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D8.1 – Common issues, approaches and lessons learned across all modes for Industry and Public Authorities

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D8.1 – Common issues, approaches and initial lessons learned across all modes for Industry and Public Authorities			
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List of acronyms

Acronym	**Meaning**
CAV	Connected and Automated Vehicle
CCAM	Cooperative, Connected and Automated Mobility
G2A	GuideToAutonomy
ICT	Information and Communication Technologies
HMI	Human-Machine Interface
MaaS	Mobility-as-a-Service accessible on demand
ODD	Operational Design Domain
PAV	Personal Aerial Vehicles
VRU	Vulnerable Road User
VMT	Vehicle Miles Traveled
V2I	Vehicle to Infrastructure
V2N	Vehicle to Network

V2V	Vehicle to Vehicle
V2X	Vehicle to anything

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Executive summary

The aim of the PAsCAL project, funded under the "Horizon 2020" Research and Innovation program, is to improve the understanding of the implications of connected and automated vehicles (CAVs) on society. The project will create a "Guide2Autonomy" (G2A) to capture this new knowledge. Outcomes from the project will contribute to the training of future drivers and passengers and will help decision-makers to move towards the new forms of individual and collective mobility made possible by the spread of driverless cars.

During the PAsCAL project, the perceptions and expectations of citizens regarding the new autonomous and connected driving technologies will be examined, trying to better understand their fears and concerns and to help to prepare solutions that will be able to bridge the anticipated emotional and cultural gaps. If these are not tackled, the barriers to adoption, inherent in the world of CAVs, may not be removed.

Likewise, the behavior of drivers in semi-autonomous vehicles and that of all other road users will be studied, again to identify the main obstacles that will need to be removed in order to make man-machine interaction commonplace, whilst being as safe as possible.

To these purposes, specific surveys have been carried out (WP3) as well as accurate behavioral analysis through simulations in the frame of WP4. The project made here extensive use of modern technologies, such as driving simulators and virtual reality platforms.

In addition, PAsCAL will finally create 5 road-transport pilot projects, conducted in different countries of the European Union (WP6). The pilot projects will focus respectively on: autonomous high-capacity buses; user training through driving schools and driving academies; different types of connected shared vehicles; autonomous bus lines and, last but not least, applications that allow people with disabilities to travel, thanks to new autonomous driving technologies within a transport network. Evaluation on key performance indicators will provide common learnings (WP7).

All this new knowledge will be incorporated into the "Guide2Autonomy" which will be made available to all relevant CAV stakeholders. Specific anticipated items for inclusion will be: how to train CAV users (the current "drivers"), the necessary certifications that must be obtained and any new traffic rules to be adopted. It is hoped that all of this will assist with a smooth transition to a wide scale CAV adoption.

The G2A will be filled with about 100 innovative guidelines, recommendations, and tools to better understand the implications of Connected and Automated Vehicles (CAVs) and Cooperative, Connected and Automated Mobility (CCAM) on society, to educate the future drivers and non-drivers, and to design more user oriented CCAM products and services in the public interests.

In order to assure that our recommendations are steered to actual improvements PAsCAL defined four thematic domains in which change could improve user acceptance and public awareness. These four topics are:

- Strategies for integrating CCAM in present public policies;
- Design of new CCAM infrastructure and technologies;
- User oriented CCAM ICT developments;
- Management of CCAM and stimulating local economy, social inclusion and environmental protection.

Each thematic leader was asked to identify key areas and related common issues and approaches that influence public awareness and user acceptance of CCAM in their specific domain.

Each of those identified key areas are presented, as well as the present common issues and current approaches. Some initial lessons were identified of discrepancies between their current situation and the needed features to improve user acceptance and public awareness of its benefits.

Subsequently, the PAsCAL recommendations will be focussed on those key areas. This will allow industry and public authorities to act upon and improve the public awareness and increase user's acceptance of CAV technologies and CCAM in general.

1 Introduction

1.1 Purpose and organization of the document

Following the CAV experiments and simulations (WP4), demonstration pilots (WP6) and evaluation (WP7), PAsCAL will develop in 2022 about 100 innovative guides, recommendations, and tools to better understand the implications of CAVs and CCAM for society, to educate the future drivers and non-drivers, and to design more user oriented CCAM products and services in the public interests.

These recommendations will be based on the learnings of cluster analysis of user characteristics, human driving and passenger simulation, real world pilots, shared space simulation with multi-users, accessible surveys designed for varying abilities, focus groups, stakeholders' hands-on workshops, and system-dynamics modelling tools. The recommendations and guidelines are co-developed with and aimed at different stakeholder groups (i.e., policymakers, industry, user representative organisations, research, etc.).

To better develop the recommendations and to be able to provide targeted guidance and/or recommendations, it is of importance to understand the legal, regulatory, strategic, design and operational management within CCAM functioning, innovation, and research. To assure that all user acceptance and public awareness related topics, requirements and needs of different types of users in relation to CCAM are considered, PAsCAL defined four thematic topics from the CCAM offer point of view, which are:

- Strategies for integrating CCAM in present public policies;
- Design of new CCAM infrastructure and technologies;
- User oriented CCAM ICT developments;
- Management of CCAM and stimulating local economy, social inclusion and environment.

A detailed literature review was carried out. Numerous papers, articles and books consulted, provided an insight into those key areas within which the PAsCAL recommendations and guidelines should be situated when aiming at an improved public awareness and user acceptance of CAVs and CCAM services. In total, more than 200 documents were consulted. Following a detailing of the specific CAVs and CCAM attributes of interest (Chapter 2), the different identified key areas of each thematic topic (Chapters 3, 4, 5 and 6) are presented. Finally, Chapter 7 will shortly present some overall conclusions and next steps for the development of the Guide2Autonomy.

