EARPA Position Paper

Connectivity, Automation, Safety – Using new tools and technologies supporting road safety and greening, and their interaction

November 2021

About EARPA

Founded in 2002, EARPA is the association of road mobility R&D organisations. It brings together the most prominent independent R&D providers in the road mobility sector throughout Europe. At present its membership numbers 52, ranging from large and small commercial organisations to national institutes and universities.

Introduction to Connectivity, Automation, Safety

In its Transport White Paper adopted in 2011[1], the European Commission communicated the target of halving the number of fatalities on European roads by 2020, compared to 2011 numbers. This target has not been met, and fatality figures have been stagnating since 2013. Even with the Covid-19 related drop in the number of travel kilometres in 2020, the decrease of road fatalities is not reaching the ambitioned level.

The European road transport system actually needs to evolve towards Vision Zero[1,2]: a system in which human life is the paramount concern and no-one is killed or severely injured anymore. In view of the limited progress in European road safety over the last few years and earlier targets not being met, clearly intensified efforts have to be made by all relevant stakeholders not to completely miss this important goal for 2050.

More recently, the EC published its Strategy on Smart and Sustainable Mobility[2], clearly advocating the free movement of people and goods, and mobility as an enabler of our economic and social life. Besides benefits, the Strategy addresses mobility related costs for society, including greenhouse gas (GHG) emissions, air, noise and water pollution, but also accidents and road crashes and congestion.

To deal with the challenges described in these documents, as well as the UN Sustainable Development Goals (SDG)[3], it will be essential to work -including the R&I efforts- with a systems approach in which single technologies and subsystems contribute to the overarching aims for the overall mobility system. Connected, cooperative and automated mobility (CCAM) has the potential to be a key enabler for substantial reductions in collisions on European roads (and thus also the related numbers of injured road users and fatalities), for a systemic reduction of congestion and a firm contribution to the reduction of GHG emissions. The setup of communication capabilities between vehicles (V2V) and between vehicles and the infrastructure (V2X) will enable new mobility services and increased safety: the vehicle will increasingly become a (moving) node in the global network of the Internet of Things (IoT).

Innovation in enabling technologies for CCAM needs to be complemented by research on the safe integration of CCAM in the road transport system -with appropriate test and validation environments- and by the development of new approaches to address a multitude of safety risks, which will not be avoided by CCAM. Understanding of the user behaviour in relation to CCAM is essential for developing for consumer acceptance and uptake, as well as for mitigating negative side effects including increased mobility demands due to CCAM availability. Integration of expertise from the fields of social sciences and humanities (SSH) with technological expertise, will be key in delivering

[1] EC, Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, Brussels, 28.3.2011, COM(2011) 144 final
[2]
[3] https://www.un.org/sustainabledevelopment/sustainable-development-goals/

user-centric and broadly accepted mobility solutions. Finally, the effects of increasing levels of CCAM technologies in the mobility system on the future city design and land use need further research.

EARPA Foresight Group CAS identified three main, overarching themes, which are detailed below:

1. Road safety
2. Greening road mobility
3. Enabling technologies

Key research needs
Concerning the Foresight Group Connectivity, Automation and Safety, EARPA stresses the importance of further research and development on these elements:

- Predicting road crashes based on AI and big data
- Further development of protective safety for highly automated vehicles
- Design for greening, including a conceptual framework for optimal scenarios
- Enabling technologies for CCAM driven greening of operation
- New tools and methods for "performance, safety, security and reliability by design" for emerging CCAM systems in their life cycle
- Design, validation and monitoring tools for AI-enabled, distributed and neuromorphic CCAM architectures and systems

Road safety

With a stagnating decrease in the annual number of fatalities on European roads since 2013, a drastic improvement of road safety remains an important need for all road transport stakeholders. Continuously evolving CCAM technologies offer the long-term perspective of major advances in the safety of equipped vehicles. At the same time, new challenges are emerging, amongst others:

- from mixed traffic of automated vehicles (with/without human occupants) & other road users,
- from completely new means of mobility/transport,
- from the modal shift from public transport to two-wheelers and other (electric) micro-mobility devices (as a result of the pandemic and other incentives),
- from (cyber-)security issues and other criminal threat scenarios.

