cause: the comm system, the GPS, the automation software, or other things; but these events did happen and must be taken into account.
    - The vehicles were connected amongst themselves on IPv6 on 802.11p-OCB (11p) at 5.9GHz, and were connected on IPv4 on 4G to the Internet; that is a drawback in that IPv4-IPv6 protocol translation might be necessary for full connectivity; ideally only IPv6 would be used, because it is the future version of the Internet protocol (remark the mandate of supporting IPv6 by 5G networks licensee, in France). Additionally, there are some problems in supporting IPv6 connectivity to the *automobiles* (groups of computers) by the 4G and 5G networks, even though these networks might support ok single computers on IPv6 (a person's smartphone or a person's laptop).
    - This networking technology for platooning on AUTOPILOT works on a linear kind of network topology. This would not work on multiple lanes, where each lane advances at a different speed. A scalable networking technology for multi-lane variable speed platooning is necessary in order to advance in the pursuit of the holy grail of solving the traffic jam problem.
    - The role of roadside infrastructure to facilitate the in and out of the platoon.

V. EXPECTED EVOLUTION OF DEVELOPMENT

Second safety ITS radio band besides 5.9 GHz Different models for providing redundancy within radio spectrum are possible like e.g. use of license and license-exempt spectrum, use of 60 GHz ITS band or additional ITS spectrum. Separate platooning lanes would solve the issue of often to solve a platoon at entrances/exits, and thus requiring a redesign of the physical infrastructure or traffic flow reorganization. Principle of truck platooning can be used for any vehicle platooning, e.g. other commercial vehicle, passenger cars. Agricultural vehicle platooning. Special vehicle platooning (e.g. snow cleaning vehicles). Public Transport such buses, pax taxis/shuttles (automated)
Quantified objectives for projects addressing this use cases 1. Scale - Size of a convoy of vehicles (platoon): 2. Validation – Communication performance: Radio Spectrum for platooning should be considered for pre-deployment projects as an important aspect to study (e.g. max. channel loads, minimum spectrum needs, max adjacent band interference, required latency and communication range in dependency of communication technology / channel load / channel shared with other vehicles or exclusive usage for platooning). 3. Validation – Reduced energy used.

ANALYSIS OF ADVANCED TRANSPORT SERVICES

March 4th 2021
Rev5
DGCNECT-H5

Use Case: Teleoperation of vehicles. High Level Description

WG6 CCAM, Connectivity and Digital Infra.

I. KEY OBJECTIVE OF THE USE CASE (MAIN POLICY ASPECTS)

Tele-operation of vehicles can be categorized[1] based on the role of the remote operator when engaging in the act of driving:

- ToV Type 0: role of **Monitoring,** i.e. no role in the act of driving.
- ToV Type 1: role of **Dispatcher**, strategic level operations of driving,
- ToV Type 2: role of **Indirect Controller**, strategic and tactical levels.
- ToV Type 3: role of **Direct Controller**, in this case, the in-vehicle user or system is not engaged in the act of driving. Only when a specific (or set of) maneuver is required.

Technically, Teleoperation is not a driverless system and, in fact, the vehicles themselves do not necessarily need to be capable of higher levels of automation. In ToV, the driving task is eventually always delegated to a human driver who takes the responsibility thereof. The motivation to push for teleoperation capabilities are related to reduction in operation costs, providing advanced services or building trust. Current applications take place in protected areas: in mining, or harbor logistics, etc.

As teleoperation can bring new businesses and services on open roads, it is subject to increased attention. Considering that technology matures very quickly and applications are expanding, the definition of a level playing field for Teleoperation may be as urgent than the one related to fully automated driving. ToV will eventually lead to policy gains in terms of productivity, safety, land use, environment, quality of life, or enforcement. In this regard, a series of measures that may help to enable further the development of Teleoperation on European Roads may include regulations, spectrum use and allocation or communication and connectivity requirements.

Key Objectives: to explore requirements and a framework of communication technologies and connectivity supporting ToV to help frame this mobility solution. Analyse the advantages of multi-purpose wireless networks deployment with defined requirements (coverage or QoS alongside roads).

II. CURRENT STATE OF THE ART. LIMITATIONS

Teleoperated Driving is a general term that can encompass many different levels of operation of a vehicle. The technology requirement is relatively well understood: (1) a reliable vehicle environment sensing platform with SoA in-vehicle sensors, (2) a reliable and responsive vehicle actuation (steering, braking, lights, etc) and (3) a reliable wireless communication between vehicle and controller. Security and trust plays an important role.

Teleoperation, in the form or remote monitoring, is common practice in automated public transports like metro or light rail. Remote operation is also an underlying requirement in operations of driverless shuttles e.g. the more-than-10-years operation of driverless shuttles in Rivium close to Rotterdam[2]. Other prominent examples of teleoperation consist of construction and transport vehicles in mines and harbors.

Teleoperation on open roads may appear faster than full automation. However, safety requirements for remote operation have not been laid down yet. As teleoperation technology matures very quickly and applications of ToV are quickly expanding to more open and public roads, the definition of a level playing field for Teleoperation may be as urgent than the one related to fully automated driving.

Open road Teleoperation will take place in gradually more challenging circumstances, e.g. in terms of road environment (protected, dedicated, limited, open, etc.). Depending on the deployment scenario, the roles and responsibilities can be quite various. The teleoperation service can be performed by many different actors from OEMs to fleet manager, site operator, or others. 5GAA has published a concise report to put a framework around this novel environment.

[1] https://5gaa.org/wp-content/uploads/2020/07/5GAA_XW5-200029_ToV_D1.1-Use-Cases-and-Technical-Requirements.pdf
[2] https://www.2getthere.eu/projects/rivium/

III. CONNECTIVITY ROLE. TECHNOLOGY

While in some limited cases, a dedicated wireless communication system may be appropriate. ToV Type 3 and ToV Type 2 defined in Section 3 of this TR, demand high network reliability that may not be achievable with the current 4G/LTE mobile network standard. ToV services increasingly relies on 5G mobile network technology.
It is obvious that any connected vehicle being remotely operated will require stringent guarantees of reliability and latency. 3GPP standard TS22.186 sets the radio requirements for remote operation of a vehicle. These requirements, among others, were used to design the 5G capabilities called URLLC.
The option to use non-public networks (NPN) has emerged, in some cases, with specific allocation of spectrum in the pioneer bands (3.x GHz), but this option is usually limited to specific geographical limits. In most cases, the option to rely on a NPN solutions is not possible. For instance, when ToV requires coverage over larger geographical areas and/or longer parts of a highway or a road network, the use of a Public Land Mobile Network (PLMN) is more appropriate.
Other 5G network capabilities are identified as important for ToV, e.g. the role of MEC application servers in order to reduce the data volume transmitted from the vehicle to the vehicle control centre
The concept of Predictive QoS is an important feature in 3GPP. Predictive QoS provides in-advance QoS degradation notifications to help the vehicle to decide whether it will be able to rely along its route on the ToV service (most of the time as a fallback service). Depending on QoS predictions, the vehicle may decide to revert to a lower level of automation, or, if the vehicle is empty, decide to re-route the vehicle or wait until network conditions are improving.

Typically, Teleoperators would sit in a control room. Distance of this room with the teleoperated vehicle is not relevant as long as QoS is preserved. One teleoperator may be in charge of multiple vehicles. Teleoperators can handover control to another teleoperator when necessary.
From an architecture point of view, a ToV Application Server would correspond with the OEM application server over a secured interface. The OEM application server uses the mobile network of choice and guarantees the required level of QoS with the teleoperated vehicle. In most cases, each entity is contractually binded to deliver the teleoperation service and maintain a SLA on its interfaces. More complex setups may require additional interfaces with the Road operator (urban management center, traffic management center, parking, etc.) or other service providers.

IV. ISSUES

As for any emerging market opportunities, the roles of the stakeholders is not clearly defined yet. It can be foreseen a first phase during which stakeholders will position themselves, test partnerships and refine roles and responsibilities in the ecosystem. This will first be done in closed or controlled ecosystems, then opening up gradually to new and larger partnerships. Operational processes and interfaces will need to be standardized if larger ecosystems are envisaged.

The balance between self-driving capability of the vehicle and the required level of Tele-operation is still to be investigated. In the majority of the cases, vehicles should be able to handle the situations on their own without the need for teleoperation. If the predicted QoS falls under a threshold, the vehicle will always be able to bring itself to a safe stop (fail-safe mode) or even continue its operation at lower speed (safe-operational mode) until the QoS is reestablished.

Solid safety treatment will have to be developed for unmanned ToV vehicles. This follows a similar process as the one developed for SAE Level 4 vehicles but adds the complexity of the variable QoS.

The regulatory aspect may become a challenging issue if larger scale introduction of teleoperation is introduced especially on public roads. If mass-produced vehicles are introduced in the ToV ecosystem, type approval or road safety discussions may need to be triggered, e.g. at UNECE WP29 and WP1.

Cross-border or cross-MNO operation would require improvement of the network reselection including IP continuity. If MEC is used, cross-MNO MEC may be required in case a vehicle falls back on an alternative RAN from another MNO.

Any sections of the road which recurrently experience lower quality will require vehicles to fall back on the on-board sensors and even on the driver if present. It is therefore important that, on road networks where ToV is foreseen, proper coverage is guaranteed for URLLC services; this generally means coverage with sub-6GHz equipment (e.g. at 3.x GHz).

On the spectrum need for this use case, it may be necessary to assess the allocation of protected spectrum resources in specific areas or along designated roads where teleoperation is planned.

Encourage the deployment of a multi-purpose wireless networks with defined requirements in terms of Coverage and, importantly, a guaranteed QoS along designated roads or road types where ToV is planned.

V. EXPECTED EVOLUTION OF DEVELOPMENT

The ToV services are expected to evolve at a higher pace than full automated driving fleet.

Low hanging opportunities already exist and are helpful to develop the technology and operational processes.

The ToV services are expected to evolve from dedicated controlled environment such as mining or harbors, towards lower speed services such as valet parking as well as short distance shuttle services then expanding to more comprehensive ToV service covering specific road sections where coverage can deliver the required QoS. The ToV services may target at first unique fleets, each covered by a single MNO, possibly supported by specific MEC resources. The ToV controlled center may initially need to be physically dependent of the MNO core network. But eventually as Multi-MNO MEC services are expanding, the ToV services may gradually detach from the needed network resources and start serving multi-OEM across multiple MNO networks in a flexible way.

11.3.2. WG6 : Project assessment criteria

Authors: Emmanuel Tricaud (Enterprise telecom Consultants), Bart Netten (TNO)

1 Introduction

Within the EU CCAM[32] single platform, the Working Group 6 working paper of September 2019 defined the following task under the following header:

- Header: Competitiveness of the European ecosystem
- Task: The experts are called upon to propose parameters for good quality projects on connectivity, including geographical scope, content, potential participants, international context, business models etc.

The present document is a tentative response to this call.

This new version takes into account comments received from BMW, CEA, UITP and 5GAA, as they have been discussed in four sub-group meetings on May 15, May 27, June 10 and June 12, 2020.

2 Pre-deployment testing: definitions, pre-requisites and outputs

2.1 Type of projects for which this document is applicable

This document is providing criteria to assess projects aiming at the pre-deployment of CCAM-specific physical infrastructure for sensing, connectivity and digital infrastructure. This document applies neither to pure research and innovation projects, nor to the roll-out of software updates. See section 2.2 for more detail.

2.2 What is pre-deployment?

Pre-deployment can mean very different things depending on the industry (network operator, road operator or local authority, automotive industry, ”over-the-top” apps providers,…).

2.2.1 Pre-deployment in different industries

For a telecom network operator, pre-deployment aims at checking that the components defined for full deployment (e.g. of a new technology) are complete and can be put in the hands of the deployment teams, without any involvement of research and innovation teams. This does not forbid that some research and innovation could be piggybacked on a pre-deployed infrastructure. However, if such a piggyback was to happen, the R&I part should be evaluated in a completely separate way from the pre-deployment itself. Such an evaluation would also imply very different criteria (e.g. R&I is about innovation, pre-deployment is about reliability). Otherwise, subsequent full deployment, without any involvement from research and innovation teams, would be put in jeopardy.

For a road operator or a local authority, pre-deployment of CCAM infrastructure follows more or less the same constraints as for a network operator. Typically, applied research would not be pre-deployment for a road operator.

For the automotive industry, pre-deployment of CCAM infrastructure means anything that is not basic research. Applied research is pre-deployment for a vehicle manufacturer.

[32] CCAM stand for Cooperative, Connected, Automated and Autonomous Mobility (Source : Continuously Open Call for Applications for the Selection of Members of the “Single Platform for Open Road Testing and Pre-Deployment of Cooperative, Connected, Automated and Autonomous Mobility”, European Commission).

For a provider of an "over-the-top" app, pre-deployment is a beta new release provided to a chosen subset of app users (in an A/B testing mode) and full deployment is only the generalisation of the new release once the initial bugs have been wiped out.

2.2.2 Pre-deployment in the EU CCAM Single Platform

Within the scope of the EU CCAM Single Platform,

- Pre-deployment implies either **safety relevant services**, or **traffic efficiency** or **environment improvement.** Pure entertainment functions should be excluded.
- **Pre-deployment of services does not follow the same rules as pre-deployment of connectivity**.
- Pre-deployment of **services** can start with **TRL6**[33]. Pre-deployment of **connectivity** or of **road infrastructure** starts with **TRL8 or 9**.
- Pre-deployment is about **pre-production vehicles on the road**. Road operators can test against them.
- Pre-deployment requires the communication infrastructure (close to what we can expect from an operational status). For the services, we can be more open.
- Pre-deployment implies **cooperation between stakeholders**.
- **Pre-deployment does not imply to redo the functional impact assessment** of a service/function if it has been completed through an earlier piece of work. However, this functional impact assessment should be part of the pre-deployment project insofar as it has not been completed as part of a prior piece of work.
- Since cars use publicly regulated space, pre-deployment is not only about **testing** technologies, but also **if a technology matches with the administrative environment**, with the governance dimension (either for new legislation or for mere authorisations).

2.3 Testing

To test is to measure an attribute of an entity and assess whether the measured indicator is close enough to a reference target. It implies five steps:

1. To define the entity attributes which are measured,
2. To define a reference value for these entity attributes,
3. To measure the actual value of these entity attributes,
4. To compare the actual value with the reference value,
5. To conclude from this comparison whether the test has been passed.

This document proposes a definition of the entity attributes, i.e. a set of criteria to evaluate pre-deployment projects. These criteria are defined to be made part of the next call for tenders of the Commission for CCAM pre-deployment projects. Currently, this document does not go beyond step 1. Steps 3, 4 and 5 clearly belong to the life of the projects. However, there is an open question about step 2: should the reference values be defined in the call for tenders or should this definition be left to the projects themselves?

---

[33] TRL : Technology Readiness Levels (https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

Where possible, the definition of reference values should be taken out of publicly available test specifications.

2.4 Outputs of a pre-deployment

The output of pre-deployment should be a green light to deploy.

All the tools to deploy, all the methodology to deploy should be available as commercial products. Further deployment should not belong to Research and Innovation, but to the roll-out of a mature technology.

The output of pre-deployment should be all the pre-requisites for deployment.

The difference between military, IT or telecom pre-deployment and Connectivity and Digital Infrastructure (C&DI) pre-deployment is that the first three are centralised efforts where orders all come from the top, while digital infrastructure for CCAM implementation decisions are decentralised: each road authority, each car manufacturer decides when and where to deploy. If there were retrofit connectivity apps, their roll-out would be decided by users who download them on their smartphones.

2.5 Pre-requisites to connectivity infrastructure pre-deployment

The prerequisites to connectivity pre-deployment is that the development phase of the project is completed, in terms of software or hardware prototypes, and in terms of packaging of the solution for each category of user. Before that, connectivity standards must be agreed upon, standards and specifications need to be published, and products conformant to these standards and specifications must be developed. The coexistence with existing electronic road charging systems, the remote enforcement of the smart tachograph and weights and dimensions has to be demonstrated in large scale tests.

In addition, interoperability of components providing the connectivity for CCAM with respect to-safety and efficiency in transport is also considered a pre-requisite for the following motivation. Road vehicles and digital infrastructure tend to live 15-20 years plus a production time of 5-7 years per model (and for tram/light Rail, considering only the lifetime under operation it is usually at least 30 years – depending on the country). There is a new mobile telecom technology every 10 years. Even if 5G was perfect today, it would not be up to date 10 years from now and beyond. Accordingly, CCAM requires solutions enabling one generation of equipment to communicate with other generations of equipment.

If a new connectivity technology is deployed, roll-out times on roadsides as well as in vehicles will be long. New use cases might come with new technologies – in this case it is important that new equipment also supports existing use cases and thus can provide interoperability with existing equipment, i.e. ensure that systems and the underlying business processes preserve the capacity to exchange data and to share information and knowledge to enable effective ITS service delivery. Since pre-deployment (and also the deployment) is embedded in an ecosystem of services, it is essential to provide the continuity of service for all equipment involved. That means that newer equipment can implement interfaces to new services, which existing equipment do not support; just when interacting with existing equipment, the interfaces used and provided by existing equipment should be supported as well. This way, sustainability of investment can be achieved while being open for novel services.