1.2 Intended audience of this document

The deliverable is the outcome of a joint identification by the partners of key areas and related common issues and approaches that influence public awareness and user acceptance of CCAM. This initial identification of key areas assures that the final outcomes are not only correctly targeting the different CCAM stakeholder groups (i.e., policymakers, industry, user representative organisations and research) yet also that all attributes of importance for user acceptance and public awareness of a CCAM service integrated in transport are being thought through. For each of those key areas, PAsCAL will identify, at a later stage within the project, the lessons learned and provide 100 recommendations that will foster more user oriented CCAM design and development approaches that safeguard public interests. Therewith the first intended audience are the different PAsCAL researchers and the wider scientific community.

Secondly, the identification of the key areas will function as one of the main dimensions of the structuring of the G2A. It will allow the project to categorise, and the users of the G2A to easily find the recommendations and guidelines of interest. The recommendations and guidelines will be integrated in the G2A toolbox at the end of the project. Therewith this deliverable also intends to provide to the wider CCAM community (i.e., CCAM service and hardware developers) an understanding on the different key areas of importance when evolving to a more user-centric approach in CCAM innovation, design, development, and service provision.

Finally, it will help policy makers to gain a better understanding of which key areas are of importance and bring the public interest (i.e., societal, environmental, and economy) into debate on the future of CCAM.

2 CCAM, user acceptance and public awareness

2.1 Introduction

CAVs, regardless of the vehicle type, can take many different forms and not less relate to the way in which they are able to drive autonomously. Characteristics of the vehicle itself and the driving in the environment, in which it is capable and allowed to drive, will have an influence on public awareness and user acceptance. Control plays here an important role, but also characteristics that relate to societal aspects, such as the environment and the way CAVs behave in traffic. The following general characteristics of CAVs can be identified:

- Level of automation and control: driver versus vehicle control, mixed control, remote control, robot and maximum speeds;
- Vehicle behaviour: behaviour when not able to cope: stopping and parking or handing over control, “polite or bullying” behaviour with other vehicles, etc.;
- Service design e.g. allowing empty driving, private versus shared usage;
- Characteristics of ODD (Operational Design Domain): public road, specific roads, dedicated lane or environment, parking space, specific conditions such as weather, as well as the present regulation and legislation.

The first two categories specifically look at the vehicle design and resulting characteristics of operational functioning. The third category looks at the transport or mobility service concept in which CAVs are embedded. The latter category looks at the wider environment in which the CAVs are operated. Although the project primarily targets road-based transport modes, the guides and recommendations will also be transferable to other transport modes such as autonomous personal aerial vehicles (PAVs).

2.2 CAVs, user acceptance and public awareness

When discussing awareness and acceptance of CAVs’ design and operating point of view, one should look at the full CCAM system and operating environment. Key concepts are in this respect:

- Attributes of CAVs, interaction of CAVs with dedicated or legacy infrastructure and digital technology that influences acceptance positively or negatively;
- Wider attributes of CCAM services concepts (e.g. public transport services using CAVs) that influence usage motives and perceived barriers as well as the attitudes toward the used CAVs;
- Societal needs of different user types identified in PAsCAL and which relate to age, gender, needs and demands that influence acceptance from a public interest point of view.

CCAM, user acceptance and public awareness

Attributes of CAV, infrastructure and technology affecting acceptance

- Attributes of CAV affecting acceptance
- Attributes of driving conditions and interaction affecting acceptance
- Attributes of physical infrastructure affecting acceptance
- Attributes of CAV in interaction with Vulnerable Road Users - affecting acceptance

Attributes of CCAM services affecting acceptance

- (perceived) security
- (perceived) safety
- Privacy
- Liability
- (perceived) comfort
- Cleanness of vehicles
- Efficiency
- Availability of help and support
- Information
- Price
- Business models
- Governance

Attributes of CCAM affecting societal acceptance

- Personal Mobility and accessibility
- Safety and security
- Health
- Equity
- Liveability of cities/towns, environment

Figure 2-1 Characteristics of CCAM that influence levels of public awareness and affect acceptance.

The different elements are shortly discussed in the following paragraphs.

2.2.1 Attributes of CAVs, infrastructure and technology affecting acceptance

This section shortly identifies the different characteristics of vehicles, infrastructure and technologies from a perspective of user acceptance. Users may or may not accept CAVs and CCAM, depending on what they are capable of doing, where they can go, what safety and security features they have. Also, the societal impacts will play a role such as the contribution of automated mobility to the liveability of cities.

2.2.1.1 Attributes of CAVs affecting acceptance

People use CAVs to go somewhere, and in an efficient way. CAVs could also be used to transport goods, to drive around cities without a predefined destination, or they could drive around without passengers (e.g., to balance the distribution of a shared fleet). Acceptance is determined by easiness to use and relates therewith to the HMI (Human-Machine Interface) and the level of automation, and specifically to whether the users should take back control in certain circumstances. If the user needs to be in the loop, the CAVs might not be suitable for certain groups (e.g., children, impaired travellers) that are not able to drive a car. The 'conditions' in which the CAV is capable to operate is called the Operational Design Domain (ODD). Next to the usage of the CAV also the ODD and the maximum allowed (or realizable) speed also affect the perceived usefulness of the CAVs.

2.2.1.2 Attributes of driving conditions and interaction affecting acceptance

Acceptance of CAVs is influenced by their behaviour on the road. The behaviour of CAVs is influenced to a large extent by interaction with other vehicles, other road-users, and the infrastructure (V2X). There may be concerns whether the network enabling the communication could be compromised, by malfunctioning or cyberattacks. The more powerful CAVs are designed to be able to drive around without any V2X support.