A number of these are likely to be solved by CCAM, while some may even be introduced by new technologies. CCAM is likely to have a distinct impact on many road safety aspects, from the evolution of driver skills over new requirements for physical and digital infrastructure to the consideration of automation levels in accident databases. EARPA identifies the following (interrelated) key research needs in this context, that would benefit substantially from international cooperation:

- **Predicting road crashes based on AI and big data**

  The ubiquitous gathering of large amounts of data in the digital transport system and Artificial Intelligence (AI) are likely to enable the timely and precise identification of safety-critical traffic situations (continuous multi factor analysis). Targeted pro-active interventions can then be issued to avoid crashes. Research should demonstrate the feasibility of such risk predictions and interventions and address ethical, legal and economic deployment issues.

- **Further development of protective safety for highly automated vehicles**

  A vehicle equipped with a CCAM technologies can use the remaining time before a crash to take measures for impact mitigation by preparing the vehicle and activation of a new generation of restraint systems outside and inside the vehicle based on information about the vehicle, its surrounding, as well as the occupants and e.g. their actual position.

- **Preparing a regulatory framework for safe, secure and inclusive operation of CCAM**

  Current non-future-proof traffic rules need to be identified, and science-based proposals for the adaptation of existing and making of new rules must be prepared. These proposals should include and assess criminal threat scenarios, protection measures and law enforcement. The human factors dimension within all user groups should be an integral part.

- **Validation of CCAM and other road safety measures**

  Validation methodologies and tools need to be expanded, e.g. to systems that make use of AI and to Human Technology Interaction (HTI) aspects. Relevant validation scenarios have to be extended and updated according to extending Operational Design Domains (ODD) and new mobility/transport devices. Full validation of a related human reference model is needed for all relevant situations. Besides, methodologies and tools should be applicable to the validation and assessment of road safety measures complementary to CCAM.

- **Crash prevention for bicyclists and users of micro-mobility devices**

  The safety of unprotected and partially protected road users riding bicycles and other types of (electric) micro-mobility devices needs to be properly addressed, not least in the view of the UN goals set for 2030[4] regarding active mobility. This includes aspects such as cooperative automatic conflict resolution, FOTs with devices for crash prevention, innovative vehicle designs, safety assessment (incl. behavioural modelling), validation methodologies and type-approvals.

- **Smart rescue in the future traffic system**

  Research shall analyse how eCall can be extended to heterogeneous connectivity technologies to mitigate low quality of service and how it can be adapted to worldwide interoperability. Extension by injury prediction tools and on-scene diagnostics is desirable. Advanced rescue procedures should consider powertrain diversity and further developed human extrication methods.

Greening road mobility

The European Green Deal (2019) aims to suppress net emissions of greenhouse gases in 2050 and decoupling economic growth from resource use. As transport accounts for a quarter of Europe's GHG emission, to achieve carbon neutrality, a 90% reduction in transport emissions is needed by 2050. All modalities will need to deliver massive contributions to this reduction.

In EC's Sustainable and Smart Mobility Strategy, amongst others, automated and connected mobility is expected to play an increasing role to contribute to the greening of transport systems and improving their climate neutrality. The actual impacts of CCAM in this direction, as well as its further potential, are not well-understood yet. These depend on many factors. Still, there are high expectations on the greening potential of CCAM as it can:

- reduce the direct emissions by leveraging several eco-friendly operating strategies;
- enable the transition toward new sustainable solutions, both in terms of new technologies and services; and
- allow beneficial large-scale effects at the transport system without compromising other indicators (congestion, costs, level of service…)

In order to unlock this potential, a systems approach is needed, with the inclusion of multi-disciplinary teams, inclusion of greening in the design process, and methods and tools to quantify (potential) greening effects.

[4] https://unric.org/en/sustainable-development-goals-cycling/

EARPA identifies the following key research needs for CCAM-enabled greening of mobility:

- **Design for greening, including a conceptual framework for optimal scenarios**
  The design approach for an environment- and energy-optimised mobility system should be extended beyond the use of lists of recommendations and policies based on a merely fixed set of possible, predefined scenarios. A conceptual framework, based on a backcasting approach, should be able to generate preferred and/or optimal scenarios (policies and technological offer) starting from objectives and targets. These scenarios should be fed into the future design process for CCAM, which furthermore needs new, advanced methods and tools on multiple levels (vehicle, fleet and mobility system), with multi-disciplinary (behavioural, societal, technical) approaches.