Over-the-air software updates might be a way to facilitate the support of new use cases as technology evolves, without a need for a hardware update. Hardware updates might be facilitated by provisions for extensions ("empty hardware slot"). However, this might become inefficient if not used in a coordinated way. Such coordination needs a migration strategy that might need agreement by a large number of stakeholders. Furthermore, hardware updates in vehicles require costly recalls by the manufacturers and might be subject to type approvals, especially when it comes to functional safety. Some

technologies are deployed in generations that create the necessity to roll-out new hardware to support new connectivity protocols. It should be noted that the current deployment of short-range communication and extensions to allow interoperability should not require a hardware update. Such interoperability is requested at the level of services and applications. As a metaphor of such a service-level interoperability requirement, let us remind ourselves that communication systems which allow two entities to negotiate, in order to select the optimal communication protocol, are based on a connection-oriented protocol (as used in mobile networks), as opposed to a connectionless protocol (as used in ad hoc direct communication systems). Without the base offered by a connection-oriented protocol or its equivalent at the level of services or applications, it is difficult to ensure interoperability between different connectivity technologies.
Innovative interoperability solutions need to be found to enable interoperability over a longer period and of availability of different generations of technologies. However, innovation should not be blocked by backward compatibility requirements either.

3 Characteristics of criteria applicable to CCAM connectivity and digital infrastructure pre-deployment projects

3.1 Ex ante and ex post criteria

CCAM digital infrastructure pre-deployment projects must be evaluated ex ante (before the project is given a go ahead) as well as ex post (to evaluate whether the concerned deliverables have fulfilled their promises). Should ex ante and ex post evaluation criteria be the same ones? Ex post criteria should be more precise than ex ante ones, but each ex post criterion should expressly contribute in a measurable way to the fulfilment of an ex ante criterion.

3.2 Input, intermediary or output criteria

A criterion can apply to the inputs of the project, to its final outputs, or to an intermediary output.

3.3 Quantitative, factual or qualitative criteria

A criterion can be quantitative: is a measured figure within the expected range?
It can also be factual. Is a characteristic of the project true or false?
Finally, there should also be room for qualitative criteria.

3.4 Intrinsic achievement criteria vs. impact criteria

An output criterion can focus on the immediate, direct achievement of a project. It can also evaluate its impact on the future perspectives of a full deployment. It is likely that intrinsic achievement criteria will be quantitative or factual, while impact criteria may be only qualitative on the final day of the pre-deployment project.

3.5 A-B testing

A well-documented testing methodology is needed to validate the impact criterion, ideally resulting in quantitative validation. If applicable, "A-B testing" could be the methodology of choice to validate the impact i.e. evaluation between one environment in which the system has been deployed and used (environment A) and the other where it has not (environment B). This methodology makes sense if environment B is comparable to environment A, with the exception of the service(s) under test. When many services are being introduced at the same time in the pre-deployment project, it might be difficult to attribute the benefit to a specific service. In this case, alternative testing methodology(ies) should be described and applied.

4 Criteria applicable to the selection and evaluation of CCAM connectivity and digital infrastructure pre-deployment projects

The following list of criteria only defines a 'toolbox' for project assessment. Assessing all these criteria for each application as an unguided effort will not yield the best suited projects. The approach towards CCAM should be based on a roadmap addressing specific technologies, services and use cases, based on their expected contribution to CCAM policy objectives. In each project, the individual use cases govern the value of the individual criteria, potentially also specific reference values for assessment. Roadmaps/strategies as they have been created e.g. by C2C-CC, 5GAA, STRIA, ERTRAC and CEDR CAD provide such use cases and can be the basis for assessing suitable criteria. As a general approach, the project criteria could be assigned a specific weight factor in the scope of services/use cases addressed in a specific call.

4.1 Pre-requisites: existence of a broader deployment strategy

As long as mobility mostly takes place in public space and on public roads, CCAM will mostly operate in a regulated space, since it exists within a broader context of road safety, railway safety, public health and public infrastructure. To be a successful pre-deployment project, a project should be socio-economically sustainable in the long-run. At the same time, starting with the short-run, it should not hinder mobility efficiency and should support continuity from already deployed Day-1 use cases.
The deployment strategy should target long-term sustainability on the basis of:

- stakeholder involvement,
- industry take up,
- road/railway parking/logistics/etc. operator support,
- regulatory framework (e.g. European data strategy, etc.).

4.2 Pre-requisites: all components should be off-the-shelf (in a two-year time frame)

There should not be any software or hardware development as part of a pre-deployment project, or as an input to the project. The project should use only off-the-shelf (in a two-year time frame) hardware and software products and solutions, except for evaluation purposes, which can include non-off-the-shelf data collection equipment or software.

4.3 Pre-requisites: lifecycle of the CCAM system

Component wear and obsolescence should be factored in when considering the total cost of ownership of the system. Future generations of equipment should be interoperable with already deployed equipment and/or services. Innovative solutions to a long-term interoperable communication environment supporting overlapping lifecycles of different generations of equipment need to be found. Safety and security are important aspects of the product lifecycle.

4.4 Scope –Main features of the mobility project

The scope of the project should always be as precise as possible.
A list of targeted categories of connected vehicles and/or users and/or travel should be completed. It could be defined with boxes ▢ to tick to make the scope clear, including e.g.:

□ Private cars ▢, commercial vehicles ▢, trucks ▢, buses ▢, tram/Light Rail ▢, new categories of "shared-vehicles" ▢, others ▢

□ Logistic domain ▢, for all categories of goods ▢ for specific categories of goods ▢

 Passenger transport domain ▢, for all categories of passengers ▢, for specific categories of passengers ▢, private transport ▢, public transport ▢

 Medium-long distance travel ▢, national ▢, EU-wide ▢, international ▢

 Local travel (urban/suburban/regional) ▢)

 Users on-board connected vehicles ▢, driver ▢, passenger ▢

 Users off connected vehicles: at public transport stops/stations ▢ on sidewalks ▢, using non-connected vehicles ▢

 Any innovative dimension not listed before: …

The scope should also provide information on the institutional background: the public stakeholders at stake and involved, the physical territory and functional competence under their responsibility and refer both on the assets side (owner and/or maintainer of the road or of the lane…) and on the traffic management side (for general traffic management – one-way or two-way road or street, traffic lights etc., for parking – on-street and off-street - or for dedicated traffic management – e.g. for public transport). Specific requirements shall have to be managed depending on the categories of authorities, e.g. at Member States level or at regions or city levels.
A whole set of factors should quantify the complexity of the mobility environment equipped and monitored under each project:

- (eg. per road segment): number of lanes, number of intersections, types of intersection, number, type and changes of static/dynamic traffic regulations (speed limits, overtaking bans, priorities for public transport, …),
- Type and coverage of traffic management services in operation, in particular automated traffic management regarding dynamic traffic regulations, lane usage and alternative routing,
- Compound theoretical infrastructure risk,
- Actual infrastructure risk, e.g. number of crashes per km per annum,
- Intermodal connective nodes.

The RAP (Road Assessment Programme) protocols could be used, where appropriate, to classify projects from this angle. There are also service / use-case related connectivity aspects, e.g. in tunnels.
New pre-deployment CCAM projects should also cover the articulation between different road networks, e.g. between motorways, inter-urban, or urban roads and intermodal nodes. Attention should be given to projects supporting the service harmonisation and interoperability between those different networks and nodes. Particular relevance for CCAM lies in the Infrastructure Support for Automated Driving (ISAD). Roadside information support and ISAD levels have to be assessed according to the services / use cases addressed by a project.

4.5 Scope – Complexity of member state environment

Building on the achievements of previous CCAM projects (e.g. Horizon 2020, CEF, national programmes), new projects should promote testing and pre-deployment in as many member-states as possible. This criterion should explicitly reflect the difference in regulations in Europe, regarding connectivity-related regulations but also, in particular, regarding Member State-specific traffic regulations.

4.6 Scope – Complexity of border environment
Building on the achievements of the main cross-border CCAM projects, new projects should test as many border-crossing cases as possible. This includes borders between member states, road networks, communication networks, and service providers.

4.7 Scope – Complexity of traffic management environment
New pre-deployment CCAM projects should cover the articulation between different traffic management domains. Attention should be given to projects supporting the service harmonisation and interoperability between those different domains.

4.8 Scope – Level of stakeholder cooperation
CCAM can only work based co-operative and collaborative operation/business models, which must include a "critical mass" of relevant stakeholders, private or public, to properly represent the market at stake. Projects should be noted which describe and/or test these, required co-operation and collaboration models, be they on technical, operational or strategic level.

4.9 Scope – Complexity of use case environment at project level
CCAM use cases should not be limited to those defined by Working Group 2 of the EU CCAM Single Platform. They can extend beyond the road network where improved mobility and sustainability can be anticipated in a project proposal. The particular example of the driving mode shows how CCAM use cases can be classified by their timeliness and data volume requirements as shown, for example, in Figure 2.

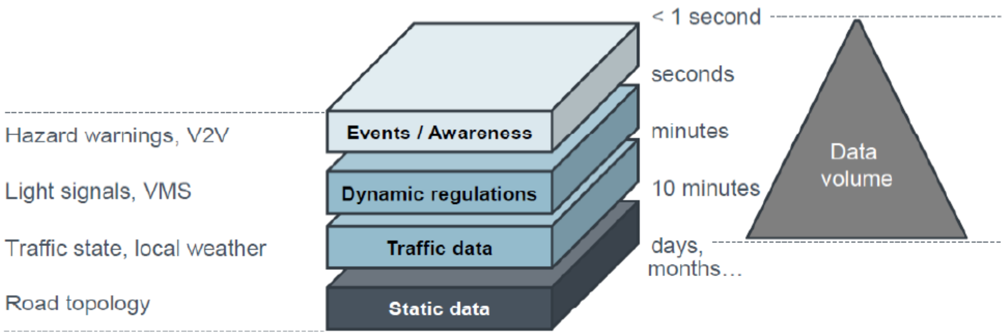


Figure 2: Example of classification of CCAM use cases according to their timeliness and data volume requirements

Thus, a key criterion for the project is the availability of the communication environment to support the use cases and their respective requirements. It should be noted that the communication environment could consist of a mixture of long-range and short-range communications. A classification of CCAM use cases could also be performed along levels of automation, ISAD levels, ODDs or other criteria. It would be valuable that a large range of attributes[34] for each use case are covered.
The number of scenarios covered should be a factual criterion, to be used both at project level and at programme levels (combining the scenarios covered by the different projects).

[34] E.g. 1,2,3,4,5 for SAE levels of automation.

4.10 Scope – Breadth of CCAM services deployed / of use cases covered at programme level

The number and variety of CCAM services (for instance, C-ITS Day 1 or Day 1.5 services, those listed in delegated regulations of the Directive 2010/40/EU or in C-ITS Platform phase 1 Final report: https://ec.europa.eu/transport/sites/transport/files/themes/its/doc/c-its-platform-final-report-january-2016.pdf) pre-deployed should be considered both at the scale of the project and at the scale of the programme. For each service considered, the variety of use cases covered should be assessed. This however should not be viewed as an isolated criterion for single projects, because there may be dedicated projects on specific services / use cases. A proper criterion for a single project would be depth x breadth. Projects should be noted that address complete clusters of coherent services / use cases, e.g. automation, fleet management, traffic safety, intermodality, etc.

4.11 Scale – Size of the traffic /mobility environment

The overall length of the traffic /mobility environment and e.g. the number of intersections or mobility nodes equipped and monitored under each project should be used to assess the suitability for full deployment of the solution that is covered by the pre-deployment project. The type of mobility network covered by the services is also an essential scaling criteria: intercity/international road system, inner-city road system, cities or countries impacted. The suitability of the infrastructure has to be assessed as well according to the services provided by the infrastructure, where the concrete use cases deployed in the project determine the requirements. Size criteria are meaningful only within environments of a given complexity (see “scope” criteria).

4.12 Scale - Number and proportion of new connected equipment and/or users participating

As part of the assessment, it is important to distinguish the different types of connected equipment and connected users, in particular it has to be differentiated between:

- A service delivered via smartphone (independent of the vehicle),
- An infotainment service delivered via the vehicle and
- A safety related service delivered via vehicle stations integrated in the safety components of the vehicle.

Requirements and assessment of participation and equipment numbers will be very different in these scenarios.

The number of new equipment (in the sense of vehicles / infrastructure /nomadic devices that are natively equipped for safety-related services) involved should also be a criterion to assess the scale of the proposed projects. Maybe the proportion of the new equipment (participating in the pre-deployment project) out of the total number of existing equipment in the observed mobility environment should also be used as a criterion, to be able to test whether the proportion equipped makes a difference in the efficiency of the digital infrastructure deployment. An alternative criterion is the number of users of in-vehicle systems.

4.13 Scale - Number and proportions of retrofitted equipment participating

Retrofits in this section should be heard as hardware retrofits, as opposed to software upgrades. A hardware retrofit may qualify an equipment for some use cases and not for others. For instance, a connected smartphone could provide a bit-pipe for enhanced connectivity for in-vehicle applications. In pre-deployment projects, it could serve as a demonstration or mock-up platform. For automated driving functions, a mobile phone

cannot substitute an integrated solution. Thus, mobile phones alone cannot be counted as retrofit vehicle solution for automated driving functions.
For automated vehicles, the possibility of a software upgrade is a different dimension than the necessity of some hardware retrofits.
For certain safety use cases, a retrofit might be a way to circumvent the very slow renewal rate of equipment. According to ACEA, the average age of passenger cars in Europe was 11.1 years in 2017 (up from 10.5 years in 2013), the light commercial vehicles in Europe was 11 years in 2017 (up from 10.4 years in 2013). For heavy commercial vehicles, it was 12.0 years in 2017 (up from 11.7 years in 2013). See figure 1 below. The renewal lifecycle of a vehicle is already over 15 years and is rising. Vehicle manufacturers have no technical ability to prepare a retrofit due to functional safety and homologation aspects.
The criterion could be further precised if a process involving several steps (and therefore various periods of time) is relevant for the retrofitting until a whole fleet is upgraded or replaced.

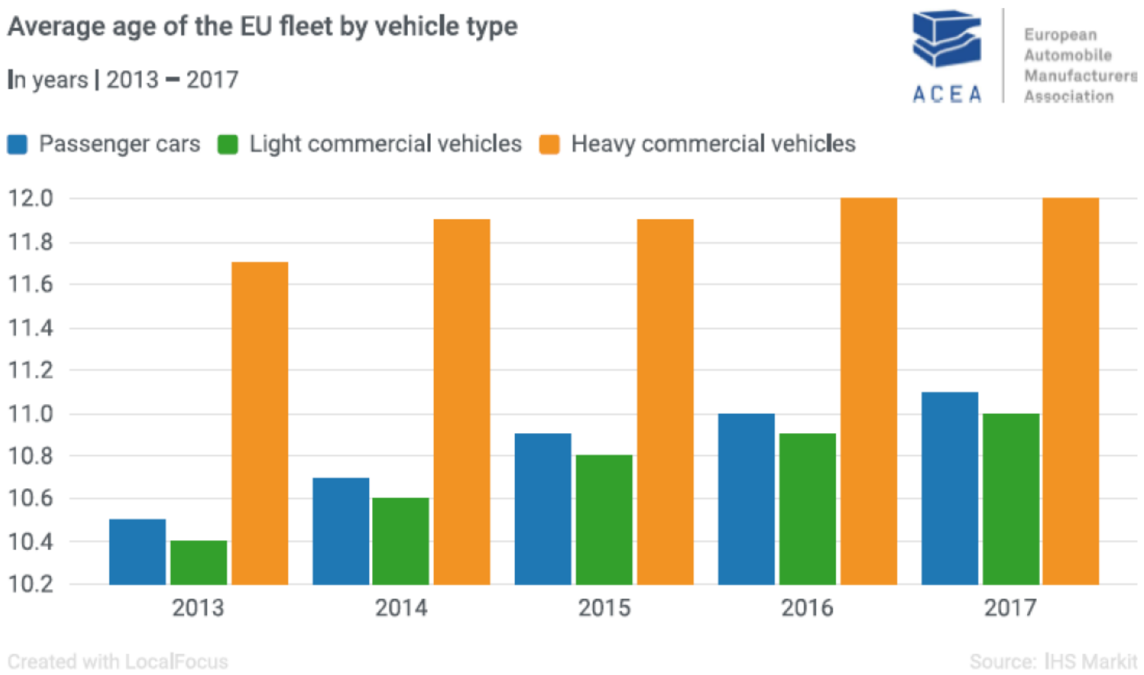


Figure 1 – Average age of the EU fleet by vehicle type

4.14 Scale - Size of a convoy of vehicles (platoon)

The size and shape of a convoy of vehicles is determined to large extent by the use of a communication system. The better the communication system scales, the larger the convoy is, and the better it avoids jams. A communication system for V2V communications used in a convoy must allow to maintain coherent convoys with the following characteristics:

- convoy of vehicles of various types: automobiles, trucks, others,
- overall size of convoy must extend to lengths longer than several kilometres,
- in terms of numbers of vehicles, the size could be larger than 3 vehicles, and up to hundreds of vehicles,
- the presence of fixed infrastructure elements (RSUs) along the road to support convoys is optional; in some areas the infrastructure is absent,
- single-lane or multi-lane convoys advancing at variable speeds,

in compliance with existing regulation, the need for special approvals or the feasibility of enhanced regulation.