Several circumstantial elements will also influence acceptance, e.g., unexpected behavior, driving differently from what human drivers would normally do; how to deal with "bullying", other road users trying to gain priority over CAVs, or the opposite - CAVs being too cautious -, making the journey uncomfortable; reaction in case of a break-down of communication networks; assurance in terms of cyber security.

2.2.1.3 Attributes of physical infrastructure affecting acceptance

The infrastructure may also influence acceptance. There might be concerns about malfunctioning and confusion about whether it supports the ODD of CAVs. Several elements to be considered include the possibilities to drive automated only on certain stretches or on the entire transport network, CAVs behaviour in case of a malfunctioning or design of the infrastructure. There might also be differences between countries and therewith a lack of interoperability in cross-border traffic.

2.2.1.4 Attributes of CAVs in interaction with Vulnerable Road Users - affecting acceptance

Specific attention needs to be given to differences in perceptions and needs of vulnerable road users. The interaction between vulnerable road users (VRUs) and CAVs may give rise to additional concerns about safety. VRUs may have different and even incorrect expectations of the behaviour of CAVs, based on what they normally would expect of traditional transportation. A question for debate is whether it should be expected that VRUs carry devices that make them recognizable for CAVs or warn them about these vehicles approaching.

2.2.2 Attributes of CCAM services affecting acceptance

Next to the physical and operational functionalities of CAVs, there is a variety of attributes of CAV services that affect the acceptance of services. Firstly, this relates to the type of usage (i.e., shared versus private) of the CCAM services. Private use relates also to the possibility for specific groups of users to be able to own and/ or individually use the vehicle. Shared use whether it be car sharing or public transport relates next to ownership also potentially to the acceptance of being with other passengers. Next to the service concept, there are also more general attributes of CCAM services that influence acceptance. These include elements like:

- (Perceived) Security,
- (Perceived) Safety,
- Privacy,
- Liability,

- (Perceived) Comfort,
- Cleanness of vehicles,
- Efficiency,
- Availability of help and support,
- Information,
- Price,
- Business models,
- Governance.

2.2.3 Attributes of CCAM affecting societal acceptance

Several impact areas were identified within work package 7 for both society as a whole and specific vulnerable groups. Another way of looking at acceptance of services is to establish to which extent the CCAM and its services fulfil the needs of wider public policy goals and wider interests of specific user groups. The hypothesis is that a more general acceptance of CCAM exists if it positively influences specifically the following domains:

- Personal mobility and accessibility,
- Safety and security,
- Health,
- Equity, affordability, and inclusion,
- Liveability of cities/towns, environment.

The specific domains are shortly detailed in the following sub-paragraphs.

2.2.3.1 Improved personal mobility and accessibility

Improving personal mobility is one of the big promises of CAVs and therewith a public policy goal pursued. Specific user groups might depend on CAVs in the future to reach certain locations. On the other hand, the lack of a driver on board might be an issue for persons that need assistance. Specific user needs might relate to:

- Going to essential places which were not reachable before such as grocery shopping, hospitals;
- Going to non-essential places which were not reachable before, such as leisure activities;

- Going to places at times that better suit individual needs.

Accessibility needs related to the accessing of CAVs itself as well as the provided support for making the trip. The CAVs may not always be able to transport exactly from door to door.

2.2.3.2 Safety and security

According to the Insurance Institute for Highway Safety [1], nearly 1/3 of fatal crashes and 1/5 of serious/moderate injury crashes could be eliminated if CAVs were introduced. Differently from human drivers, autonomous systems will not be distracted due to long driving times. CAVs can sometimes also allow the communication between nearby vehicles, which can be helpful to increase driving safety. However, it can also provide more opportunities to be attacked, which can put both the passengers and other road users in danger. Based on the CAV technology, safety can be improved not only for those in the vehicles, but also for pedestrians, bicyclists, and other drivers on the road.

Cyber security is a huge contributing factor affecting CAVs security and therewith wider public awareness and user acceptance. The potential security issues can be caused by different sources, such as CAV intelligent systems, traffic control systems, nearby CAVs and other road users. CAVs could increase privacy data theft, due to large quantity of personal data generated without the permission of the CAV users or even being in the future at the cause of traffic accidents due to a cyber-attack.

2.2.3.3 Health

Ideally automated transport should not replace active forms of transport. Overall public health can be improved if offered in a clean shared service concept. CCAM might also improve the health of specific user groups as it creates a higher level of accessibility and therewith improves their quality of life. Health in this respect is also related to cleanness and crowdedness of the CAVs and/ or its performance in comparison with alternative mobility solutions. After the pandemic, people will worry more about the cleanness of vehicles, sharing rides and that vehicles should not be too crowded as to allow for social distancing.

2.2.3.4 Equity, affordability, and inclusion

Vulnerable user groups are expected to benefit the most of CCAM if properly implemented. With lower car ownership in this group than the average population, CAVs offer the potential to access education and better paid jobs therewith creating higher levels of inclusion. Depending on the CCAM service concept, it might bring more, or less equity. There may be a danger that individual automated transport is for the rich and shared transport for the less affluent. Public interest for CCAM relates also to the possibility to create more affordable transport, on the other hand it should also be looked at the wider social impact in terms of possible job creation and job destruction (taking away the professional drivers).

2.2.3.5 Liveability of cities and environment

CAVs have the potential to improve liveability in cities and potentially save energy and reduce emissions at a societal level. This might specifically be the result of overall gains in operating efficiency, less pollution and noise, optimisation of the transport system and reduced need for parking places leading to improved land usage and change towards more green space and less traffic space.