- **Enabling technologies for CCAM driven greening of operation**
  CCAM technologies will be increasingly important enablers for new technological solutions, while reducing the emission and noise footprint for vehicles already in-use, without significantly inhibiting mobility and logistics. A more efficient energy use can be enabled through operational and logistics measures, while optimising cost, travel time and decreasing environmental impacts. To this end, research needs include:
  (i) the seamless integration of charge/refuelling in transport and logistics planning;
  (ii) context-aware, predictive vehicle- and fleet-level energy management systems, maximising the energy efficiency up to and beyond the overall mobility system;
  (iii) V2G services for shared charging management, using various information sources in a scalable manner, scheduling charging actions, supporting the use of renewables;
  (iv) scalable traffic management systems to reduce energy use, leveraging the connection between different means of transportation.

- **Methodology to quantify (potential) greening impacts of CCAM**
  An overall methodology to quantify the energy optimisation and environmental impacts of CCAM on a scale of a city, region or beyond is missing. Furthermore, there is a need to get a better, quantified and qualified understanding of the further potential greening by implementing CCAM on a wide scale. Research needs include:
  (i) modal-shift/traffic assignment, with methods to optimally fulfil the forecasted mobility demand based on the forecasted CCAM offer, in terms of path, mode, and navigation;
  (ii) impact generation, with methods and tools to scale-up models, predict impacts on a large scale, to come to evidence based information for e.g. policy makers and users. Known side effects, caused by e.g. human behaviour and mobility choices based on intrinsic user needs, will need to be incorporated to go beyond existing impact tooling.

Enabling Technologies

Future mobility and transport will be connected, cooperative, automated and shared. The end-user acceptance and trust in these new technologies still requires significant research efforts to prove functional safety, security, performance, availability, predictive maintainability, and reliability of emerging software-defined systems (of systems). Enabling technologies play a pivotal role in efficient and effective development of CCAM systems allowing European industries to retain competitiveness and capitalise on new markets. AI enabled CCAM systems do require completely new methods, tools, and processes for development, validation, verification and testing. The explosion of test efforts needs a paradigm shift towards virtual approval, implicitly demanding credible simulation, trusted models, and approved methods. Simulation governance, a managerial function concerned with assurance of reliability of information generated by numerical simulation, immediately comes into play as a key enabling technology. There is a strong research need to accomplish AI solutions able to support low power computations, latencies, and adaptability. In this context, neuromorphic architectures describing large-scale systems of integrated circuits that mimic neuro-biological architectures present in the nervous system, will be a future CCAM enabler. Below, emerging and enabling technologies driving the advancement of CCAM systems are introduced.

- **Design, validation and monitoring tools for AI-enabled, distributed and neuromorphic CCAM architectures and systems**
  Requirements for AI functions for performance and reliability imply exponential complexity. It is crucial to enable interoperability and multi-domain complex simulation for testing and validation by fusing and combining prototypes with many different software and hardware components, varied scenarios, multisensory set-ups and physical sensor models. To enable these simulations, high performance computing and scalability are required. The computational and network load for data upload, storage, processing, streaming, and simulation execution, taking advantage of edge-to-cloud architectures should be balanced for the complete simulation chain: from in-vehicle first processing at remote data sources to multi-cloud scalability. As volume and speed of data increases, the need for a Computing Continuum emerges, as the concept of interconnecting deep-edge devices, local servers and cloud resources in a single, homogeneous processing pipeline. As a key for contributing to virtual approval scenarios ("prototype-free release of product variants"), the credibility and trust of all models, simulation tools and numerical methods will have to be quantified and also their technical/operational limits.

- **AI design, AI data, AI safety, AI applications**
  To safely and efficiently integrate Artificial Intelligence (AI) technologies in CCAM, the algorithm design principles, the data used and the application specific challenges need to be brought together, in a modular and reliable way. Improved data quality and standardization guidelines should enable AI algorithms to be designed in a trustworthy, safe (including formal verification) and robust way. AI should respond in a way which the users can understand and interact with; explainable AI will be key. Application driven expert knowledge should be hybridized with AI-algorithms to enable safe system design, continuous integration and deployment. Neuromorphic architectures need to be developed along with tailored AI algorithms, ensuring a tight interaction between "AI hardware" and "AI software". Dedicated AI hardware architectures should be built as low power, low latency, re-configurable, and adaptable systems.