4.15 Scale - Number and proportions of Vulnerable Road Users (VRUs)

There is room for research and innovation applied to vulnerable road users (VRUs) in CCAM applications. While pedestrians, powered and non-powered two-wheelers and other vulnerable road users are mostly present in urban areas, more controlled environments seem better suited for research, testing and pre-deployment of automated driving. C-ITS use-cases could be adapted to pedestrians and other VRUs. There is a high penetration with mobile phones and thus an opportunity to use them for safety-related applications. The lifetime of phone batteries and liability are also questions to be considered, as quality of service on communication and application side needs to be specified and implemented. Relying on best effort services may otherwise endanger pedestrians by creating a false expectation of safety. Vulnerable road users represent a significant group of seriously to fatally injured road users and therefore deserve significant Research and Innovation.

4.16 Scale – Duration and circumstances of observation

A pre-deployment project should envisage a continuous observation of a deployed digital infrastructure system for a much longer period, ideally one year, day and night, to cover all lighting and weather conditions. This would require not only new or retrofit equipment, but also recording/communication capabilities to store all requested experience data. This duration should be monitored CCAM service by CCAM service and use case by use case. The introductory remarks in this section regarding the service/use case-driven relevance of project criteria are of particular importance here.

4.17 Scale - Data capture and storage

Projects with a long observation period (e.g. one year) could log all messages sent and received (for those C-ITS services sending or receiving standard messages) or capture the user experience, e.g. for transport logistics or commuting. This data capture helps to check the functioning of the planned improvement and it could be useful to compare the efficiency of the various communication scenarios. This should be done use case by use case.

4.18 Validation – Privacy and Security (non-functional aspects)

A pre-deployment should consider operational requirements regarding privacy (e.g. handling of mobility data according to GDPR) and security (e.g. compatibility with the C-ITS trust domain, regulatory requirements for critical infrastructure, etc.).

4.19 Validation – Communication performance

Obviously, communication performance is expected to be validated during pre-deployment. The classes of communication should be identified and the Quality of Service evaluated on:

- Tactical and strategic communication
- Time-criticality
- Reliability, latency
- Bandwidth, spectrum, …

in relation to:

- Relevance in context of Functional Safety

- Level of automation (e.g. according to SAE level[35]) and other criteria for CCAM use case environment complexity listed in Section **Error! Reference source not found.**
- CCAM services and use cases
- Infrastructure environment (e.g. high traffic density with higher channel load, coverage issues in tunnels, signal interference, …)

The validation of communication performance could use legacy systems (e.g. road signage) as a benchmark of the added value of the evaluated CCAM system.

4.20 Validation - Number of lives saved / injuries avoided / collisions avoided

Pre-deployment should be the step when early promises of technology are checked against reality, at a large scale. Such promises belong to the following family of objectives: better road safety, less congestion, greater transport efficiency, mobility and service reliability, reduced energy use, fewer negative environmental impacts, and support for economic development.

As regards road safety, estimating the number of lives saved, of injuries or collisions avoided by the introduction of digital infrastructure for CCAM is a global issue. Many factors play a role besides connectivity. However, since pre-deployment implies a large scale of observation, it might be possible to envisage a statistical comparison in terms of periods (before and after introduction) or in terms of locations, provided with a connectivity equipped location and a non-equipped one can be considered as statistically comparable.

4.21 Validation –Greater transport efficiency - Improved traffic management

A greater transport efficiency (for example, less congestion before new induced traffic) is not strictly a message connectivity issue but highly linked to road environment that combines traffic management services and connectivity in a seamless manner. It might be possible to envisage a statistical comparison in terms of time periods (before and after introduction) or in terms of locations, provided an equipped location and a non-equipped one can be considered as statistically comparable.

4.22 Validation – Mobility service reliability

An enhanced reliability of mobility services could be assessed through a statistical comparison in terms of time periods (before and after introduction) or in terms of locations, provided an equipped location and a non-equipped one can be considered as statistically comparable, and a clear definition of "enhanced reliability" can be produced.

4.23 Validation – Reduced energy used

Similarly, a reduction of the quantity of energy consumed could also be evaluated in terms of time periods (before and after introduction) or in terms of locations, provided an equipped location and a non-equipped one can be considered as statistically comparable.

4.24 Validation – Fewer negative environmental impacts

[35] See https://www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-%E2%80%9Clevels-of-driving-automation%E2%80%9D-standard-for-self-driving-vehicles

Other negative environmental impacts (e.g. CO_2 emissions, noise,…) also be compared before and after the introduction of the CCAM service or between locations, provided an equipped location and a non-equipped one can be considered as statistically comparable.

4.25 Validation – Inclusiveness

How does CCAM help the lives of elderly people, handicapped people? How does it help rural areas? Some projects or some aspects of some pre-deployment projects should focus on assessing the contribution of CCAM to a more inclusive European society.

4.26 Validation – Support for socio-economic development

The validation of the contribution to such a broad objective of the policy programme should probably be done at the scale of the programme and not at the scale of each project. Two approaches could be combined:

- Production: part of CCAM in European GDP, imports and exports,
- Utility, i.e. Costs vs. Benefits for European users of CCAM: monetary equivalent of lives saved, collisions avoided, avoidance of time lost in traffic congestion… as compared to the cost of ownership of CCAM systems.

The « efficiency » of the road system in a given project/programme should be measured through classical Cost-Benefit Analysis comparing the expected costs and benefits of the project/programme with a situation without the project/programme. Among the indicators related to traffic evolution, the following should also be used:

- the variation in the number of vehicles (fleet and vehicle x km);
- the variation in the number of people carried (in absolute value number and in passenger x km).

4.27 Validation - Robustness of the business model proposed for deployment

In terms of impact on full deployment, posterior to the pre-deployment project, in the absence of a mandatory requirement to proceed with a full deployment or in the absence of the adequate subsidy level, the robustness of a business model could be measured in terms of size (a quantitative criterion) and firmness (a qualitative criterion) of the order book obtained on the technologies used in the pre-deployment project.

4.28 Validation – Global benchmarking

Global benchmarks, at least between Europe, the United States and China, should be performed at the scale of the programme. They could be the subject of specialised projects within the programme. Direct comparisons might be difficult between very different environments, especially in terms of roads and regulations. The road system is in fact a "system of road systems" serving different users and purposes, and in itself every road system is an intermediary for achieving broader objectives, and especially: a "better" and "sustainable" economy, a "better" and "sustainable" mobility for all categories of citizens or for specific categories. So, the conditions of the benchmark need to be relevant with the higher-level objectives of the programme. However, such benchmarks could try and track each of the criteria proposed in this document, between the compared continents, under the form of secondary research, whenever this is possible and meaningful. On a global level, the comparison could focus on the increased efficiency of the road system brought in by CCAM over each continent, as well as the potential for export of the technologies and services developed in each continent. On a more basic level, the comparison could include the availability of mobile services supporting CCAM services.

4.29 Validation - Contribution to completeness of deployment toolkit

An output of any pre-deployment programme should be that, after such a programme, deployment projects should not involve any research and innovation activity. This means that the methodologies to plan, design and implement digital infrastructure systems should be as well described as the ones to plan, design and implement classical physical road signage projects. Road operators, logistics operators, vehicle manufacturers and other stakeholders in the mobility community should be provided with a rule book of how to plan, design and implement that system or equipment accordingly. Either this already exists, and this should be an input of the pre-deployment projects, or such methodologies do not exist or are not packaged, and their development and packaging should be a part of the pre-deployment programme and a feature of some of the pre-deployment projects. The methodology should highlight as well which level of public authorities are involved or need to be depending on the nature of the road and of the targeted categories of users. The intention is to have implementation guidelines rather than experience reports. If the post analysis comes to the conclusion that certain features are not providing the expected benefits or functional capabilities for part or all investigated aspects, then we can accept lessons learnt rather than an implementation guideline. The outcome may be even different for different regions/cultures/countries.

4.30 Validation - Post-requisites criteria for continued reuse after project end

Post-requisites are criteria for continued reuse after the end of a pre-deployment project, including sustainability during deployment, replicability to other locations, and reusability for future testing and new pre-deployments:

- Ease of use of the service for motorists
- Technical support for reuse, including test facilities
- Financial conditions for reuse
- Maintenance of deployed systems and services, and communication networks
- Sustainability of the service produced by the project.

4.31 Validation – Assessment of investment required for roll-out

It is important for each technology developed by a project to assess investment needs for roll-out per involved stakeholders over the implementation period of the project (and the time period of the economic evaluation). This is of particular importance for required infrastructure and equipment investment, since regular operations, large-scale roll-out has to be based on long-term, phased investment plans, which need to be supported by the results of the pre-deployment projects. Investment assessment must not be limited to roll-out of roadside devices, but should also include backend processes, systems, licencing fees, and staff skill requirements.

5 Synthesis

	Input or output?	Ex ante or ex post?	Qualitative, factual or quantitative?	Intrinsic achievement or impact assessment?	A-B testing?
1. Pre-requisites: existence of a broader development strategy	Input	Ex ante	Quantitative	N/A	N/A
2. Pre-requisites: all components should be off-the-shelf(in a two-year time frame)	Input	Both	Factual	Intrinsic	N/A
3. Pre-requisites: lifecycle of the CCAM system	Input	Ex ante	Qualitative	N/A	N/A
4. Scope – Main features of the mobility project	Input	Ex ante	Factual	Intrinsic	N/A
5. Scope – Complexity of member state environment	Input	Ex ante	Factual	Intrinsic	N/A
6. Scope – Complexity of border environment	Input	Ex ante	Factual	Intrinsic	N/A
7. Scope – Complexity of traffic management environment	Input	Both	Factual / qualitative	N/A	N/A
8. Scope – level of stakeholder cooperation	Input	Both	Factual	Intrinsic	N/A
9. Scope – Complexity of use case environment at project level	Input	Both	Factual / qualitative	N/A	N/A
10. Scale – Breadth of CCAM services deployed / of use cases covered at programme level	Input	Both	Factual	Intrinsic	N/A
11. Scale – Size of the traffic/mobility environment	Input	Both	Quantitative	Intrinsic	N/A
12. Scale - Number and proportion of new equipment and/or users participating	Input	Both	Quantitative	Intrinsic	N/A
13. Scale – Number and proportions of retrofitted equipment participating	Input	Both	Quantitative	Intrinsic	N/A
14. Scale – Size of a convoy of vehicles (platoon)	Both	Both	Quantitative	Intrinsic	N/A
15. Scale - Number and proportions of Vulnerable Road Users (VRUs)	Input	Both	Quantitative	Intrinsic	N/A
16. Scale – Duration and circumstances of observation	Input	Both	Quantitative / factual	Intrinsic	N/A
17. Scale - Data capture and storage	intermediary	Both	Quantitative	Intrinsic	Applicable
18. Validation – privacy and security (Non-functional aspects)	Both	Both	Factual / qualitative	Intrinsic	N/A
19. Validation – Communications performance	Output	Both	Quantitative	Intrinsic	Applicable
20. Validation - Number of lives saved / injuries avoided / collisions avoided	Output	Both	Quantitative	Impact	Applicable
21. Validation – Greater transport efficiency / Intermodality	Output	Both	Quantitative	Impact	Applicable

	Input or output?	Ex ante or ex post?	Qualitative, factual or quantitative?	Intrinsic achievement or impact assessment?	A-B testing?
22. Validation – Mobility and service reliability	Output	Both	Quantitative	Impact	Applicable
23. Validation – Reduced energy used	Output	Both	Quantitative	Impact	Applicable
24. Validation – Fewer negative environmental impacts	Output	Both	Qualitative	Impact	Applicable
25. Validation – Inclusiveness	Output	Both	Partly qualitative, partly factual	Impact	Applicable
26. Validation – Support for socio-economic development	Output	Both	Quantitative	Impact	Applicable (at programme level)
27. Validation – Robustness of the business model proposed for deployment	Both	Both	Partly quantitative, partly qualitative	Impact	Applicable (between projects)
28. Validation – Global benchmarking	Both	Both	Partly quantitative, partly factual, partly qualitative	Impact	Applicable (between continents)
29. Validation - Contribution to completeness of deployment toolkit	Output	Both	Qualitative	Impact	N/A
30 Validation - Post-requisites criteria for continued reuse after project end	Output	Both	Factual	Both	N/A
31 – Validation – Assessment of investment required for roll-out	Both	Both	Quantitative	Impact	N/A

6 Further required work in CCAM project assessment criteria

As announced in section 2.1, this document defines the entities to be measured to assess a CCAM pre-deployment project. Working Group 6 of the EU CCAM Single Platform has now to decide whether the reference values of each of these criteria should be defined at the level of the EU CCAM programme, or this definition should be left to the projects themselves. In case the first of these two options is selected, further work needs to be done to determine these reference values.

7 Version control

The version control of this document is done by:

- Defining new versions by changing the last eight characters of the name of the Word file, the title and the footer of the document, which are the date when the version is released, in reverse order (AAAAMMDD),
- Mentioning the new version at the end of the following list, with a brief description of the nature and authors of the changes.

C-ITS connectivity predeployment projects criteria - 20191118 : initial version, Emmanuel Tricaud.

C-ITS connectivity predeployment projects criteria - 20191119 : comments and additions, Bart Netten.
C-ITS connectivity predeployment projects criteria - 20191120: version sent par ET + BN to Eddy Hartog, president of WG6 of the EU-CCAM Single Platform.
Connectivity and Digital Infrastructure Pre-deployment for CCAM - Projects Criteria - 20191121 : version including the revisions of DG CNECT/ H5 (Juan José Arriola Ballesteros).
Connectivity and Digital Infrastructure Pre-deployment for CCAM - Projects Criteria - 20191125 : correction of a typo in section 2.4.
Connectivity and Digital Infrastructure Pre-deployment for CCAM - Projects Criteria – 20200121 : incorporation of comments made during the December 2019 WG6 meeting.
Connectivity and Digital Infrastructure Predeployment for CCAM - Project Criteria - 20200305: incorporation of comments from CEDR, ASECAP and ASFINAG.
Connectivity and Digital Infrastructure Predeployment for CCAM - Project Criteria - 20200325: incorporation of comments heard during the March 9 virtual meeting and of email contributions received between March 5 and March 24, 2020.
Connectivity and Digital Infrastructure Pre-deployment for CCAM - Project Criteria - 20200520 – partial incorporation of comments from BMW, CEA and UITP.
Connectivity and Digital Infrastructure Pre-deployment for CCAM - Project Criteria - 20200602 – improved definition of pre-deployment applicable to the EU CCAM Single Platform.
Connectivity and Digital Infrastructure Pre-deployment for CCAM - Project Criteria - 20200610 – partial incorporation of comments from BMW, CEA, UITP and 5GAA.
Connectivity and Digital Infrastructure Pre-deployment for CCAM - Project Criteria - 20200614 – Integration of contributions from ASECAP and 5GAA.
Connectivity and Digital Infrastructure Pre-deployment for CCAM - Project Criteria - 20200615 – Final version by subgroup handling comments from ASECAP, BMW, CEA, UITP and 5GAA.
Connectivity and Digital Infrastructure Pre-deployment for CCAM - Project Criteria - 20200623 – Replacement of TRL definition in footnote 2 (reference to Horizon 2020 instead of Wikepedia).

Table of contents

1 Introduction……………………………………………………………………..1
2 Pre-deployment testing: definitions, pre-requisites and output………………………1
2.1 Type of projects for which this document is applicable 1
2.2 What is pre-deployment? 1
2.2.1 Pre-deployment in different industries 1
2.2.2 Pre-deployment in the EU CCAM Single Platform 2
2.3 Testing..2
2.4 Outputs of a pre-deployment 3
2.5 Pre-requisites to connectivity infrastructure pre-deployment 3
3 Characteristics of criteria applicable to CCAM connectivity and digital infrastructure pre-deployment projects 4
3.1 Ex ante and ex post criteria...4
3.2 Input, intermediary or output criteria...4
3.3 Quantitative, factual or qualitative criteria 4
3.4 Intrinsic achievement criteria vs. impact criteria 5
3.5 A-B testing 5
4 Criteria applicable to the selection and evaluation of CCAM connectivity and digital infrastructure pre-deployment projects...5
4.1 Pre-requisites: existence of a broader deployment strategy.......................................5

4.2 Pre-requisites: all components should be off-the-shelf (in a two-year time frame) ...6
4.3 Pre-requisites: lifecycle of the CCAM system 6
4.4 Scope –Main features of the mobility project 6
4.5 Scope – Complexity of member state environment 7
4.6 Scope – Complexity of border environment..7
4.7 Scope – Complexity of traffic management environment 7
4.8 Scope – Level of stakeholder cooperation 7
4.9 Scope – Complexity of use case environment at project level...................................8
4.10 Scope – Breadth of CCAM services deployed / of use cases covered at programme level …………………………………………………………………………………..8
4.11 Scale – Size of the traffic /mobility environment 8
4.12 Scale - Number and proportion of new connected equipment and/or users participating 9
4.13 Scale - Number and proportions of retrofitted equipment participating 9
4.14 Scale - Size of a convoy of vehicles (platoon) 10
4.15 Scale - Number and proportions of Vulnerable Road Users (VRUs).....................10
4.16 Scale – Duration and circumstances of observation 11
4.17 Scale - Data capture and storage 11
4.18 Validation – Privacy and Security (non-functional aspects) 11
4.19 Validation – Communication performance 11
4.20 Validation - Number of lives saved / injuries avoided / collisions avoided 12
4.21 Validation –Greater transport efficiency - Improved traffic management..............12
4.22 Validation – Mobility service reliability 12
4.23 Validation – Reduced energy used 12
4.24 Validation – Fewer negative environmental impacts..12
4.25 Validation – Inclusiveness 13
4.26 Validation – Support for socio-economic development 13
4.27 Validation - Robustness of the business model proposed for deployment 13
4.28 Validation – Global benchmarking 13
4.29 Validation - Contribution to completeness of deployment toolkit 14
4.30 Validation - Post-requisites criteria for continued reuse after project end................14
4.31 Validation – Assessment of investment required for roll-out...................................14
5 Synthesis 15
6 Further required work in CCAM project assessment criteria 16
7 Version control 17

11.3.3. WG6 : project criteria quantification

1 Introduction
1.1 Problem Statement

Extract of Minutes of WG6 meeting of June 23, 2020
"Reference values for the Projects Assessment Criteria
The next step (Annex 6, section 6) is to determine reference values for the project assessment criteria. It is discussed whether this should be defined at the level of WG6. The discussion pivoted around three aspects:

- *The concern is raised that settings reference values inherently pose the risks that the reference values are too strict and conservative, and based on our current thinking and requirements. This may hamper real innovation.*
- *On the other hand, setting reference values is useful to get the projects we are asking for.*
- *Setting the right reference values right will also require a lot of work. First of all it should be clearly defined when we assume by a reference value.*

The consensus is that this is relevant for WG6 and that we should continue this discussion. The chair will also stress the relevance of this work with other work groups in the plenary meeting. "
Extract of minutes of WG6 meeting of October 6, 2020
"The Plenary meeting on 30th June 2020 approved the presented document on Project Criteria (Annex 4).
The next step is discussed to include reference values for the project criteria. Emmanuel Tricaud indicated that he can continue with the coordination of this activity, but input is needed from experts to express reference values. Niels Skov Andersen (C2C-CC), Alexandre Petrescu (CAE), Paul Spaanderman (InnoMo) volunteered to participate in this activity.
Chair: A web meeting will be organised where everyone will be invited to participate."