3 Strategies for integrating CAVs recommendations in present public policies

3.1 Introduction

There are many public policies and regulatory areas related to the implementation of autonomous vehicles and connected systems, such as road safety policies (e.g., Vision 0 Initiative[1]), sustainable urban mobility planning (SUMP's[2]), policies fostering innovation, social inclusion of vulnerable citizens. Based on a first analysis of the previous work packages and related European practices investigated[3], this chapter specifies the main policy and regulation issues that may positively influence the acceptance of new CCAM technologies and those which may constitute barriers, with a view to safeguard the public interest. Traffic laws; data protection; privacy and IoT; insurance policies; legislation on disabled users are the PAsCAL policy and regulation key areas of interest for which PAsCAL will work on a set of guides and recommendations. The different policy and regulation related key areas, common issues and present approaches will be shortly presented in the following sub paragraphs. Next to a literature research, inventory of the preceding PAsCAL works, some of the following considerations were also taken from: "The Autonomous Vehicles Readiness Index (AVRI) - edition 2020" [2]. The index is a tool to help measure the level of preparedness for autonomous vehicles across 30 countries and jurisdictions.

CAVs, legislation, regulation and insurance

- Traffic laws
- Data protection regulation
- Privacy regulation and IoT
- Insurance
- Legislation on disabled users

Figure 3-1 Key areas of CAVs, legislation, regulation and insurance

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[1] The Vision Initiative is a Swedish approach to road safety thinking. The EU has as one of their goals to reduce road deaths to almost zero by 2050 [Web 1].

[2] A Sustainable Urban Mobility Plan is a strategic plan designed to satisfy the mobility needs of people and businesses in cities and their surroundings for a better quality of life. It builds on existing planning practice and takes due consideration of integration, participation, and evaluation principles [Web 2].

[3] PAsCAL investigated practices in over 10 EU Member States.

3.2 Selected key areas

3.2.1 Traffic laws

The introduction of self-driving vehicles raises various common issues and approaches that need to be addressed at the institutional and legislative level to balance the progress in the field of CCAM with the protection of the rights of European Union citizens.

To date, however, only a limited number of countries have introduced specific provisions on the matter. Current European Directives already provide for principles that are substantially suitable for adapting to automated and connected vehicles.

The EU framework law for the approval of vehicles, updated in 2018, already ensures a real internal market for motor vehicles, however, a special regime for new technologies has still to come. In May 2018, the Commission presented "European strategy for connected and automated mobility" [Web 3] , which outlines a common approach between the Union, private sector actors, Member States, and regional and local authorities in order to significantly reduce the number of fatalities from road accidents, harmful emissions from transport and traffic congestion.

In the Amsterdam Declaration of 2016, focusing on cooperation around connected and automated mobility, the Member States had in fact asked the Commission to launch a shared European strategy in this regard, to review and adapt the regulatory framework, to implement a coordinated approach on research and innovation and to encourage the deployment of cooperative and interoperable intelligent transport systems.

The Commission has already taken measures to promote connectivity infrastructures and services in support of automated vehicles, with strategies relating to the fifth generation of communications networks ("5G") [Web 4], cooperative intelligent transport systems [Web 5] and the space strategy [Web 6]. Recently, the Commission has also proposed an initiative on artificial intelligence which will support the development of autonomous vehicles [Web 7].

Furthermore, on January 15, 2019, the European Parliament approved a non-binding resolution on autonomous driving in transport, which photographs the status quo relating to autonomous transport, with the aim of protecting consumer rights and competition in this new sector [Web 8].

At national level, initiatives are underway relating to the testing and experimentation of autonomous vehicles (i.e. in Italy, the experimentation of autonomous driving systems was regulated for the first time through the so-called Smart Road Decree).

Significant initiatives have also been undertaken outside the European Union (i.e. Singapore, Canada and United States).

To further push forward connected and automated driving technologies, it is understood that there is a need and an interest of the public authorities to coordinate to prevent a patchwork of legislation, rules, and procedures. The lack of harmonised and public interest-oriented legislation will represent an obstacle to the wider introduction of new CCAM technologies. Towards the public and individual users, public consultation when producing EU guidelines, standards as well as National legislation may represent an instrument to promote participation and increased knowledge on the topic. Its outcomes might also encourage a harmonised public interest-oriented approach in research, development, testing and deployment.

3.2.2 Data protection regulation

Among the key areas identified, data protection is of particular importance.

On 29 March 2021, the European Data Protection Board ("EDPB" or "Board"), following the outcome of the public consultation started on 7 February 2020, adopted the Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications ("Guidelines") which focus on the processing of personal data in relation to the use of connected vehicles in contexts other than professional activity. The Guidelines are part of a context in which connected vehicles are generating an increasing amount of data, many of which - being attributable to drivers or passengers - constitute personal data pursuant to EU Regulation 679/2016 ("GDPR" or "Regulations").

In this context, the objective of the Guidelines is to facilitate the compliance of the processing of personal data and that carried out in the context of the non-professional use of connected vehicles by the interested parties (e.g., Drivers, passengers, vehicle owners) and in relation to personal data:

- processed inside the vehicle;
- exchanged between the vehicle and personal devices (e.g., the user's smartphone); or

- collected locally in the vehicle and exported to external entities (e.g., vehicle manufacturers and insurance companies).

This need arises, in particular, in the face of the proliferation of functions for connected vehicles, including those that allow drivers to reach a destination quickly and efficiently (e.g., providing timely information on GPS navigation), those that help drivers to reduce the costs of use (e.g., notification of vehicle conditions and personalized "Pay As / How You Drive" insurance), as well as those that warn the driver of external dangers (e.g., detection of driver drowsiness or black boxes for accident investigation).

In the Guidelines, the EDPB first underlines the concerns that the use of connected vehicles could raise, emphasizing above all the risks of constant surveillance of individuals linked to the use of location technologies.