- **Functional safety, SOTIF, and UL4600 of CCAM systems**
  CCAM will need a deeper analysis in the control architecture design, based on different Key Performance Indicators and beyond the existing testing framework for validation. Functional safety methods are capable of detecting (system) failures in both software and hardware, during the driving task. ISO26262 describes the general framework for functional safety, and the SOTIF (ISO 21448) covers safety hazards for specific functionalities for higher levels of automation. The design of fail-aware, fail-tolerance, and fail-operational components ensure the appropriate performance of such a system of the future vehicle. The emerging UL4600 will play a crucial future role to design safe autonomous products by quantifying residual risks, nominal performance of E/E architectures, with guidance for verification and validation.

- **New tools and methods for "performance, safety, security and reliability by design" for emerging CCAM systems in their life cycle**
  Connectivity will enable advanced AI applications based on federated learning. 6G should provide extreme bitrates (Tbps+), imperceptible latency and localization with highest possible precision. Trustworthiness and security for data and connectivity must be guaranteed under all conditions (cybersecurity/trust by design and as a culture across the mobility ecosystem, i.e. anomaly detection, industry-wide threat intelligence). Security issues typically trigger (functional) safety issues; future connectivity needs to be developed "secure and safe by design". This requires advanced methods, tools, and processes for CCAM components and systems, throughout their lifecycle.

Expected impact

Road safety

The research needs described under the headline "Road Safety" above will contribute to the EC's long-term objective of moving close to zero fatalities and serious injuries until 2050[5]. They will avoid human suffering and grief, reduce the related burden for the EU's health care system and contribute to total socio-economic cost savings of many billion euros per year.

In particular, the use of AI and big data for crash prevention will enable targeted, highly efficient interventions, in the long term also in real-time. Thus, it will enhance the leverage effect of better data collection and analysis, which was set as a transport safety priority under Flagship 10 of the EC's Sustainable and Smart Mobility Strategy. At the same time, it will implement recommendations by the International Transport Forum on new directions for data-driven transport safety[6].

In addition to its direct impact on road safety, the further development of protective safety for highly automated vehicles will enhance the acceptance of such vehicles, in particular if completely driverless. Such vehicles will be crucial in the transformation of supply-based transport to demand-driven, safe, climate neutral and sustainable mobility and transport services for passenger and freight, as described under the expected impact no. 26 in the EC's Strategic Plan for Horizon Europe 2021-2024[7]. This transformation shall make sure that mobility will be available and affordable for all, and that rural and remote regions will be better connected and accessible for all citizens, which is part of the vision described in the EC's Sustainable and Smart Mobility Strategy.

Greening

The European Green Deal calls for a 90% reduction in greenhouse gas emissions from transport, in order for the EU to become a climate-neutral economy by 2050, while also working towards a zero-pollution ambition. The role of CCAM in contributing to this target is not yet clear, as several impact paths exist and are not yet fully understood. However, there is consensus that CCAM systems could bring benefits (GHG emission reductions) when considering direct impacts related to the operation of new systems and services, as well indirect impacts related to the large-scale availability of such offer. In contrast, indirect impacts related to the demand (rebound effects, induced traffic) might be negative, while direct impacts related to the LCA and indirect impacts related to the behaviour of the transport system could be either beneficial or adverse.

The research on impact assessment as described can help to quantify the environmental effects of increasing levels of CCAM technologies in the mobility system. Furthermore, in combination with the work on the operational and logistics measures within the mobility system, there will be tools to leverage and increase the greening of road mobility significantly, without negatively affecting road safety nor congestion.

Enabling Technologies

The European Commission is aware of the importance of enabling technologies. In its Sustainable and Smart Mobility Strategy[8], the EC states that the EU must ensure that the key digital enablers (such as data technologies or artificial intelligence) are in place to promote Europe's digital transformation. Here, it must be secured that the digital infrastructure is at the highest level in order to achieve a higher degree of automation in various mobility applications. The EU's focus on enabling technologies should lead to a Digital Europe and, as a result, to the achievement of the zero-emission-strategy. This also aligns with the UN Development Goals such as Goal 9 (Industry, Innovation and Infrastructure), Goal 11 (Sustainable Cities and Communities) and Goal 13 (Climate Action).