1.2 Method
1.2.1 Sub-group work method
The sub-group on Project Assessment Criteria met three times (October 30, November 16 and December 1, 2020).
The sub-group has combined three approaches to the quantification issue:

- A top-down approach
- A bottom-up approach
- Other approaches defined in sub-group meetings.

For the time being, the present document is kept separate from the document on project assessment criteria which was adopted by the CCAM plenary session of June 20201[36],

[36] https://circabc.europa.eu/sd/a/41e007f1-df02-4fc8-adab-a0320f7a6271/Connectivity%20and%20Digital%20Infrastructure%20Pre-deployment%20for%20CCAM%20-%20Project%20Criteria%20-%2020200623.docx

because the level of maturity reached by this document is much lower and because the document is much more analytical and much less prescriptive.

1.2.2 From criteria to indicators, from programme level to project level

It is necessary to distinguish between "criteria" that refer to fairly general objectives and "indicators" that are tools associated with a criterion to measure the degree to which the objectives of the concerned criterion are met. As a result, reference values must be associated rather to "indicators" than to "criteria." And since the criteria and indicators can evolve according to the project, the working method should let the issuer of the call for projects responsible for defining the criteria and proposing relevant indicators and allow the responders to propose useful adjustments of the indicators (or even criteria?) on a case-by-case basis (for each Use Case).

However, the most important thing is the “representativeness” of project participants: as indicated in the §4.4 of the “Project Assessment Criteria” document, the first step of any mobility project is to clarify the scope and institutional context, and thus the categories of actors who should be involved (decision makers on the implementation of the outcomes of the project). After this clarification of the categories of actors impacted has been made in the preparation of tenders (by the European Commission), calls for projects would include a criterion related to the actors making jointly proposals: the offers should prove that the project shall involve all required categories of "legitimate" actors (with the possibility of power of attorney for one actor partner of the project to represent another who is not, and maybe with the obligation for a consortium, during the course of the project, to establish “End Users Groups” gathering representative actors who are not partners of the project but who are committed to comment on important draft deliverables and would receive some kind of compensation for that). A "critical mass" (of actors) criterion could eventually be defined as part of section 4.1 to clarify what is meant by "legitimate representativeness" of the stakeholder involvement.

1.2.3 Which criteria are supposed to be quantified?

Apart from its most right-hand column, which is an addition, the following table is copied from section 5 (Synthesis) of the document on Project Assessment Criteria.

	Input or output?	Ex ante or ex post?	Qualitative, factual or quantitative?	Intrinsic achievement or impact assessment?	A-B testing?	What is to be quantified? (Examples)
1. Pre-requisites: existence of a broader development strategy	Input	Ex ante	Quantitative	N/A	N/A	Is the project backed by enough stakeholders of each kind?
2. Pre-requisites: all components should be off-the-shelf (in a two-year time frame)	Input	Both	Factual	Intrinsic	N/A	
3. Pre-requisites: lifecycle of the CCAM system	Input	Ex ante	Qualitative	N/A	N/A	
4. Scope – Main features of the mobility project	Input	Ex ante	Factual	Intrinsic	N/A	
5. Scope – Complexity of member state environment	Input	Ex ante	Factual	Intrinsic	N/A	
6. Scope – Complexity of border environment	Input	Ex ante	Factual	Intrinsic	N/A	
7. Scope – Complexity of traffic management environment	Input	Both	Factual / qualitative	N/A	N/A	
8. Scope – level of stakeholder cooperation	Input	Both	Factual	Intrinsic	N/A	
9. Scope – Complexity of use case environment at project level	Input	Both	Factual / qualitative	N/A	N/A	
10. Scale – Breadth of CCAM services deployed / of use cases covered at programme level	Input	Both	Factual	Intrinsic	N/A	
11. Scale – Size of the traffic/mobility environment	Input	Both	Quantitative	Intrinsic	N/A	Is the project environment deployed at at a wide-enough scale (in terms of infrastructure)?
12. Scale - Number and proportion of new equipment and/or users participating	Input	Both	Quantitative	Intrinsic	N/A	Is the project environment deployed at a wide-enough scale (in terms of users of new equipment)?

	Input or output?	Ex ante or ex post?	Qualitative, factual or quantitative?	Intrinsic achievement or impact assessment?	A-B testing?	What is to be quantified? (Examples)
13. Scale – Number and proportions of retrofitted equipment participating	Input	Both	Quantitative	Intrinsic	N/A	Is the project environment deployed at a wide-enough scale (in terms of users of retrofitted equipment)?
14. Scale – Size of a convoy of vehicles (platoon)	Both	Both	Quantitative	Intrinsic	N/A	Is the project significant in terms of size of the convoy (in km)? Of number of vehicles in the convoy?
15. Scale - Number and proportions of Vulnerable Road Users (VRUs)	Input	Both	Quantitative	Intrinsic	N/A	Is the project environment deployed at a wide-enough scale (in terms of vulnerable users)?
16. Scale – Duration and circumstances of observation	Input	Both	Quantitative / factual	Intrinsic	N/A	Do project observations last long enough to bring significant results?
17. Scale - Data capture and storage	intermediary	Both	Quantitative	Intrinsic	Applicable	Does data capture last long enough to bring significant results?
18. Validation – privacy and security (Non-functional aspects)	Both	Both	Factual / qualitative	Intrinsic	N/A	
19. Validation – Communications performance	Output	Both	Quantitative	Intrinsic	Applicable	Ex post: Did enough occurrences of each test happen? Were they run in critical conditions (e.g. in terms of simultaneous users)? Was the result satisfactory in a high enough proportion of the runs?
20. Validation - Number of lives saved / injuries avoided / collisions avoided	Output	Both	Quantitative	Impact	Applicable	Ex ante, does accident analysis (field of effect analysis and effectiveness analysis) show ex ante how many lives could be saved / injuries avoided / collisions avoided by the use case?
21. Validation – Greater transport efficiency / Intermodality	Output	Both	Quantitative	Impact	Applicable	Is the traffic more fluid once the service is introduced (other things being equal)?
22. Validation – Mobility and service reliability	Output	Both	Quantitative	Impact	Applicable	By how much is a bus service less prone to delays once the service has been introduced?
23. Validation – Reduced energy used	Output	Both	Quantitative	Impact	Applicable	By how much is the overall quantity of fuel burnt by all users involved reduced once the service has been introduced?
24. Validation – Fewer negative environmental impacts	Output	Both	Qualitative	Impact	Applicable	By how much is the quantity of CO2 released lower in the area once the service has been introduced?
25. Validation – Inclusiveness	Output	Both	Partly qualitative, partly factual	Impact	Applicable	
26. Validation – Support for socio-economic development	Output	Both	Quantitative	Impact	Applicable (at programme level)	Production: part of CCAM in European GDP, imports and exports? Utility, i.e. Costs vs. Benefits for European users of CCAM: monetary equivalent of lives saved, collisions avoided, avoidance of time lost in traffic congestion... as compared to the cost of ownership of CCAM systems?
27. Validation – Robustness of the business model proposedfor deployment	Both	Both	Partly quantitative, partly qualitative	Impact	Applicable (between projects)	What is the order book of the technology in the EU at the end of the pre-deployment project?

	Input or output?	Ex ante or ex post?	Qualitative, factual or quantitative?	Intrinsic achievement or impact assessment?	A-B testing?	What is to be quantified? (Examples)
28. Validation – Global benchmarking	Both	Both	Partly quantitative, partly factual, partly qualitative	Impact	Applicable (between continents)	What is CCAM roll-out in the EU as compared with the US and China?
29. Validation - Contribution to completeness of deployment toolkit	Output	Both	Qualitative	Impact	N/A	
30 Validation - Post-requisites criteria for continued reuse after project end	Output	Both	Factual	Both	N/A	
31 – Validation – Assessment of investment required for roll-out	Both	Both	Quantitative	Impact	N/A	How much does a full deployment cost?

Table 1 – Summary of CCAM Pre-deployment project assessment criteria

Out of these 31 criteria, only 18 are supposed to be totally or partially quantitative. One of them belongs to the 'pre-requisite' category, none to the 'scope' category; all of the criteria belonging to the 'scale' category are labelled quantitative, as well as most of the 'validation' criteria.

2 Top-down approach

Whatever the domain, objectives must be defined in a qualitative way before they can be quantified. In other words, there is no good wind for the one who does not know where he wants to go. Applied to the CCAM programme of the EU, this means that the objectives of programme must be set, that the vision must be defined, before reference values can be given to project assessment criteria.

Regarding mobility in the future, we should look at the bigger picture. The quantification exercise should be with the widest view in mind.

In order to look for an expression of wide policy goals regarding C-ITS and CCAM, the sub-group has looked at several documents as potential and valuable sources of inspiration for the assessment of projects on their quantification elements:

- Official documents of the EU or of the European Commission, with a policy or regulatory perspective which set the overall framework for projects, and
- Documents produced by industry groups, including useful reference or guidance.

2.1 Quest for broad programme goals out of European Union documents

2.1.1 ITS Action Plan (2008) and ITS Directive (2010)

The initial steps towards the current European ITS programme were laid down in 2008 with the ITS Action Plan (COM (2008) 886). This policy document described 6 priority areas with specific actions and timelines. Specifically, the Action area 4 called for "integration of the vehicle into the transport infrastructure" from which triggered many European projects on Cooperative systems as well as the Mandate m/453 for C-ITS standardisation. At the time, very little was discussed about mobile network connectivity in future vehicles and even less about Automated Vehicles.

The legal basis was then transposed into the ITS Directive of 2010[37], which defines priority areas:

I. Optimal use of road, traffic and travel data,

II. Continuity of traffic and freight management ITS services,

III. ITS road safety and security applications,

IV. Linking the vehicle with the transport infrastructure.

[37] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32010L0040

For each priority area, a list of priority actions is given. The Directive mandated the Commission "*to adopt the specifications necessary to ensure the compatibility, interoperability and continuity for the deployment and operational use of ITS for the priority actions*".
These specifications had to respect 11 principles, listed in Annex 2 of the Directive.
All these objectives remain at a meta level, making them impossible to quantify.
The following Delegated Acts have been adopted by the European commission under the ITS Directive of 2010:

- Commission Delegated Regulation (EU) No 305/2013 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the harmonised provision for an interoperable EU-wide eCall
- Commission Delegated Regulation (EU) No 886/2013 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to data and procedures for the provision, where possible, of road safety-related minimum universal traffic information free of charge to users
- Commission Delegated Regulation (EU) No 885/2013 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of information services for safe and secure parking places for trucks and commercial vehicles
- Commission Delegated Regulation (EU) No 962/2015 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide real-time traffic information services
- Commission Delegated Regulation (EU) 2017/1926 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide Multimodal Travel Information Services.

These Delegated Acts adopted in application of the ITS Directive are mere specifications. Even if the respect of these specifications is mandatory when implementing a given function, the respect of the specification can be monitored, the speed of implementation of systems and devices conforming to the specification can be monitored, but there is no objective in terms of speed of deployment of the standardised function itself.

2.1.2 2019 Impact Assessment of the ITS Directive of 2010

The ex-post evaluation[38] of the Intelligent Transport Systems Directive 2010/40/EU revisits the objectives of the Directive, their root causes, actions, results and impacts. The evaluation assesses the implementation of the ITS Directive in all 28 Member States between 2008 and 2017.

[38] https://ec.europa.eu/transport/sites/transport/files/legislation/swd20190368-its-ex-post-evaluation.pdf

Figure 1: Intervention logic of the ITS Directive; Part A - From root causes to actions

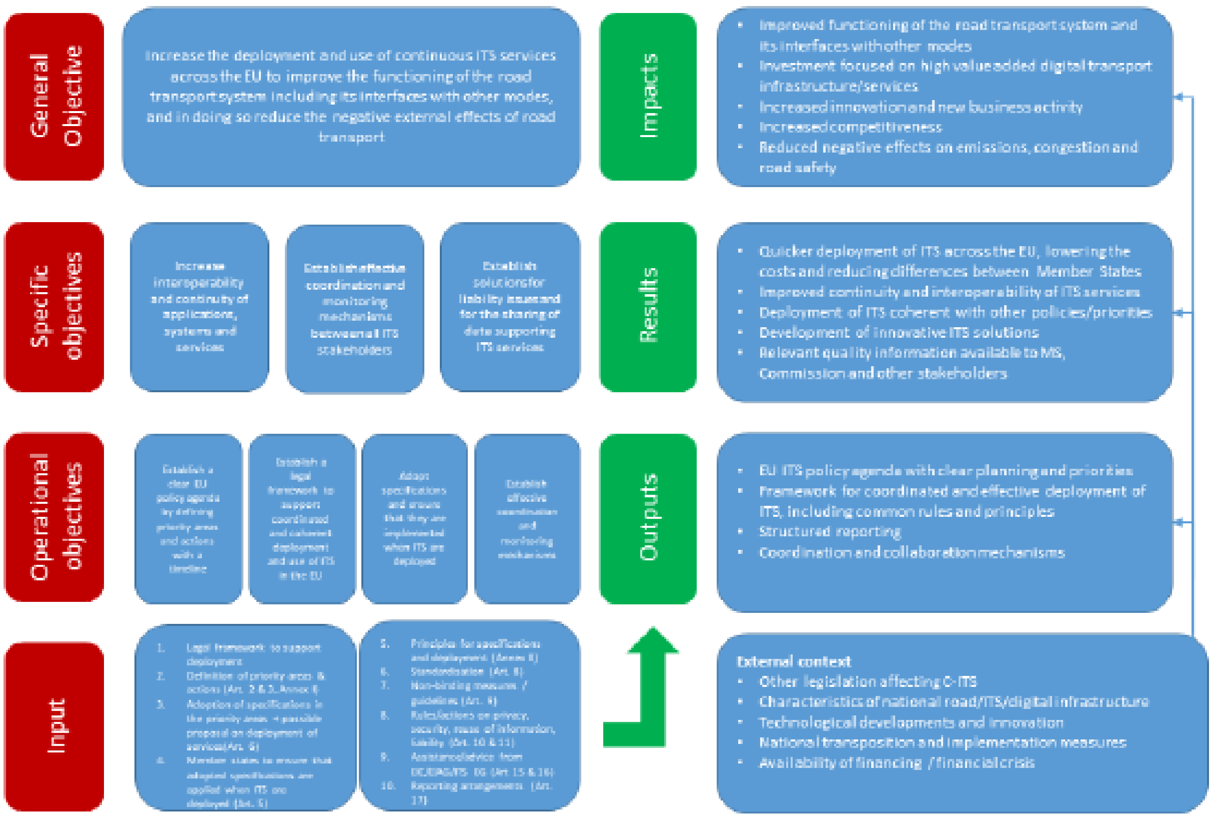


Figure 2: Intervention logic of the ITS Directive; Part B - From operational objectives to results and impacts

This level of assessment of the Directive is fully qualitative. If we look at section 5 of the document, out of the 17 questions of the evaluation, 12 are fully qualitative, 3 could be interpreted as partially quantitative (§5.2.1, 5.2.4 and 5.5.1) and 2 are fully quantitative (§5.3.1).

The fully quantitative questions concern the costs of the programme (§5.3.1) and the relationship between costs and benefits (§5.3.2). The answer on the costs is quantified regarding the costs incurred by the European Commission, and very patchy regarding the costs incurred by the member-states, not to mention private actors. The answer on the comparison between costs and benefits mention that this comparison has not been possible.

Answers to §5.2.1 (level of deployment of ITS applications and services) remains very high level or only quantifies the answers to an opinion poll of respondents and answers to §5.5.1 (Added value of EU intervention in ITS) are purely qualitative.