In particular:

- lack of control over their personal data, given that the information can only be provided to the owner of the vehicle, who is not necessarily the driver (and is in any case different from passengers, even occasional ones, of the vehicle);
- low quality of user consent, who may not be adequately informed about the data processing carried out in the vehicle. Added to this is the difficulty of obtaining and tracing the consent of any drivers and passengers other than the owner, as well as - in the case of resale, leasing or loan - of the person who takes possession of the vehicle in second place;
- processing of personal data other than those for which consent was given. For example, the telemetry data collected during the use of the vehicle for maintenance purposes cannot be disclosed to insurance companies without the consent of users in order to create driver profiles to offer insurance policies based on driving behaviour;
- excessive data collection linked to the development of new functionalities based on machine learning algorithms;
- security of personal data, which could be compromised by the plurality of functionalities, services and interfaces used in conjunction with connected vehicles.

The EDPB has provided stakeholders with useful information for the correct processing of user data, identifying three categories of personal data generated by a connected vehicle that deserve particular attention in light of the potential impact on the rights and freedoms of data subjects and, in particular, location data, biometric data and those that may reveal the commission of crimes and / or other infringements.

In this regard, it should be noted that the Board recommends, among other things, to:

- collect location data only when necessary, allowing the interested party to disable the location option at any time;
- ensure that biometric authentication solutions are particularly "resistant" to possible attacks, also by providing for limited number of access attempts and encryption of the biometric model;
- consider appropriate security measures to ensure that the processing of personal data inside vehicles remains "local" and, if a person acts as a manager pursuant to GDPR, pay attention to the security of the so-called "In-car applications" (think, for example, of the eco-drive apps that allow you to send notifications on the vehicle's screen in real time);
- in the event that the transmission of personal data outside the vehicle is envisaged, consider making such data anonymous;
- provide the information referred to in art. 13, GDPR through concise and easily understandable clauses in the vehicle sales contract or service provision, using documents such as the vehicle user manual or projecting them onto the on-board computer;
- implement preferences and privacy settings management systems (e.g., with a cancel button or with a dedicated app) to facilitate user control over their data.

As a lesson learned starting from these GDPR guidelines, the PAsCAL project will set up an initial version of a data protection handbook of which the procedures are followed within the different simulations and CCAM demonstrations. It is expected that within this key area several guidelines and recommendations will be formulated that will safeguard the general public interest and individual users' rights. It will be investigated if this indirectly will also foster acceptance.

3.2.3 Privacy regulation and IoT

Related to the key area of data protection is the issue of privacy. It is expected that PAsCAL will specifically be able to contribute to safeguarding the public interest in relation to the integration of Internet of Things (IoT) components into vehicles, by which they become part of a network. Vehicles can communicate with each other, with the surrounding infrastructure and with other drivers. Gradually the technologies of IoT for connected and autonomous vehicles (combined with the evolution of Artificial Intelligence (AI) and communication networks) support assisted driving (steering, acceleration and brake support), then conditional automation (the system has longitudinal and lateral control in a specific use case), followed by high automation (the system can cope with all situations automatically in a defined use case) and finally full automation (the system is able to drive the vehicle in all conditions; no driver is required).

Particular care, therefore, is necessary to ensure the right balance between the data processing necessary to allow CAVs to operate safely and respect for the privacy of drivers, passengers and other users. Ethical issues are an important topic and self-driving vehicles must respect human dignity and freedom of choice. The EU is currently developing guidelines for artificial intelligence and the Commission is proposing the first ever legal framework on Artificial Intelligence (Proposal for a Regulation laying down harmonised rules on Artificial Intelligence), which addresses the risks of AI, but specific standards on automated mobility will be needed.

The EU has strong standards for security, safety, and privacy at both national and European level. Examples are the European legislation regarding the IoT enabled safety measures that vehicles must be equipped with as of 2022 (including driver distraction warning and advanced emergency braking systems) and the EU guidelines on processing personal data related to connected and autonomous vehicles.

For public authorities, one of the great opportunities of connected vehicles is the optimization of road capacity. If they know the position and destination of all vehicles in a particular area, an intelligent traffic management system can set the speeds and routes of all these vehicles in order to minimize journey times and congestion levels. But doing so, requires vehicle tracking and sharing of personal information in a way which in many cultures is currently regarded as politically unacceptable. Some companies may also be wary of involvement in such work for similar reasons. Countries already diverge significantly over the extent to which they protect the privacy of road users.

The heterogeneity of legislation among countries means the data that CAVs and other connected vehicles collect and transmit is likely to vary substantially from country to country. It is understood that for those with strict data protection rules, vehicles will need to anonymize data and minimize what is passed on, while other jurisdictions may require CAVs to tell the authorities where they are at all times.

3.2.4 Insurance

Some countries have already legislated to clarify liability in relation to AVs (e.g. Germany) but with such vehicles potentially capable of moving autonomously across national borders, like as it is for traffic legislation it will be necessary to have a degree of consistency in legislative approach to safeguard the public interest and indirectly foster acceptance.

The wider introduction of CCAM will lead to the need of a rethinking of the European legislation on product liability and compulsory insurance for the circulation of motor vehicles, which is currently based on the Product Liability Directive [Web 9] and the Motor Insurance Directive [Web 10].

The first Directive imposes responsibility for the damage caused by a product defect to its manufacturer, providing for the burden of proof of the damage, defect and causal link on the injured party, and without prejudice to "...the rights that the injured party exercise under the law relating to contractual or extra-contractual liability or under a special liability regime existing at the time of notification of the directive...".

The second Directive, on the other hand, revolves around the concept of "territory in which the vehicle is usually parked", leaving the Member States with the competence to adopt"... all appropriate measures, without prejudice to the application of Article 5, so that civil liability relating to the circulation of vehicles usually stationed in its territory is covered by insurance…".

The European Parliament considers the current legislation insufficient and hopes to update it. Consequently, the Commission has initiated a review process of the two Directives.

With regard to the Motor Insurance Directive, the Regulatory fitness and performance program (REFIT) was launched with the aim of verifying whether the Directive is still effective in light of recent technological developments.