[5] https://ec.europa.eu/transport/sites/default/files/3rd-mobility-pack/3rd-mobility-pack-factsheets-safety.pdf
[6] https://www.itf-oecd.org/sites/default/files/docs/new-directions-data-driven-transport-safety_0.pdf
[7] https://op.europa.eu/en/web/eu-law-and-publications/publication-detail/-/publication/3c6ffd74-8ac3-11eb-b85c-01aa75ed71a1
[8] European Commission, Sustainable and Smart Mobility Strategy – putting European transport on track for the future, Brussels, 9.12.2020, COM/2020/789 final

Three key words within Enabling Technologies can play a decisive role in creating overarching impacts in the field of Connectivity, Automation and Safety:

- **AI** is seen as an enabler of higher levels of automated driving (replacing human intelligence, in particular in situations which the system has not be taught in advance), enhancing road safety by increasing the time to act and creating overarching approaches for e.g. traffic management and emission reduction;
- **functional safety** will be a more and more important enabler of traffic safety when machines / technical systems take over vehicle control to a growing extent; and
- **cyber security** will be key in ensuring road safety of connected vehicles -also in interaction with non-connected road users-, in particular with future CCAM systems relying on connectivity for safety-critical functions

Relation to other roadmaps

Following the approach above, EARPA fully supports the respective research topics from the Strategic Research Agenda (SRA) of the European Road Transport Research Advisory Council (ERTRAC)[9]. These topics are detailed quite extensively in the dedicated ERTRAC roadmaps on Connected and Automated Driving; on Urban Mobility and on Road Safety, to which EARPA members have made substantial contributions.

The Euro NCAP roadmap 2018-2025[10] within its mission of providing information on the safety performance of vehicles, already considers the grading protocols for AD functions and the creation of a dedicated task force for the definition of rating protocols of V2X connectivity. Other organisations as the 5GAA and the C2C-CC also include Day-2 and beyond applications/functions that foster CCAM solutions.

For the Enabling Technologies, there is a clear link to the fourth edition of the ECS Strategic Research and Innovation Agenda[11] (ECS-SRIA 2021), jointly developed by members of three industry associations: AENEAS, ARTEMIS-IA and EPOSS. The ECS-SRIA 2021 roadmap covers the wide variety of topics of the three industry associations engaged, on micro- and nanoelectronics, smart systems integration, and embedded system of systems. CCAM systems play an important role here, which is reflected by dedicated chapters on mobility, connectivity, AI, edge computing, or embedded software. This roadmap will have a central role in the Key Digital Technologies Partnership.

AI, Data and Robotics[12] are transversal and cut across sectors affecting many actors in the value chain. There is widespread acceptance that AI, Data and Robotics will have significant impact on all economic sectors. The recently published research agenda of the AI, Data and Robotics Partnership shows direct and indirect interactions with the development of CCAM as described in this EARPA position paper.

The ACEA position paper "AI in the automotive industry" clearly shows the increasing role of AI in the automotive domain, and in CCAM specifically.[13]

Conclusion

As much as Europe needs green vehicles, it also needs safe vehicles embedded in a safe transport system. The automation of road transport can be a key enabler in this context and contribute substantially to overcome the stagnation in the numbers of injured road users and fatalities. It may also contribute to the greening of road mobility and reaching climate neutrality. Research on enabling technologies at lower TRLs will be essential to achieve all expected positive impacts.

[9] ERTRAC Strategic Research Agenda, Input to 9th EU Framework Programme, April 2018
[10] euroncap-roadmap-2025-v4.pdf
[11] https://artemis-ia.eu/publication/download/ecs-sria-2021-final.pdf
[12] AI-Data-Robotics-Partnership-SRIDA-V3.0.pdf
[13] Position paper - Artificial Intelligence in the automobile industry | ACEA - European Automobile Manufacturers' Association

With the longer-term objective of moving towards Vision Zero, a dedicated action/instrument focussing on "Roads without victims" should be set up following the mission of saving about 300,000 lives and avoiding ten times as many serious injuries on the EU's roads until 2050. At the same time, the European Green Deal sets ambitious targets in terms of GHG emissions, to which CCAM systems will play an increasing role. Some of the key research needs which should be addressed by such a dedicated action/instrument are mentioned above from the EARPA's experts' point of view.

For further information, please contact our contact persons of the Foresight Group Connectivity, Automation, Safety:

Contact

FG CAS Speaker

Margriet van Schijndel-de Nooij

E: m.v.schijndel@tue.nl

T: +31 6 53846379

FG CAS Secretary

Bastiaan Krosse

E: bastiaan.krosse@tno.nl

T: +31 6 22545619

More information at our website: www.earpa.eu