Regarding §52.4 (To what extent has the deployment of ITS contributed to improving the functioning of the road transport system, including its interfaces with other modes? How has this consecutively contributed to reducing the negative effects concerning road safety, congestion and pollutant and CO2 emissions?), some quantified results are provided:

- "*The eCall impact assessment estimated a reduction of all road accidents by 1% to 7.5%, and a 2% to 15% reduction in the severity of the injury. Over a 20-year period, the study estimates that regulatory measures requiring eCall would save nearly 7,000 lives and mitigate over 70,000 serious injuries. eCall has been extensively tested through projects such as HeERO, and I_HeERO, which have ensured that the system works as intended and is interoperable across the EU. However, the device is only mandatory in new types of vehicles from 31 March 2018, and so the impacts up until now have been limited.*

- *The NEXT-ITS and NEXT-ITS2 deployment corridor estimated (preliminarily) a small reduction in the number of fatalities from traffic management ITS services (0.87 fatalities per year between 2012 and 2015 and 0.11 fatalities per year between 2015-2017). A reduction of injury accidents is also estimated to be 31 per year between 2012 and 2015, and 2.45 per year for 2015-2017. As expected, improved traffic management will only have a small positive impact on road safety.*

- *Safe and secure truck parking information services are expected to help drivers locate adequate rest facilities, reducing the likelihood of dangerous parking and exceeding the driving times. However, the impact on safety from truck parking projects has not been evaluated, so it is difficult to estimate the magnitude of this effect.*

- *In the national reports, reporting on the KPI of 'change in road accidents results in death or injury' was variable, and different levels of disaggregation were offered by each country, so no assessment at European level could be made. Finland estimated a 14% decrease in accidents based on recent project experience, Germany a 30% decrease. Spain reported detailed figures (before* *and after ITS implementation or improvement) for interurban roads and urban roads, with contrasted results: strong improvement for interurban roads (e.g. 56% less fatalities, 31% less accidents with victims), bad results for urban roads (e.g. 68% more fatalities, 26% more accidents with victims) – these figures may deserve additional analysis, in particular regarding the typology of victims (e.g. VRUs in urban areas), the type of deployed ITS and possible other factors influencing these changes. Sweden did not produce a KPI but provided indicative savings based on project experience; between 2014 and 2016, 400 new cameras along a road network of around 1000 km saved the lives of four people.*

To conclude, the primary actions affecting road safety are eCall and C-ITS. However, they are both in the early stages of deployment, so the current impact has been small but is expected to increase in the future as eCall gains fleet penetration and C-ITS services are deployed on a larger scale. »

The first take-away from this analysis is that it is very difficult to quantitatively assess something ex post, if the objectives were not quantified ex ante.
A second take-away is that discrepancies between the statistical apparatus of the different member-state makes the top-down evaluation of EU-level action extremely difficult.

2.1.3 Support study for Impact Assessment of Cooperative Intelligent Transport Systems

This 'Support study for Impact Assessment of Cooperative Intelligent Transport Systems", reference MOVE/B4/2016-239[39], quantifies the expected benefits of three possible Policy Options regarding the development of C-ITS systems:

- "*Policy Option 1 (PO1) consists of a series of non-binding measures such as guidelines, memoranda of understanding (MOUs), stakeholder coordination or knowledge exchange platforms. A similar type of support was provided via the EC's C-ITS Platform.*
- *Policy Option 2 (PO2) consists of a Delegated Act under the existing ITS Directive. It is a legally binding Act that provides common system and service profiles and definitions of services. For those deploying C-ITS, compliance with the Act would be mandatory.*
- *Policy Option 3 (PO3) builds on the Delegated Act from PO2 and adds a Vehicle to Vehicle (V2V) mandate for deployment of C-ITS that begins in 2021. In addition, PO3 includes the assignment of legal bodies for the C-ITS governance framework.*"

Section 5 of the report includes a large number of quantified aspects of these policy options. Table 2 below provides a summary of the whole financial impact of the three policy options:

[39] https://op.europa.eu/en/publication-detail/-/publication/426495e6-81c1-11e9-9f05-01aa75ed71a1

	PO1	PO2	PO3
In-Vehicle Equipment costs (PV 2020-2035)	€2.9 bn	€12.8 bn	€23.6 bn
Personal C-ITS Device costs (PV 2020-2035)	€0.9 bn	€3.8 bn	€5.9 bn
Upgraded RSU costs (PV 2020-2035)	€0.3 bn	€0.5 bn	€0.4 bn
New RSU costs (PV 2020-2035)	€0.1 bn	€1.2 bn	€1.5 bn
Central sub-systems costs (PV 2020-2035)	€0.7 bn	€0.9 bn	€0.9 bn
Total equipment costs (PV 2020-2035)	**€4.9 bn**	**€19.1 bn**	**€32.3 bn**
Accident reduction benefits	€15.0 bn	€53.4 bn	€76.9 bn
Time saved benefits	€2.0 bn	€10.8 bn	€28.2 bn
CO_2 emission benefits	€0.7 bn	€3.2 bn	€5.3 bn
Other emissions benefits	€0.1 bn	€0.2 bn	€0.3 bn
Fuel saving benefits	€2.5 bn	€11.2 bn	€18.2 bn
Total Benefits (PV 2020-2035)	**€20.3 bn**	**€78.9 bn**	**€128.9 bn**
% modelled costs incurred by private sector (PV 2020-2035)	76.9%	86.8%	91.2%
% modelled costs incurred by public sector (PV 2020-2035)	23.1%	13.2%	8.8%
Total net benefits (PV 2020-2035)	**€15.4 bn**	**€59.8 bn**	**€96.5 bn**

Table 2 - Efficiency of policy options relative to the baseline

Although this report concluded that Policy Option 3 was bringing the highest net benefits, this report has been followed by the proposition by the European Commission of Policy Option 2. However, the rejection of the Delegated Act means that Policy Option 1 has *in fine* been chosen, i.e. the option with the lowest expected net benefits.
What were the causes of these two steps of regression? Dissent between promoters of different industrial standards has resulted in the European Union selecting the Policy Options bringing the lowest expected net benefits. As far as we have investigated, we haven't been able to find alternative documents justifying in a quantified way the fact that the selected policy option was in fact the best one.

Another way to look at this would be to say that dissent on standards induces suboptimal net benefits, and that nobody contests this sad truth.
Before the standards dispute is closed, is it possible to transpose this top-down quantification approach to the EU CCAM Single Platform?

2.1.4 Document creating the EU CCAM Single Platform

The full name of the EU CCAM Single Platform is the following: "*Single Platform **for open road testing and pre-deployment** of Cooperative, Connected, Automated and Autonomous Mobility*".

As the invitation to apply specified it, « *The group's task shall be to provide advice and support to the Commission in the field of testing and pre-deployment activities for Cooperative, Connected, Automated and Autonomous Mobility (CCAM). In particular, the group shall assist the Commission in the following CCAM related thematic areas:*
a) The coordination of CCAM research, testing, piloting, and pre-deployment activities, herein collectively referred to as "testing and pre-deployment activities", in order to increase efficiency and effectiveness, and to integrate existing fora at EU-level.

b) Within the scope of testing and pre-deployment activities, there are important challenges towards the deployment of CCAM that the group shall address, such as those pertaining to data access and exchange, road transport infrastructure, digital infrastructure, communication technology, cybersecurity, road safety, and legal frameworks, etc.

c) In its Communication, the European Commission also announced that it would be establishing a partnership under the next European multiannual financial framework to give a clear long-term framework to the strategic planning of research and pre-deployment programmes on driverless mobility at EU and national levels. The single EU-wide platform shall advice on and support the generation of the work programme for this partnership.

In particular within the scope of testing and pre-deployment activities, the group shall advise and support the Commission in the following ways:
a. To work towards developing an EU agenda for testing, in order to maximise coherence and complementarities between ongoing Research and Innovation (R&I) and testing activities in Europe, exploit synergies and identify possible fields for cooperation. This includes the definition of common priority use cases while keeping testing environments open for a broad range of forward-looking innovative use cases;

b. To support the coordination of EU supported/financed R&I projects as well as pilots, demonstrations, large-scale testing and pre-deployment activities in Europe, with a focus on cross border issues, related to highly automated vehicles and driving systems for passenger vehicles, freight transport and shared mobility services;

c. To gather and exchange experiences, best practices and knowledge on pilots, demonstrations and large-scale trials;

To develop a common evaluation methodology in order to allow for comparison of results between tests. This includes establishing key performance indicators and common framework for the assessments of impacts from large-scale trials on safety, on mobility, and on the environment;

e. To promote collaboration between the various actors involved and, if required, give inputs on pre-normative activities, standards and technical specifications within the European Standards Organisations or any relevant organisation; work towards a safety assessment methodology for Connected and Automated Vehicles (CAVs) that takes into account acceptable behaviour (especially in mixed traffic).

f. To identify how access to, and exchange of, vehicle and infrastructure data may be facilitated through testing and pre-deployment activities, and assist in establishing a data governance framework in this context, taking into account the provisions and the implementation of relevant Commission Delegated Regulations under the Intelligent Transport Directive (2010/40/EU);

g. To find, through testing and pre-deployment activities, common ground for addressing technical and legal issues that are relevant to access to, transfer, sharing, use and storage of data, including the use of data by artificial intelligence solutions;

h. To carry out an assessment of the state-of-play of the cybersecurity framework for CCAM, identify possible gaps to tackle cybersecurity challenges for CCAM both at vehicle system and infrastructure system level, and identify best practices to ensure security of smart vehicles against cyber threats for car manufacturers and other actors of the smart mobility ecosystem. This shall include addressing vulnerability and robustness issues of artificial intelligence systems, and procedures for reporting cyber incidents;

i. To identify how the physical and digital road infrastructure (such as signage, markings, traffic management centres, digital maps etc.) as well as the data requirements that support road usage applications/services (e.g. traffic regulations translated into a harmonised digital representation) can support automated mobility and improve road safety. The safety aspects to be addressed shall cover areas such as vehicle safety (including ability to cope with the different quality and type of roads, markings and signage), vehicle safety assessment/validation, interaction with other road users and road authorities e.g. by reporting incidents, driver reaction time, driver training, issues linked to mixed traffic conditions in the different physical infrastructures (motorways, urban and suburban roads), and whether, or how, these could lead to a possible classification in a harmonised way. The group will also promote collaboration between the various actors (e.g. public authorities, traffic managers etc.) to ensure high quality standards and accuracy of data.

j. To support the coordination of activities that focus on telecommunication infrastructure including satellites and cellular networks, the internet of things, data storage, and information and communication technology (ICT) platforms that support CCAM and related services, and identify those hurdles that need to be overcome (e.g. spectrum, silo approaches);

k. To identify how satellite navigation, notably Galileo and the European Geostationary Navigation Overlay Service (EGNOS), as well as satellite communication, can support the pre-deployment of automated vehicles; monitor progress and propose new activities for research and pre- deployment;

To work on identifying actions to address societal and environmental concerns and support public awareness that are decisive for public acceptance, and consequently the uptake of connected and automated mobility by the diverse user groups;

m. To review those legal issues that could affect the testing and pre- deployment of CCAM, such as traffic rules, vehicle legislation, processing of data and privacy, and how legal hurdles for testing and pre-deployment could be addressed in the context of projects."
These initial objectives are thus purely qualitative.

2.1.5 Inception Impact Assessment prior to the revision of the ITS Directive

This short document issued by the European Commission[40] comprises the following thoughts about the limits in the implementation of the objectives of the Directive.

40 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12534-Revision-of-the-Intelligent-Transport-Systems-Dsrective-

"***The deployment of ITS infrastructure and services*** *among Member States still often* ***remains restricted to a limited geographical scope and is not continuous****. The provisions of the EU specifications adopted through delegated acts have been focused more on the data enabling services than on the deployment of services itself.*
This has reduced the effectiveness of this deployment and it will not achieve its full potential in improving the functioning of the transport system and associated benefits*, notably to increase road safety and traffic efficiency, promote multimodality and reduce negative externalities such as congestion, air pollution and CO2 emissions.*
Three key problem drivers are identified: (a) a lack of interoperability and continuity of applications, systems and services (b) a lack of concertation and effective cooperation among stakeholders and (c) unresolved issues related to the availability and sharing of data supporting ITS services.
The current Directive and its Delegated Regulations are already contributing to addressing these problem drivers and recently implementation of a new working programme for the Directive has started. However, where current specifications address the accessibility of data if it exists, they do not yet address the issue of availability (i.e. existence in machine-readable format) of key data types on the whole network, which is important to support new services such as advanced driving assistance systems (e.g. Intelligent Speed Assistance).
In addition, new ITS themes and challenges are emerging, such as connected and automated mobility and mobility platforms (e.g. Mobility as a Service - MaaS), and the insufficient cooperation between private and public stakeholders e.g. for traffic management. Moreover, the ITS Directive initially has had a strong focus on the core and comprehensive TEN-T network. More efficient and sustainable multi-modal transport solutions - in particular between long-distance and last mile connections in urban nodes - should get more attention.
Without further EU action, ITS services will continue to develop in a slow and more fragmented manner, limiting sustainable, inclusive and multimodal mobility of passengers and freight, and will not contribute enough to wider EU policy objectives, in particular the target to reduce greenhouse gas emissions by at least 55% by 2030.
The COVID-19 crisis is significantly impacting transport demand and use. However, improving information exchange through further digitalisation will remain key to address congestion, traffic incidents, air pollution and CO2 emissions and transport resilience, especially when mobility demand increases again and the operational capacity of public transport could be constrained."
This inception impact assessment remains purely qualitative.

2.1.6 Other relevant documents

The documents mentioned in this section provide useful context information, but do not provide any guidance in quantifying CCAM pre-deployment project assessment criteria.

2.1.6.1 EU Digital Strategy

One of the EU's overall political goals is "Shaping Europe's digital future." The digitalisation of transport infrastructure and vehicle is one of the targets where major improvements can be achieved during this "Digital Decade". 5G is seen as one of the strategic enablers to deliver connectivity to many sectors, enabling the Internet of Things (IoT), telemedicine, connected vehicles, smart energy management, green cities, virtual reality entertainment, more remote collaborations and remote operations in industry.

2.1.6.2 5G Action Plan

The 5G Action Plan is a strategic policy framework to make deploy 5G for all citizens and businesses. Among others, the plan aims to promote 5G uninterrupted deployment in all urban areas and major terrestrial transport paths by 2025. The 5G Observatory[41] monitors the evolution of the 5G action plan in all European Member States.

2.1.6.3 CEF2 Digital

The future Connecting Europe Facility (CEF) will offer grants for funding strategic infrastructure investments in the period 2021-2027. It will include funding for 5G corridors along major transport paths, gigabit connectivity for 5G-ready communities, including to socio-economic drivers - schools, hospitals and others – and surrounding households, linking users across Europe to high performance computing centres etc.

2.1.6.4 Display of RSU deployment

The level of deployment of Cooperative Intelligent Transportation Systems (C-ITS technology at the 5.9GHz frequency band) in Europe can be evaluated - informally - by using several sources of information. The maps of deployed Road-Side Units that emit CAM messages is a good indicator. Such maps can be obtained, for example, from the following sources:

- The Layer "C-ITS stations" in the TENtec Interactive Map viewer. This information has been provided by members of the "C-Roads Platform".[42]
- The 5 pilot sites of project SCOOP in France. This lists several areas on highways that have deployments of RSUs.[43]
- The information from the "C-ITS Deployment Group"; a few success stories from Austria and Netherlands.[44]
- The private mapping information maintained by the highway road operators. For example, in France, Cofiroute and APRR operators have deployed several Road-Side Units ("Unité de Bord de Route") which are visible on the road although not yet publicly useable.
- The private mapping information maintained by the City authorities in conjunction with RSU manufacturers; for example, in France, several RSUs are deployed in the city of Versailles with manufacturer Lacroix.
- The private RSUs deployed by research centres for local experimentation purposes, outdoors.
- The information from administrators, deployers and manufacturers of connected Traffic Lights, such as EPI78-92 in Paris Region, France and manufacturer Aximum.
- The large-scale deployment of On-Board Units (at 5.9GHz) carried by automobiles. For example, the Volkswagen Golf Series 8 V2X.

2.2 Quest for broad programme goals out of industry group documents

2.2.1 5GAA White Paper - Cost Analysis of V2I Deployment

The European Commission is not the only body to publish a quantification of V2I deployment. 5GAA has also undertaken such an exercise, with the help of the same consultancy – Ricardo – as the European Commission for its *Support study for Impact*

[41] http://5gobservatory.eu/
[42] https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/map/maps.html
[43] http://www.scoop.developpement-durable.gouv.fr/les-5-sites-pilotes-scoop-a4.html
[44] https://c-its-deployment-group.eu/activities/c-its-deployments/

Assessment of Cooperative Intelligent Transport Systems.[45] However, the scope of this study is limited to the cost of V2I deployment. Expected benefits are only listed. Evaluation of these benefits are out of scope. Business plan options are listed and discussed, but not quantified. The executive summary of this study includes the following text:

"*This is the final report of a study carried out by Ricardo, with support from our partner Roke, on behalf of the 5G Automotive Association. The purpose of the study has been to analyse different Vehicle-to-Infrastructure (V2I) deployment options from a financial, business and market point of view, while avoiding going into the technical discussion of the superiority of one technology over the other. Therefore, the objective of this report is to improve the understanding of the costs and their variability, as well as the challenges and opportunities around the four deployment options, to inform the development of business cases. The focus is on the EU and US markets and four deployment options were considered, which comprise of a combination of direct and mobile network communications technologies. Mobile network communications with the vehicle supported by the cellular network (Uu) is considered as part of the V2I system in each option, while three of the options also include direct communications (802.11p and PC5) that uses dedicated spectrum.*

***Option A** – Pure cellular network-based (Uu) system*

***Option B** – Combined system of Uu and an 802.11p-enabled RSU*

***Option C** – Combined system of Uu and a PC5-enabled RSU (i.e. C-V2X solution)*

***Option D** – Combined system of Uu and a dual radio RSU with both 802.11p and PC5*

Research and development activities related to connected vehicle applications have been ongoing for over two decades, and there is now movement towards wider scale deployment of communication technologies in both vehicles and road infrastructure. However, deployment activities have been fragmented and relatively slow due to continued emphasis on research, no common vision of communication technologies and market uncertainty, making it challenging for most stakeholders to develop suitable business cases. A lack of widespread and aligned commitment by vehicle manufacturers, which in part has been caused by unclear regulatory positions, has negatively impacted other drivers and overall confidence in the wider market."