The Product Liability Directive is also under review, with the aim of verifying its consistency with other European provisions and correspondence with the interests of the parties involved and their balance.

The overall assessment is that the current system, if applied to the self-driving vehicles, could alter the balance in the allocation of responsibility between producer and consumer. This system, in fact, was not designed to cope with the assumptions of liability inherent in vehicles so technologically complex and different from those on the market until not so long ago. It will be looked at what from the PAsCAL point of view could be concluded on this matter.

3.2.5 Legislation on disabled users

Article 20 of the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD) states that "States Parties shall take effective measures to ensure personal mobility with the greatest possible independence for persons with disabilities".

Article 21 of the European Charter of Fundamental Rights states that "the Union recognises and respects the right of persons with disabilities to benefit from measures designed to ensure their independence, social and occupational integration and participation in the life of the community".

Like any EU citizen, disabled persons have the right to use CCAM independently, all the more as these will offer them, as well as elderly persons for instance, unprecedented individual mobility perspectives.

This calls for coordination among EU countries certifying autonomous vehicle technologies.

There are other barriers to disabled people using CAVs that need to be considered, not only scepticism or cost issues. It is necessary to take into account needs and abilities of a diverse range of people upstream from the design stage (*Universal Design*) to fully address the accessibility needs of disabled operators (cars) or passengers (bus). The adoption of national/international legislations encouraging the wider use of the Universal Design principles by CAVs manufacturers will be instrumental in this attempt. Universal Design is the design and composition of an environment so that it can be accessed, understood, and used to the greatest extent possible by all people regardless of their age, size, ability or disability.

Disabled people cannot rely on only one type of input or feedback. Visual displays may not be suitable for some passengers, just as voice input may be inappropriate for others. Accessible operation features will be a pre-requisite towards CAVs' adoption by disabled operators.

The European accessibility act covers products and services that have been identified as being most important for persons with disabilities while being most likely to have diverging accessibility requirements across EU countries. Several exemptions, however, are made even in case of products and services covered by the Act. PAsCAL works in several simulations and demonstration with vulnerable user groups. Also, within its evaluation specific KPI's have been set for impacts of CCAM on vulnerable user groups. This should lead to some clear recommendations and guidance.

4 Integration of public awareness and user acceptance in the design of new CCAM infrastructure and technologies

4.1 Introduction

This chapter specifically looks at the incorporation of user acceptance into the design of new CCAM services and digital infrastructure.

It identifies key areas in new services and infrastructure initiatives that relate to the autonomous vehicles and connected systems studied in PAsCAL. It will then specify acceptance factors (selected from PAsCAL findings in previous WPs, in particular WP3) which represent usage motives and perceived barriers as well as the attitudes toward the respective technology. Individual factors (e.g., age, gender, technology generation, needs and demands) will also be considered so that guides and recommendations for new CCAM technologies and infrastructure are holistic, comprehensive, and fair, and made specifically for different users and social groups.

In this chapter, a distinction will be made between the physical & digital infrastructure, digital technologies that allow the external connections with the vehicles, and CCAM services dealing with the way in which CAVs are deployed to provide mobility services to the public and to specific user groups. In-vehicle ICT platforms and interface aspects are dealt with in chapter 5.

CCAM digital infrastructure

- EU wide and national CCAM digital infrastructures
- Digital CCAM communication technologies
- CCAM V2X portable communication devices

CCAM services

- Shared connected CCAM services and MaaS
- CAVs and V2VRU

Figure 4-1 Key areas of CCAM digital infrastructure and services

4.1.1 EU wide and national CCAM digital infrastructures

There is a debate over how much effort countries and jurisdictions should put into digital infrastructure for CCAM, including sensor networks, roadside equipment such as smart traffic lights that can tell CAVs when to stop or go, and high-quality digital mapping. Level four CAVs, which are only capable of autonomy in certain conditions, may be ‘geo-fenced’, or geographically limited, to areas with adequate digital infrastructure.

But if this introduction of CAVs requires sensors, on-road equipment, and detailed mapping to work well, their popularity and use will be limited to areas that can afford and have invested in such infrastructure. From a safety point of view, level five CAVs should not need to rely on external infrastructure to operate.

However, their safety is likely to come at the cost of efficiency, with several studies suggesting slower traffic speeds and worse congestion with CAVs because they will drive more defensively than humans. Digital infrastructure, allowing vehicle-to-infrastructure (V2I) communication, is potentially the solution to this. V2I systems use a centralized traffic management system to optimize the use of a region’s highways by orchestrating how vehicles operate for the benefit of all users.

This means potentially different CAV operating scenarios. In areas where road capacity is unconstrained, for example in rural areas, CAVs may rely more on their own systems. In areas where capacity is constrained, for example in cities and on major highways between cities, it will be more important for governments to invest in digital infrastructure and require CAVs to interface with the systems they establish. Having the PAsCAL demonstrations running in different scenarios, it is expected that the project will be able to contribute with guidelines and recommendations that will foster the public interest.

To realise the full deployment of CAVs, also the traditional road infrastructure will need to be adapted. Infrastructure encompasses many different elements, related to the road, but also to the smart communication technology available on the roads, and a variety of technology, traditional such as traffic lights and new, such as sensors detecting CAVs. The following characteristics of present road infrastructure can be identified:

- Roads, different road types, smart roads,
- Parking spaces, in-door, outside,
- Road-site units,

- Present general digital infrastructure (traffic lights, info panels etc.),
- Different types of infrastructure in different countries,
- New infrastructure needed to support ODD (e.g. sensors),
- Maintenance services.

Infrastructure plays a major role in the ODD, in which a CAV is able and allowed to operate, for example in pedestrianised areas or on highways. Maintenance issues of new infrastructure will be an important factor in realising infrastructure needed for automated driving.