On what the study quantifies, i.e. V2I deployment costs, the main output is that the only important decision about the cost of V2I deployment is the presence or the absence of short-range communication infrastructure, as opposed to cellular infrastructure. Whether the short rang infrastructure is 802.11p only, C-V2X only or a mixture of both is irrelevant in terms of deployment costs. See figure 7.1 taken from this study.

[45] https://5gaa.org/news/cost-analysis-of-v2i-deployment/

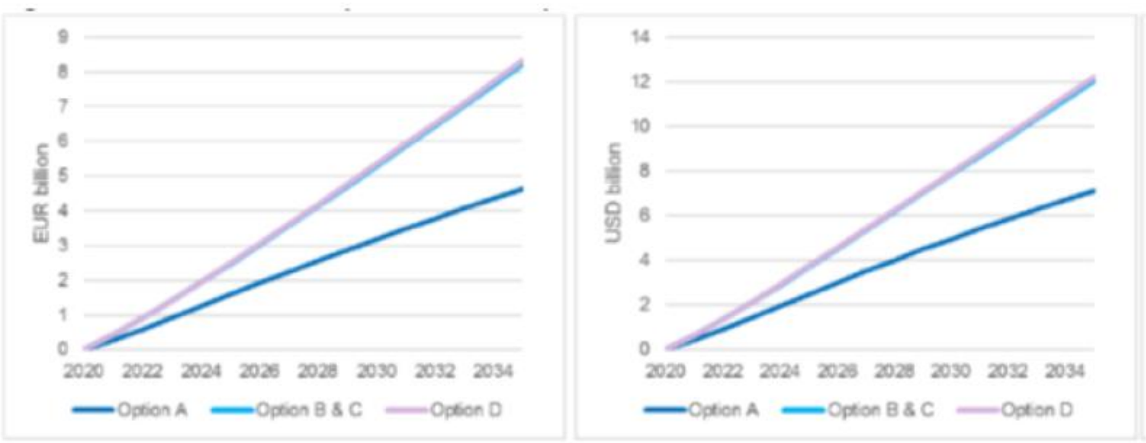


Figure 3 – Cumulative cost comparison between options in central scenario (in the EU and in the USA)

Another major take-away from this study is that the Ricardo study compares different scenarios. To follow the logic of this study when quantifying project assessment criteria for the EU CCAM Single platform, we need to be open in the way we quantify. Use cases can define which technology we use. The scenarios in this document are the way we need to think.
This last sentence raises the following question: what is the point of quantifying different scenarios?

- Is it to select one of them out of this quantification exercise, and reject the others?
- Is it to launch projects corresponding to each of these scenarios, and to use the quantification as a yardstick to evaluate the performance of the projects against their quantified objectives?

2.2.2 5GAA White Paper - MNO Network Expansion Mechanisms to Fulfil Connected Vehicle Requirements

On June 23, 2020, 5GAA published a white paper *entitled MNO Network Expansion Mechanisms to Fulfil Connected Vehicle Requirements*[46].
In its final chapter, *Recommended stepwise approach,* the 5GAA concludes:
"Public-private cooperation on the country-level is highly encouraged to achieve the required road coverage quality as there are strong dependencies between different types of stakeholders.
The previous chapters have indicated that cellular network demands for connected vehicles can vary a lot between countries, within countries and depending on respective use cases. Furthermore, the ways to complement cellular network coverage and network performance along the road vary a lot per country and per specific geographical area within countries. Hence, there is no single recommendation that serves all needs.
The 5GAA rather recommends a stepwise process to road authorities, public/private road operators and municipalities in order to identify their specific situation and suited mechanisms:
1. What drives the need for road coverage for the specific stakeholders?

[46] https://5gaa.org/news/mno-network-expansion-mechanisms-to-fulfil-connected-vehicle-requirements/

a. What are the governmental priorities (safety, efficiency, CO2 emissions, operational cost savings, economic stimuli, etc.)?
b. What are the key stakeholders and use cases for these priorities?

2. What is the current road coverage situation?
a. Identify/measure road coverage across the complete road network and broken down by:
i. Motorways
ii. Federal roads
iii. Secondary road network (state roads/local roads/municipal roads)
b. Who are the relevant stakeholders (regions, municipalities, countries in border areas, owners of public infrastructure, etc.)?

3. Which of the suggested mechanisms in chapter 3 can improve the situation?
a. Road coverage obligations (as part of a series of linked policy measures)
b. Provision of public roadside infrastructure
c. Cross-border coverage improvement
d. Public co-funding for critical corridors
e. Incentives to expand rural coverage
f. Neutral host model for infrastructure sharing
g. Spectrum auctions without strict road obligations for competitive MNO markets with high customer demands
h. Ensure sufficient 5G spectrum

4. What steps need to be taken and which key stakeholders need to support this?
This stepwise approach will provide clear markings for stakeholders to define a forward-looking action plan and requirements underpinning the connected vehicle future."

Couldn't we use these recommendations as questions to be asked to quantify a project? On the one hand, at the start of the proposed process, one finds big public policy objectives. The subsequent taking into account of the viewpoint of each stakeholder is interesting. The implementation of these 8 mechanisms in large deployment projects will certainly help to prepare for much larger 5G CAM deployment. Future predeployment projects should address these challenges and eventually propose how to put these mechanisms in place taking into account cross-MNO, cross OEM and cross-Road operators experiences and complex relations.

2.2.3 TNO Report - TNO report - Environmental Benefits of C-V2X for 5GAA

This very interesting study, published on November 10, 2020, exists in a summary[47] and a full[48] version. It is based on interviews, on a review of existing field test reports and on a traffic simulation tool. The results are quantified, but only in the form of ranges, because differences in environment parameters could trigger very different levels of environmental benefits and because different methodological approaches bring different results. The following figures 4 and 5 are taken from this study.

[47] https://5gaa.org/wp-content/uploads/2020/11/26112020-Presentation-TNO-Study-Environmental-Benefits-Connected-Mobility-20201124.pdf
[48] https://5gaa.org/wp-content/uploads/2020/11/Environmental-Benefits-of-C-V2X.pdf

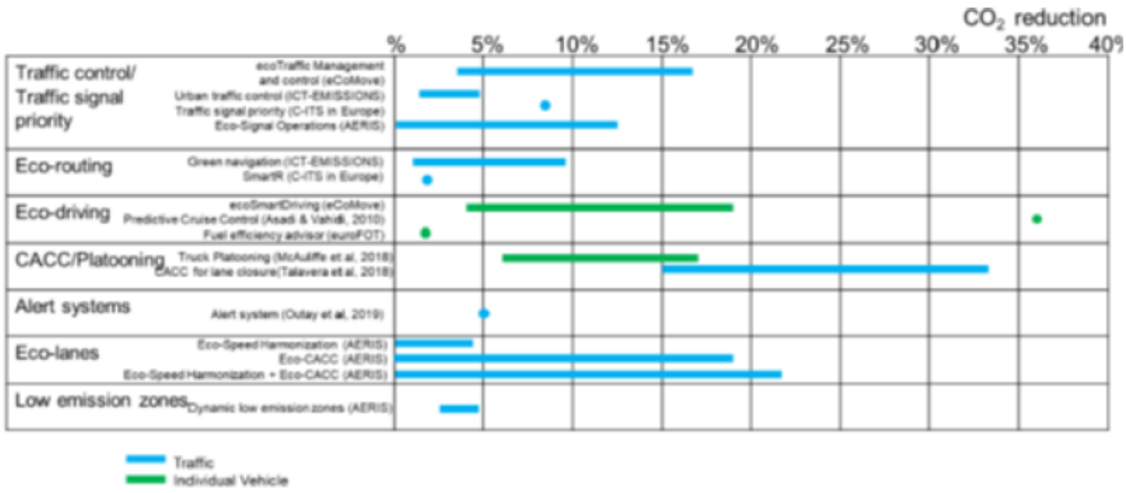


Figure 4 – Impacts of different applications classified per level on which the impact is described

Figure 5 below illustrates the impact of the estimation method on the results.

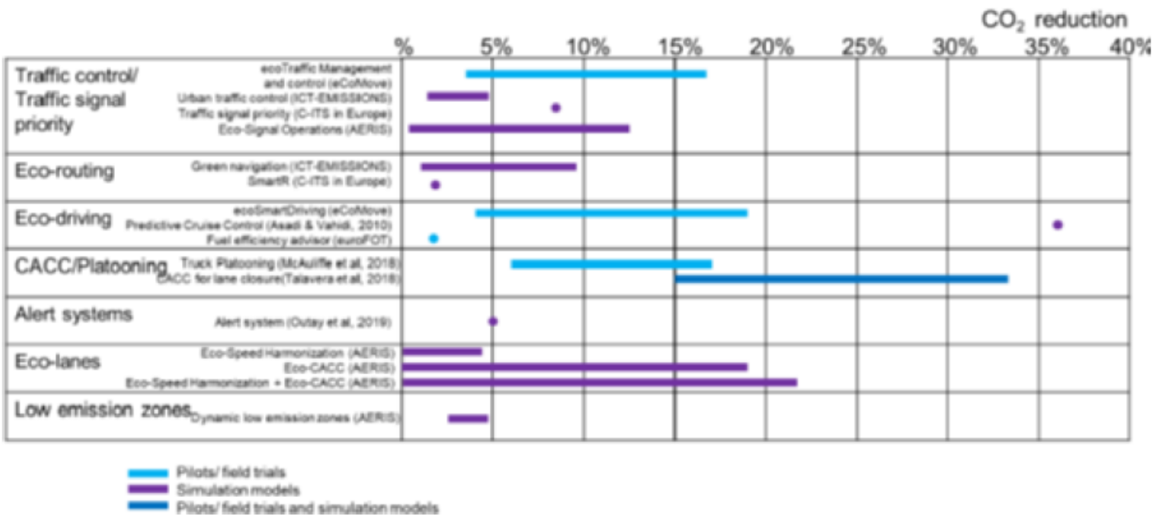


Figure 5 – Impacts of different applications classified per method

This study is a sobering reminder of the prudence required by an ex-ante quantification approach of the impacts of CCAM applications.

2.3 Validation of Spectrum Needs of V2X

In the following, studies are referenced which quantify C-ITS spectrum needs for C-ITS message types, each of them allowing several different C-ITS use cases.
Pre-deployment projects could implement existing or new use cases which are already covered by those message types or identify new use cases related to new message types. The question to future pre-deployment projects is weather their spectrum needs are in line with the findings here and how they are able to complement the spectrum needs picture. This will be especially relevant for CCAM use cases which might change assumptions of those existing studies, may be the use cases require to send this message type more often or may be CCAM use cases define new message types not yet covered in the existing studies.
Spectrum needs studies should be included in pre-deployment projects when communication is a central part. Pre-deployment projects should explain beforehand that

they can be deployed with existing spectrum regulation if the proposed use cases/technology would be implemented in a big scale.
The highest spectrum efficiency of proposed pre-deployment projects can use as a quantitative selection criteria.

2.3.1 CAR 2 CAR Communication Consortium - Position Paper on Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Cooperative Automated Driving[49]

Evaluating C-ITS Day-1 application regarding spectrum needs show that C-ITS basic awareness applications (day 1 use cases based on CAM, DENM, MAP, SPaT, IVI message types) will require 10 MHz bandwidth during the initial 10 years. The spectrum needs analysis of applications for Day-2 and beyond was done based on European C-ITS projects and based on already in ETSI or SAE specified advanced C-ITS applications and their message types (see Table 3 below), including CPM, MCM, PCM.
CPM and VAM address Day 1,5 use cases for VRU and especially pedestrian protection.

Phases of V2X application roadmap[2]	Message types[1]			Examples of applications based on the message types
	Europe	USA	Abbreviations explained	
Awareness driving	CAM, DENM	BSM	Cooperative Awareness message, Decentralized Environmental Notification Message, Basic Safety Message	Intersection Collision Warning Emergency Vehicle Warning Dangerous Situation Warning Stationary Vehicle Warning Traffic Jam warning Pre-/Postcrash Warning
	SPaT, MAP, IVI	SPaT, MAP, IVI	Signal Phase and Time, MAP message, In-Vehicle-Information message	Enabling Infrastructure-to-Vehicle Communication at e.g. traffic lights
	VAM	PSM	VRU Awareness Message, Personal Safety Message	VRU warning for (C-ITS) equipped Vulnerable Road Users
Sensing Driving / sensor sharing	CPM	CPM	Collective Perception Message	Overtaking Warning Extended Intersection Collision Warning Vulnerable Road User Warning for non-equipped VRU´s Cooperative Adaptive Cruise Control Long-term Road Works Warning Special Vehicle Prioritisation
Cooperative Driving with Coordinated maneuvering and cooperative automated driving	MCM, PCM	MCM, PCM	Maneuver Coordination Message, Platooning Control Message	(Static or dynamic) Platooning Area reservation Cooperative Merging Cooperative Lane Change Cooperative Overtaking

Table 3 – Relationship of V2X applications to message types to phases of V2X application roadmap

The C2C-CC study is a communication technology independent spectrum analyses and confirmed by vehicle manufacturers showing that at least 70 MHz bandwidth will be needed for today's well defined C-ITS applications, based on the C-ITS messages from (these phases follow table 1 and C2C-CC application roadmap):

- awareness driving (day-1)
- sensing driving

[49] Position Paper on Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Cooperative Automated Driving by CAR 2 CAR Communication Consortium (car-2-car.org), https://www.car-2-car.org/fileadmin/documents/General_Documents/C2CCC_TR_2050_Spectrum_Needs.pdf

- cooperative automated driving

The underlaying assumption for the spectrum needs in table 4 below are the ETSI or ISO standards and technical specifications for the message types and that those are implemented with one short range communication technology only. Duplicating communication with different technologies would lead to a duplication in spectrum needs.

Safety spectrum needs for a single short-range V2X communication technology in MHz bandwidth, in 5.9 GHz safety band

	environment			
message type	**urban**	**suburban**	**Rural** (Highway)	min number of 10 MHz Channels
CAM cooperative awareness message	9	10	10	0,9
DENM decentralized environmental notification message	4	2	1	0,1
SPATEM signal phase and timing, **MAPEM** road/lane topology and traffic maneuver , **IVI** in-vehicle-information and other I2V messages	1	1	1	0,5
VAM VRU awareness message	4	0,2	2	0,5
PCM platooning control message	3	6	10	1,0
CPM collective perception message	23	26	24	2,0
MCM maneuver coordination message	23	26	24	2,0
Minimum basic spectrum needs in MHz	**67**	**72**	**72**	
total number of 10 MHz channels required				**7**

Table 3 – European V2X spectrum needs for safety in 5.9 GHz

2.3.2 ACEA[50] and CLEPA[51] paper - Perspectives of the European automotive industry on future C-ITS spectrum needs for Cooperative, Connected and Automated Mobility

The automotive industry strongly supports ambitious policy goals towards achieving a European environment for Cooperative, Connected and Automated Mobility (CCAM), which can contribute to a safer, more convenient and sustainable mobility ecosystem. Cooperative Intelligent Transport Systems (C-ITS) have been proven to reduce traffic fatalities and increase traffic efficiency. Automated driving functions will initially be supported by C-ITS. However, for automated driving level 5 C-ITS will be a pre-condition.

[50] ACEA-CLEPA paper: Future C-ITS spectrum needs | ACEA - European Automobile Manufacturers' Association, https://www.acea.be/publications/article/acea-clepa-paper-future-c-its-spectrum-needs

[51] CLEPA and ACEA publish a joint paper on future C-ITS spectrum needs for cooperative connected and automated mobility - CLEPA ; https://clepa.eu/mediaroom/clepa-and-acea-publish-a-joint-paper-on-future-c-its-spectrum-needs-for-cooperative-connected-and-automated-mobility/

For this to become a reality and for the new functionalities currently being researched and developed to fully achieve the potential of reducing road fatalities and making road transport more efficient and environmentally friendly overall, additional spectrum will be needed in addition to the currently harmonised ITS spectrum in Europe.

All of the following advanced C-ITS use cases are seen important and part of CCAM. All of them depend on sufficient radio spectrum:

- Advanced safety and efficiency (day 1 and beyond, awareness driving)
- Collective perception
- Cooperative driving
- Sensor driving: sensor sharing
- Remote driving
- Vulnerable road users (VRUs)
- Vehicle automation levels with initially vehicle platooning

To deploy Day-1 safety C-ITS use cases, the safety-related C-ITS spectrum currently available in Europe in the 5.9GHz band (5875- 5915 MHz) will be used and sharing possibilities in 5915-5925 MHz (10 MHz) with urban rail will be important to achieve. However, studies carried out within the Car2Car Communication Consortium and in the 5GAA show that the 50 MHz designation for safety related ITS and road user automation will not be sufficient.

2.4 Study of safety benefits of V2X using short range communication in 5.9 GHz by selected projects

The following projects demonstrated that quantified benefits in road safety can be achieved if the project objectives are including a quantifiable accident analysis from the beginning. A combination of well described use cases, combination of simulation, test tracking and in-field testing and accident analysis can quantify the benefit of use cases for traffic fatality and injury reduction.

2.4.1 The input of the Drive C2X project

Safety benefits of V2X using short range communication in 5.9 GHz by Project Drive C2X[52] The DRIVE C2X project investigated Day-1 cooperative functions which are primarily focused on improving road safety. The analysis revealed that the safety results are promising for the DRIVE C2X functions individually. When the cooperative systems are brought to the market, they will be offered in bundles of systems on vehicles. That is, multiple systems will be offered in a package. Because all functions contributed in safety, the safety impacts of the bundles will be larger than the impacts of the individual systems analysed, however, lower than sum of individual effects because the targeted accidents are partly the same. The main safety results showed that the functions affected traffic safety in a positive way by preventing fatalities and injuries. The most effective functions from the safety point of view were In-vehicle signage/ Speed limit and Weather warning. The next were Electronic emergency brake light, Traffic jam ahead and Road works warning functions. However, even the GLOSA function developed primarily for improvement of environmental impacts enhanced safety slightly.

[52] https://trimis.ec.europa.eu/project/drive-c2x-driving-implementation-and-evaluation-c2x-communication-technology-europe

Figure 6 below shows the estimated percentage reduction in fatalities and injuries in 2030 for the low, medium and high passenger car penetration rates due to the DRIVE C2X functions in the EU-28. The findings are based on equipping only passenger cars. It is expected that equipping heavy goods vehicles will result in a larger percentage improvement in safety.

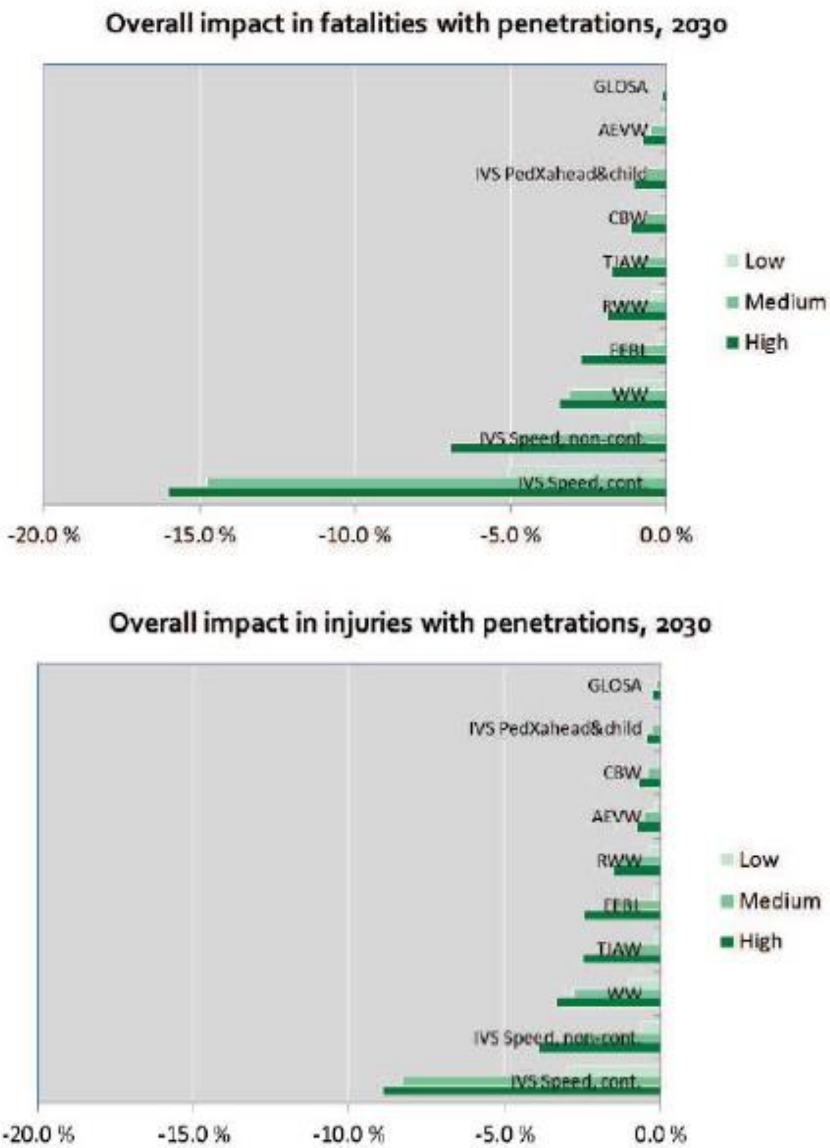


Figure 6 - Estimated percentage reduction in fatalities and injuries in 2030 for the low, medium and high passenger car penetration rates due to the DRIVE C2X functions in the EU-28

2.4.2 Safety benefits of V2X using short range communication in 5.9 GHz by Project simTD[53]

SimTD was the biggest single field test in Europe for short range V2X technology (ITS-G5) being integrated in the vehicle´s architecture of 120 passenger cars from six different OEM plus 3 motorcycles and 100 RSU all connected to a simTD traffic management centre as well as the traffic management centre of the city of Frankfurt and operated for a period of 6 months.
13 safety Day 1 use cases (based on CAM and DENM) under study generated quantifiable reduction in traffic fatalities and serious injuries.
In an accident analysis the number of reduced fatalities and injuries were calculated in a stepwise process for the use cases traffic sign warning, electronic brake light and intersection assistant.

2.4.2.1 Determine field of effect

In the first step the field of effect is analysed which describes the proportion of all accident situations in which a specific test case can have a positive effect. Details of the use case can be derived from in-depth accident data such as GIDAS (German In-Depth Accident Study). See figure 7 below.

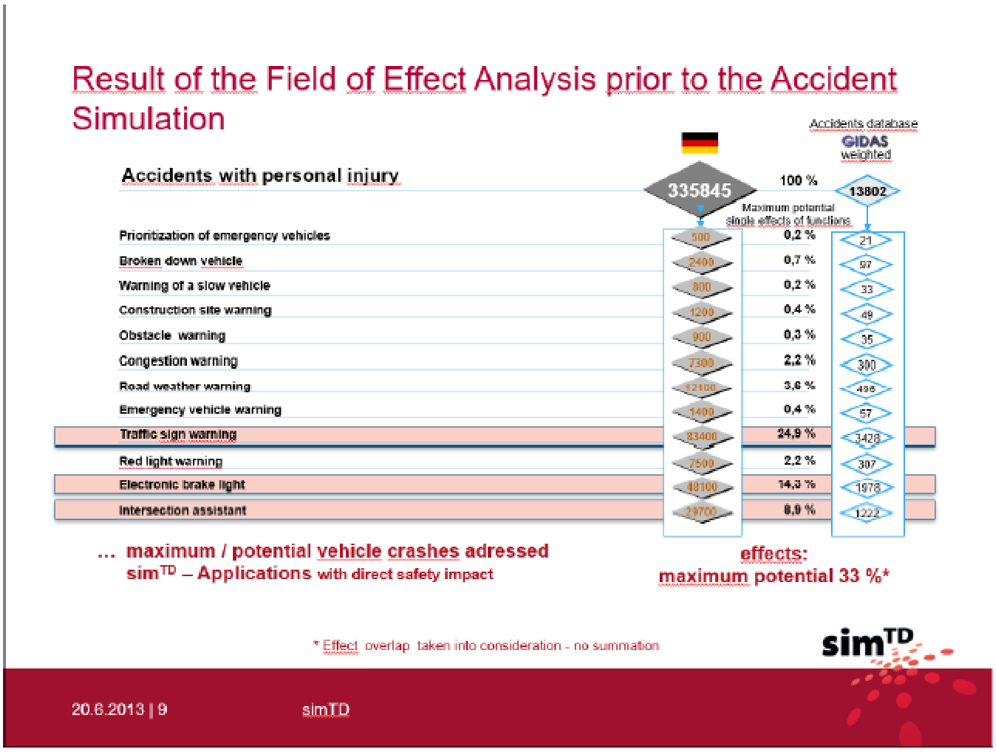


Figure 7 – sim TD: Result of the field of effect analysis prior to the accident simulation

[53] https://trimis.ec.europa.eu/project/safe-intelligent-mobility-test-field-germany; BMWi - CONVERGE/simTD - Intelligente Vernetzung von Fahrzeugen und Verkehrsinfrastruktur ; simTD deliverables can be found here : https://www.eict.de/projekte/

2.4.2.2 Determine the effectiveness

Secondly the effectiveness is determined which defines how well all possible accident situations within the defined field of effect are address by the use case. This can be done prospectively by virtual simulation or by vehicle tests on the proving ground.

Figures 8 and 9 below show the effectiveness calculated for intersection assistant and electronic brake light. Remarkable is the effectiveness of intersection assistant, which is able to reduce about 2/3 of all severe and fatal crashes at an intersection between vehicles. The intersection assistant account for 8.9 % of the total severe and fatal accidents in Germany between vehicles.

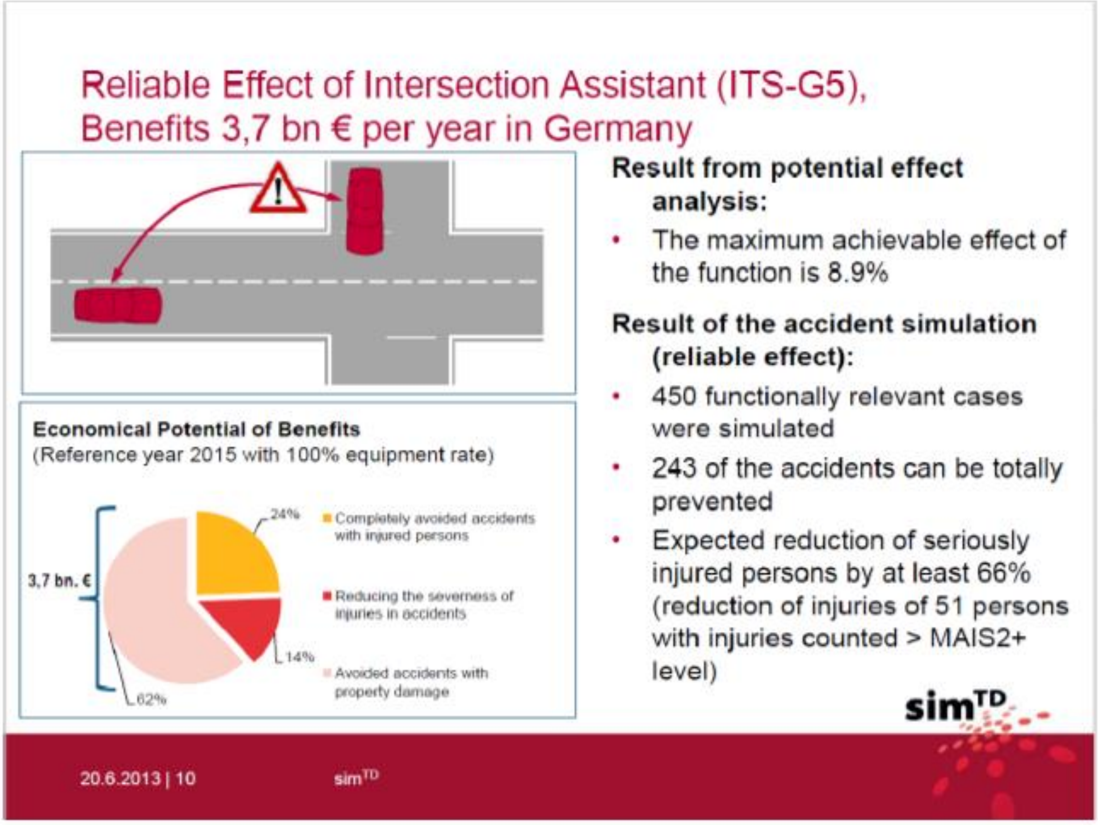


Figure 8 – Reliable effect of Intersection assistant (ITS-G5)

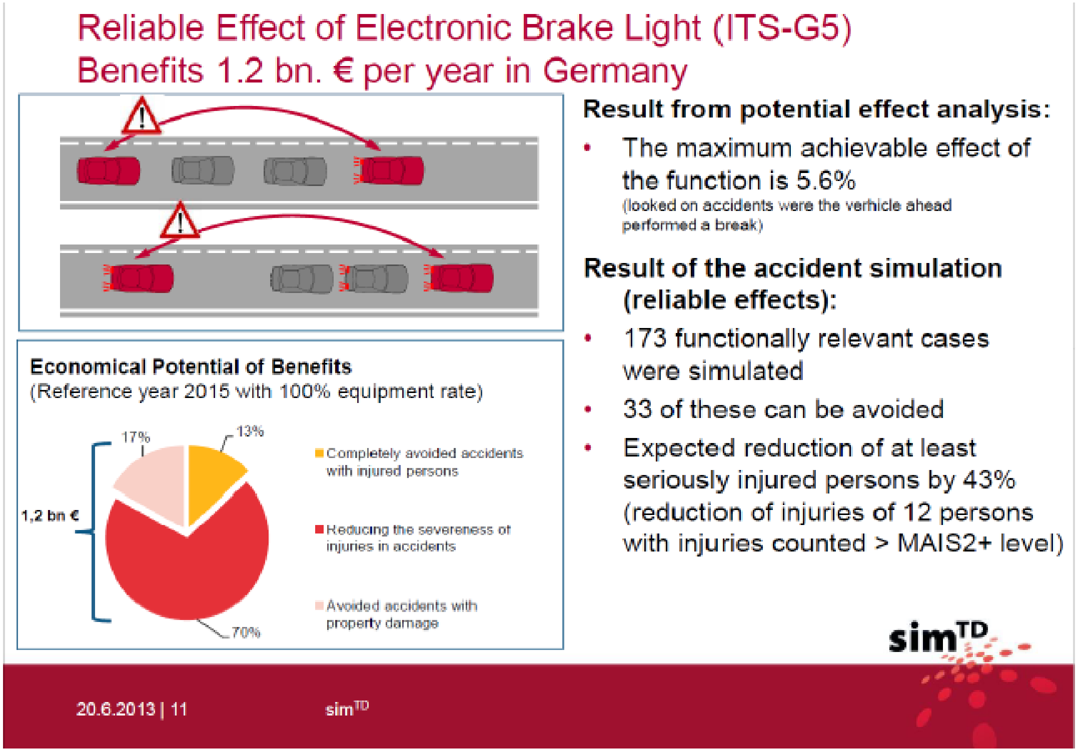


Figure 9 – Reliable effect of Electronic Brake Light (ITS-G5)

This approach fits with the characteristics of criterion 20 (Number of lives saved / injuries avoided / collisions avoided) in the document on Project Assessment Criteria, which is classified as an Output criterion, but usable both ex-ante and ex-post. The simTD approach is an excellent illustration of the ex-ante quantification of this validation criterion.

As a result of a cost/benefit analysis these safety use cases -and taking a 20 year ramp up curve for V2X equipment in vehicles into account – are able to generate 142 bn. € benefits over 20 years (see figures 10 to 12 below).