4.1.2 Digital CCAM communication technologies

The digital communication technology outside of CAVs can be divided into technology that relates to the automated vehicles and technology of the infrastructure with which the CAV communicates. Other technology may be embedded in other devices, such as smart phones. In Figure 4-2 the possible connections between the vehicle and digital infrastructure are shown.

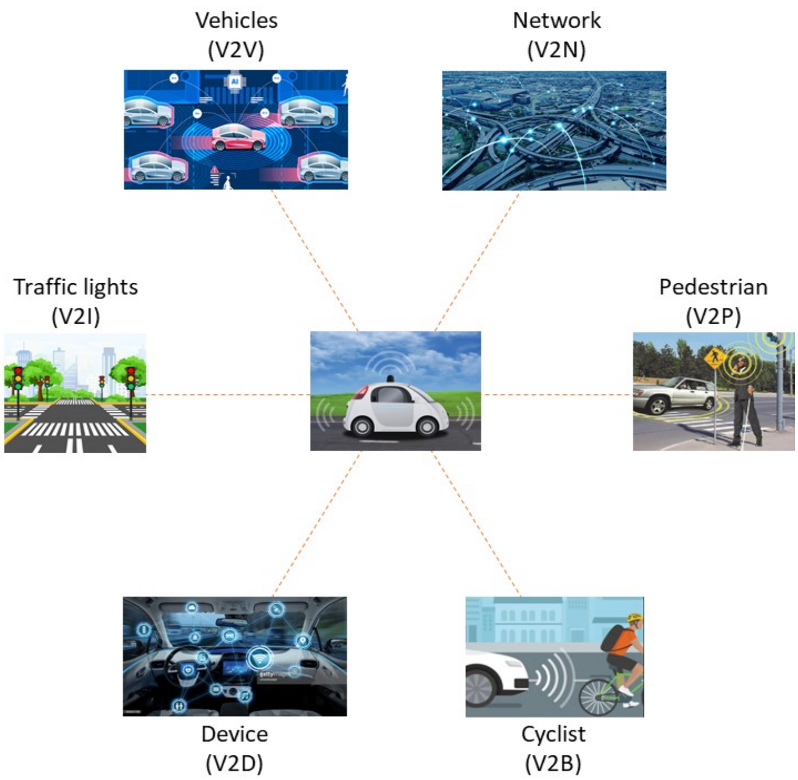

Figure 4-2 Different digital communications technologies (Source : UNIVLEEDS 2021)

Most of the ICT solutions installed in CAVs today are connected to the environment around the vehicle to ensure that the maximum amount of data can be collected. This includes connections to other vehicles (V2V), the surrounding infrastructure (V2I), to the internet via mobile networks (such as GSM, 3G, 4G or 5G connections, V2N) and to other systems, devices or humans (V2X).

To communicate with its immediate surroundings, most CAVs use Dedicated Short-Range Communications (DSRC), which is wireless and functions only on a very short range. Another option is Bluetooth, which is used to transfer data over short distances with high security [3].

In this section, an inventory of the different types of technology is presented (see Figure 4-2)**Error! Reference source not found.**. This inventory cannot be complete, since developments in the area of connected and automated mobility are evolving rapidly. However, characteristics of the technologies are of great influence on the acceptance of CAVs. For example, people may or may not accept a CAV depending on the speed at which it is allowed to travel, or in which circumstances it is allowed to drive automatically.

Communication with other vehicles, road-users and infrastructure is therefore an important characteristic of CAVs. Communication with other automated vehicles and other road-users will have a great influence on traffic and on the behaviour of CAVs. The network will play an important role in determining how CAVs will be able to drive, for example platooning and following distances. The same holds for communication with infrastructure. For example, having smart highways that can communicate directly with CAVs will allow safer autonomous driving. Several PAsCAL simulations and demonstrations investigate V2X communications, and a set of guidelines and recommendations will be developed in this area.

4.1.3 CCAM V2X portable communication devices

There is a large variety of portable devices, in the CAVs and in the infrastructure that makes it possible to drive automatically. In the V2X, the following portable type of devices can be identified:

- Road-site units,
- Devices for non-automated road users,

- Human-machine interactive devices.

Also, non-automated road-users may have a device that warns them about the presence of a CAV, for example cyclists and pedestrians may have a device that gives warnings about an approaching CAV. Here we do not provide an extensive inventory. Characteristics that are of interest are the interface with the user and the energy used by the device and the source of energy, for example smartphones may run out of power.

4.1.4 Shared connected CCAM services

A selected key area is the potential of CCAM in strengthening shared mobility services. Several new mobility services are evolving. The inventory, presented in Figure 4-3 below, below, cannot be complete, as new services are developing rapidly. Those new mobility services are using technologies that provide a different mobility service to users that is different form the privately owned or leased vehicle. They are related to new business models and value cases.