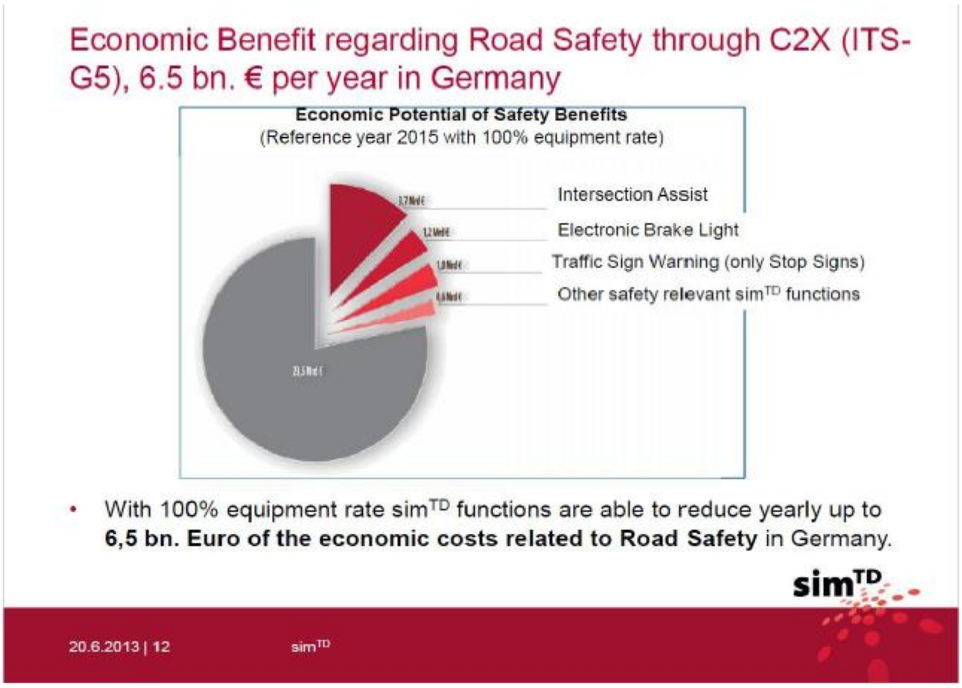


Figure 10 – Economic benefit regarding road safety through C2X per annum

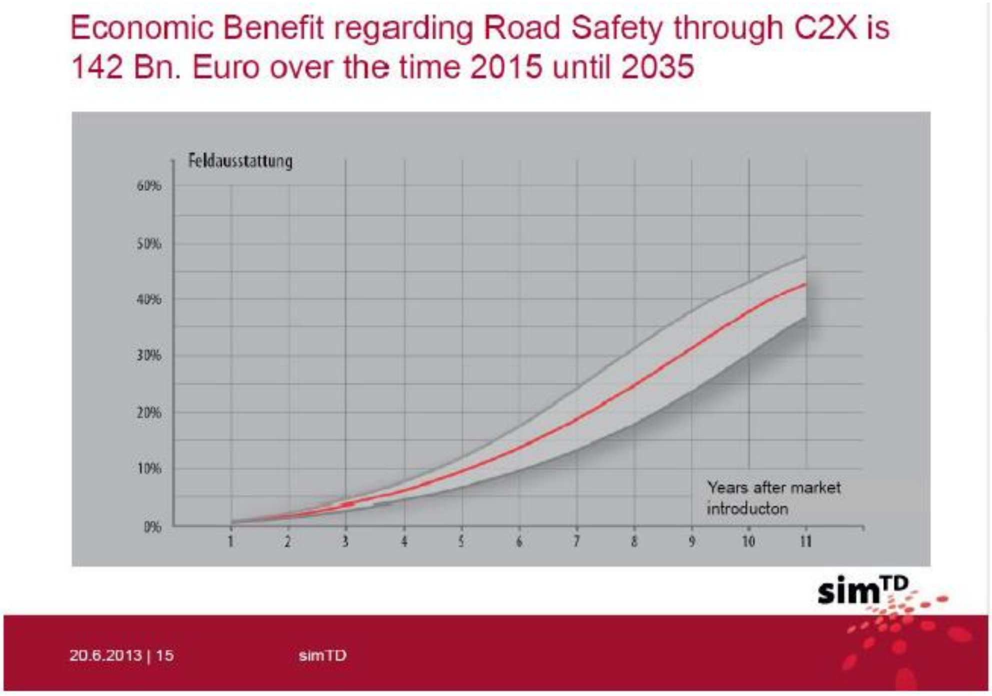


Figure 11 - Economic benefit regarding road safety through C2X (ramp-up)

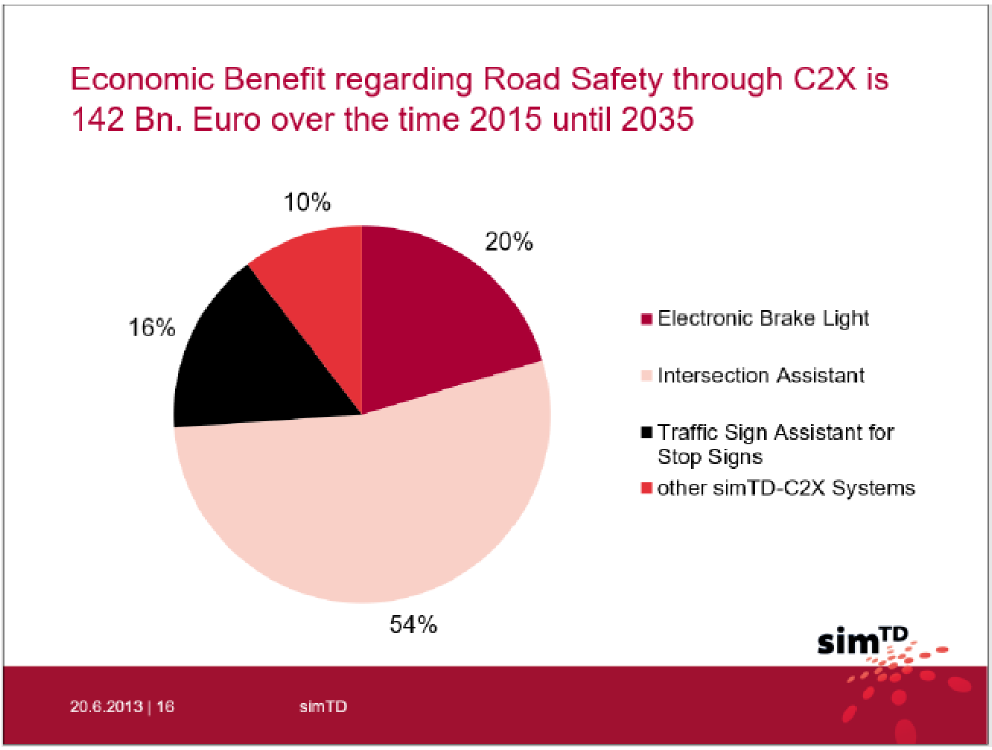


Figure 12 - Economic benefit regarding road safety through C2X (cumulated)

As a conclusion, we can say that, for pre-deployment projects covering safety, the following will be important to tackle to generate quantified safety benefits:

- Driving scenarios for crash avoidance are often not possible in real traffic but needs to be tested, verified in test track and/or simulation environments.

- Accident analysis should be included in safety relevant pre-deployment projects to quantify possible reduction in fatalities/injuries.
- State-of-the-art accident analysis use field of effect and effectiveness analysis per individual safety use case.

2.5 Outcome of the top-down approach

Objectives must be defined in a qualitative way before they can be quantified. In other words, there is no good wind for the one who does not know where he wants to go.
It is very difficult to quantitatively assess something ex post, if the objectives were not quantified ex ante.
Discrepancies between the statistical apparatus of the different member-state makes the top-down evaluation of EU-level action extremely difficult.
A study quantifying a Policy Option as bringing the highest net benefits is not enough for this Policy Option to be adopted.
The contestation of a recommended Policy Option takes other forms than a debate on net global benefits.

Dissent on standards can result in the worst policy option in terms of net benefits being finally selected.
What is the point of quantifying different scenarios?

- Is it to select one of them out of this quantification exercise, and reject the others?
- Is it to launch projects corresponding to each of these scenarios, and to use the quantification as a yardstick to evaluate the performance of the projects against their quantified objectives?

Quantification of the objectives should help express how a given scenario represents the maturity of the system.
Ex ante quantification of benefits is not an exact science. Multiple methodological approaches to quantifying the same benefits can improve the level of confidence in the results of the quantification exercise.
Spectrum needs studies should be included in pre-deployment projects when communication is a central part. Pre-deployment projects should explain beforehand that they can be deployed with existing spectrum regulation, at least for the part to be deployed in a next step. Highest spectrum efficiency can be a quantitative selection criterion for pre-deployment projects.
Accident analysis should be included in pre-deployment projects for safety use cases. Field of effect analysis and effectiveness analysis (both parts of accident analysis) can guide the selection of most important safety use cases for pre-deployment projects.

3 Bottom-up approach

Considering the difficulties of pursuing a top-down only approach, the subgroup also explored a bottom-up approach, the starting of it of which being the documents shared in WG6 defining the use cases which are important form the EU CCAM Single Platform.

3.1 Examination of WG6 use cases and request to WG6 use cases sub-group to formulate goals of action on each use case

The subgroup has analysed the three following use case documents (in the version uploaded on June 17, 2020 on the CIRCABC platform):

- Use case #1: Emergency braking[54]

[54] https://circabc.europa.eu/sd/a/8f7a6526-872d-43c8-a617-0a1963e5e908/Emergency%20breaking.pdf

- Use case #2: Pedestrian_v5[55]
- Use case #3: Lane_Merging_v4[56]

These documents provide good descriptions of the use cases. Sometimes, this description includes quantified parameters[57]. However, the final section of each of these three documents is called *Expected Evolution of Development*. This is the point of view of an external observer, this is clearly not an objective, not to mention a quantified one.
This is why the subgroup on project assessment criteria kindly asks the WG6 subgroup on use cases to continue their effort and issue documents providing quantified objectives for projects addressing these use cases.

3.2 Role of scientific testing methods in determining the maturity of a technology
We have to break-down the high-level European goals (mentioned above in section 2) down to tests that go beyond simulation, test with two vehicles or test in remote areas, and concentrate on how to do scientific experiments, or maturity assessments of the proposed technologies, and thus engaging in tests that allow to really measure the societal benefits brought by the solutions proposed to handle each use case.
Everyone has claims about the maturity of one's technology. Such claims must be proven. We need references to best practice in radio communication testing. One of the key factors which determine performance is the number of subscribers sharing the physical communication channel. How fast does the performance decrease with the increase of subscribers? This is never linear, we have been knowing this for 102 years, since the Erlang formula. The key factors are: what is my radio channel? How is it used by each user? How many users are using it?
Most of the time, one performs stress testing in an artificial environment. Ideally, stress testing should be performed in a realistic environment. When does the system break down? Projects showing what is the maximum number of users in their use case should receive preference. The execution methods should evolve, the trial execution methods should be more precise, but the use cases should not be bent to accommodate with the technical difficulties. Technology Readiness Levels (TRLs) are also a part of this testing methodology. Test objectives and methods should be specific to the degree of realism aimed at in the case of a given TRL.
For instance, a given penetration rate might be necessary to observe the benefits of a service; however, such a penetration rate might be difficult to achieve in the frame of a project; simulation (modelling) can be a way to circumvent this difficulty. However, the TRL of a simulation is not the TRL of an operational system.

3.3 Conformance to standards: from nominal circumstances to extreme ones
Large C-ITS projects in the Horizon 2020 programme, such as C-ROADS[58] and CAR2CAR[59] have produced very useful specifications of (respectively I2V and V2V) C-ITS messages. In its section 2.5 (Pre-requisites to connectivity infrastructure pre-deployment), the document "Connectivity and Digital Infrastructure Pre-deployment for CCAM - Project Assessment Criteria – 20200623" acknowledges the importance of

---

[55] https://circabc.europa.eu/sd/a/4bd6f8d6-952d-4da5-a71a-81a4a499f5e7/Pedestrian_v5.pdf
[56] https://circabc.europa.eu/sd/a/5a77d906-5fe8-4748-a8c9-58f3f2fe9858/Lane_Merging_v4.pdf
[57] *« Euro NCAP describes three different driving scenarios: (i) driving towards a stationary vehicle (30-80 km/h), (ii) closing in at a slower vehicle in front (30-80 km/h) and (iii) following a car in front which suddenly starts braking (50 km/h, gentle and harsh braking). »*
[58] https://www.c-roads.eu/fileadmin/user_upload/media/Dokumente/Harmonised_specs_text.pdf
[59] https://www.car-2-car.org/documents/basic-system-profile/

standards, at the connectivity level. This document also perceives standards as an issue to be tackled before pre-deployment is started. However, the very detail of the C-ROADS and CAR2CAR specifications shows that standards are crucial not only at the level of connectivity, but also at the level of C-ITS (and tomorrow of CCAM) services.
This being said, how can the C-ROADS and CAR2CAR specifications help quantify project assessment criteria? A closer look at the C-ROADS test plan can help answer this question. For each I2V message, this test plan defines how each I2V message should be tested. However, this test plan very precisely defines unit tests, but not performance tests. If we follow the recommendations defined in the previous section, the key questions are:

- What is my radio channel? This is where the spectrum needs mentioned in section 2.3 have to be met, prior to performance tests being conducted.
- How is it used by each user?
- How many users are using it?

Only when these three sets of circumstances are defined for extreme expected scenarios can such tests be performed in a quantified way.

3.4 Review of role of TRLs in project assessment criteria
The subgroup revisited the notion of Technology Readiness Level (TRL). The following opinions were heard:

- a scale defined for the space industry did not fully apply to CCAM in the automotive industry, better described in 3 steps than 9:

o Table model
o Concept car
o Duplication

- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies) –requires a lot of permissions.
- In CCAM, human factors are key, especially in late-stage TRLs.
- Does a given sub-system always remain at TRL9? For instance, is 2G mobile telephony still TRL9?

However, in the case of CCAM, the opinion prevailed in the subgroup that the use case is the system. As a consequence, the system has the technology readiness level of its weakest component. Introducing a TRL5 service in an otherwise fully TRL9 environment creates a TRL5 system, from a point of view which includes this TRL5 service.
This very harsh view can be mitigated by the notion of fallback scenario. If a new service is only intermittently available (e.g. through a lack of deployed fixed infrastructure, or through too low a level of penetration), the TRL of the system including this new service can be low, but the TRL of the fallback system can be TRL9. The question of the level of danger induced by the occurrence of the fallback is key.
Moreover, in CCAM, it is expected that the infrastructure and communication sub-system has a much higher TRL than the new CCAM services tested per se. However, for pre-deployment, the expectation in terms of communication infrastructure must be a realistic environment: e.g. the expectations in terms of latency should be that different vehicles should be supposed to be connected through different MNOs.

We should define the sequence of test environments before defining the quantified objective of each test. This hierarchical look at scenarios could be a way to rank them.

3.5 SAE International – Taxonomy and Definitions for Terms Related to Cooperative Driving Automation for On-Road Motor Vehicles

A copyrighted document from SAE combines the well-known Driving Automation levels with a new and interesting notion: Cooperative Driving Automation (CDA) Cooperation Classes. These classes are defined as follows:

- Class A: Status-sharing – Here I am and what I see
- Class B: Intent-Sharing – This is what I plan to do
- Class C: Agreement-seeking – Let's do this together
- Class D: Prescription – I will do as directed

This classification suggests that CCAM use cases, their tests and the quantified criteria they should reach would need to be positioned across this scale of CDA cooperation classes.

3.6 Outcome of the bottom-up approach

Use cases as they are presently described in WG6 are not precise enough in terms of objectives to build quantified targets. The subgroup on project assessment criteria kindly asks the WG6 subgroup on use cases to continue their effort and issue documents providing quantified objectives for projects addressing these use cases.
CCAM use cases should specify the class of cooperation they address.
Regarding communication technologies, testing requirements should focus on the robustness of the solution. Tests should focus on how fast does the performance decrease with the increase of subscribers. This is never linear, as per the Erlang formula.
Testing environments must be specific to the Technology Readiness Level (TRL) of the experiment. The higher the TRL, the more realistic the testing environment should be.
Most tests of CCAM services require a higher TRL for the communication infrastructure than for the CCAM service itself. However, the use case is the system, and the TRL of the system is the TRL of its least mature component.
In the higher TRLs, we should also define which business relations should be established (e.g. between MNOs if we need a given latency between two vehicles served by two different MNOs).

Other outcomes of sub-group meetings

4.1 Taking the right lessons from unreached objectives

When projects do not reach their objectives, it might be due either to implementation errors or to specification errors. It is important to analyse reasons and come up to the right conclusion.

4.2 Competitive pressure to hide information vs. benefits of a common goal

When quantifying objectives, one has to balance the competitive pressure to hide information vs. the benefit of a quantified common goal.

5 Temporary conclusion

The temporary conclusion of the subgroup it that it is not possible to quantify the project assessment criteria for the time being because:

- The top-down objectives of the programme are still too fuzzy.
- The bottom-up objectives cannot be quantified because use cases.

Should we be able to progress?

- Is our mandate is to see whether it is possible to quantify. If it’s not possible, ii it acceptable to say so?
- Shouldn’t we say what needs to be done so that one can quantify the objectives of a project?

From a top-down perspective, prerequisites for progress are the following:

- Objectives must be defined in a qualitative way before they can be quantified.
- If a quantified ex post assessment is envisaged, the objectives should be quantified ex ante.
- If a member-state level statistical measure is needed, its requirement should be formulated and agreed upon ex ante in EU law.
- If a proposed decision based on a quantified impact assessment is contested, the contesting party should provide an impact assessment of its proposed course of action.
- If alternative solutions are pursued in parallel, comparative quantified impact assessments of their costs and benefits should be produced, following a similar methodology allowing for quantified top-down comparisons.
- Using different methodologies to quantify expected benefits ex ante can help build the confidence in the expected benefits.

How can we progress, from a bottom-up perspective?

- Use cases should be very specific in terms of objectives (described as operational scenarios).
- A given use case should be tested as a sequence of tests, to be performed on an increasing ladder, in terms of Technology Readiness Levels, or of realism of their operational environment.
- A realistic operational environment should define the physical (e.g. radio) parameters which must be set correctly, not which technologies should be deployed.
- In the latest TRLs (8 or 9), some business relationships should be defined, in order to account for a realistic operational environment (e.g. the latency expectations should include the fact that two actors are served by two different MNOs).

1. **List of participants to the subgroup on quantifying project assessment criteria**

- Enterprise Telecom Consultants: Emmanuel Tricaud
- 5GAA: Maxime Flament
- ACEA Joost Vantomme
- Autonomychain: George Grama
- BMW: Georg Schmitt, Abayomi Otubushin
- Car2car: Niels Peter Skov Andersen
- CEA: Alexandre Petrescu

- Continental: Bettina Erdem
- Ericsson: Maciej Muehleisen
- Eurorap: Lina Konstantinopoulou
- Qualcomm: Anne-Lise Thieblemont, Juliana Koza
- UITP: Yves Amsler
- Vicomtech: Oihana Otaegui