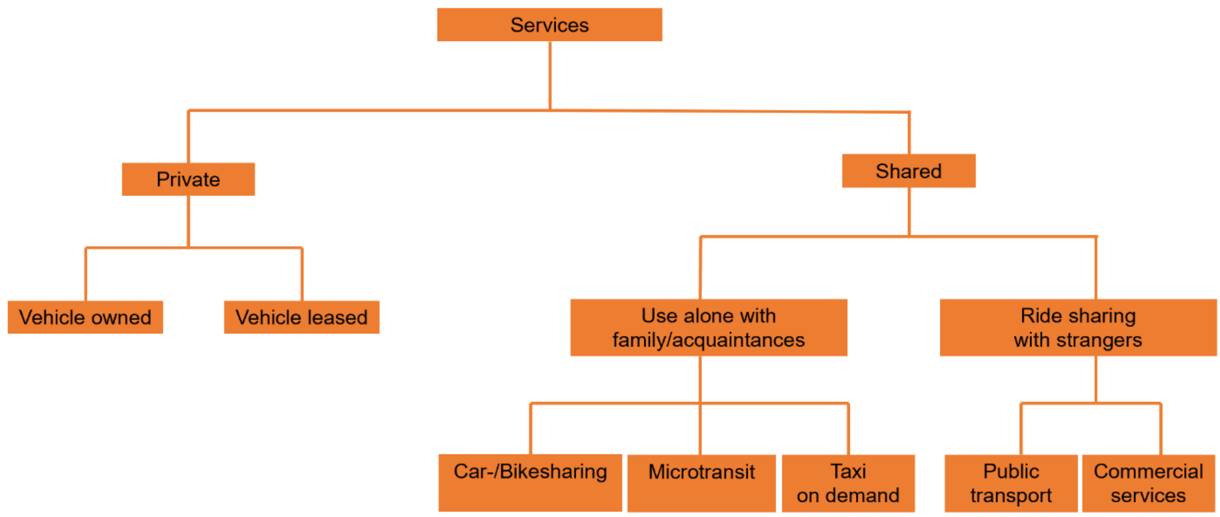

Figure 4-3 Examples of shared and private services (detailed definitions may be found at: https://www.sae.org/shared-mobility)

PAsCAL will specifically look at increased user acceptance and public interests of these shared services as the result of adding CCAM vehicles, features and services. It will be investigated in several PAsCAL demonstrations how shared mobility and public transport services can benefit from CAVs.

Services usually target different groups of users, and can be used for short rides, for example a last mile service, or for longer trajectories. Characteristics of shared services relate to the way in which the service is organised and offered to users. We may distinguish the following characteristics to the types of new mobility services:

- Short or long distance,
- Types of business models, and governance,
- Method of paying,
- Method of requesting service,
- Connection between services, taking care of door to door transport, using different modes,
- Operator available distant or in the vehicle,
- Help and support,
- Data privacy and security.

It will be looked at if CAVs will have an influence on any of these specific features. They can be provided by private or by public (or mixed) organisations. This influences the governance and the business models. There are differences in the ways in which a service can be demanded, for example asking for a robotaxi via an app on a smartphone or an automated bus running as normal public transport.

4.1.5 Mobility as a Service and CAVs

Mobility-as-a-Service (MaaS)[4] is a joint digital channel that enables users to plan, book, and pay for multiple types of mobility services. CAVs could reinforce the MaaS trend by eliminating driver costs and reducing other cost elements, making it competitive with public transport. They could also eliminate the need of finding drivers which seems to be a typical issue in

[4] https://en.wikipedia.org/wiki/Mobility_as_a_service [Retrieved Jul 28, 2021]

many places (e.g. rural areas). Some authors anticipate that by 2030, 95% of US Personal Miles Travelled (PMT) will be based on shared on-demand autonomous electric vehicles [4]. A similar path would be followed in other geographic areas, including Europe [4]. This forecast may seem too extreme relative to other estimates but invites to reflect on a possible future mobility landscape, where transport services might even become free (or nearly free) on the basis of advertisement supported business models [4] [5].

While CAVs may provide greater efficiencies, fewer empty movements, and greater ride-sharing in a MaaS system, specific attention will be paid to MaaS in combination with CAVs and its accumulated effect on user acceptance and public interest. To run a service, data will be collected from the user, raising issues on privacy and security. Services can offer a complete mobility package, such as in the MaaS concept, where different transport modes and transport providers are combined. For the target groups in PAsCAL it might be of importance whether there is a human operator or support service available, in the vehicle and/or at the station/stop. Assistance/Help services in general could be available at any time, especially during a trip.

4.1.6 CAVs and V2VRUs

A specific selected key area within the PAsCAL project is the communication between CAVs and vulnerable road users (V2VRUs). VRUs can be pedestrians, cyclists, motor cyclists, but also non-automated vehicles, or users of new forms of micro mobility such as e-scooters. In PAsCAL we also pay attention to VRUs that have specific vulnerabilities due to disabilities. We can distinguish between detection of VRUs, reacting to VRUs and communicating with VRUs. For detection we must take into account that some VRUs are difficult to perceive by sensors if they have a non-standard shape, for example pedestrians in a wheelchair or blind pedestrians with a white cane. VRUs can behave erratically, suddenly crossing a street or trying out the reaction of a CAV, getting it to stop. The behaviour of CAVs when detecting a potential conflict with VRUs may be problematic. When a CAV stops automatically when it detects a VRU this may lead to not moving at all, but the CAV may also resort to "bullying", trying to force priority. There are also cultural differences between countries, for example when using the horn.

The following characteristics can be identified:

- Detection of all kinds of VRUs (pedestrians, cyclists, wheelchairs, animals,…), including specific appearances (new forms of micro-mobility, white canes of blind pedestrians…);
- Vehicle behaviour around pedestrians and cyclists, priorities;
- Reaction to erratic VRU behaviour;
- Interaction between VRUs and small vehicles for micro-mobility (e.g., scooters).

5 Public awareness and user acceptance in-vehicle CAV ICT developments

5.1 Introduction

In the context of CAVs, ICT tools bridge the gap between automated processes and the human passenger or driver. It is vital for humans onboard CAVs to understand the decisions the vehicle takes but in the case of autonomous vehicles also for co-road users to anticipate the trajectory the vehicle might take. Information Communication Technology tools (ICT tools) in the PAsCAL project includes all the technical hardware as well as subsequent software components that operate a CAV. On any given CAV, a wide range of ICT tools can be found onboard. To give an adequate overview over all these tools, they can be categorised by the kind of task they serve for the vehicle's operation. A list of the most common ICT tools encountered in an autonomous vehicle can be found in **Error! Reference source not found.**.

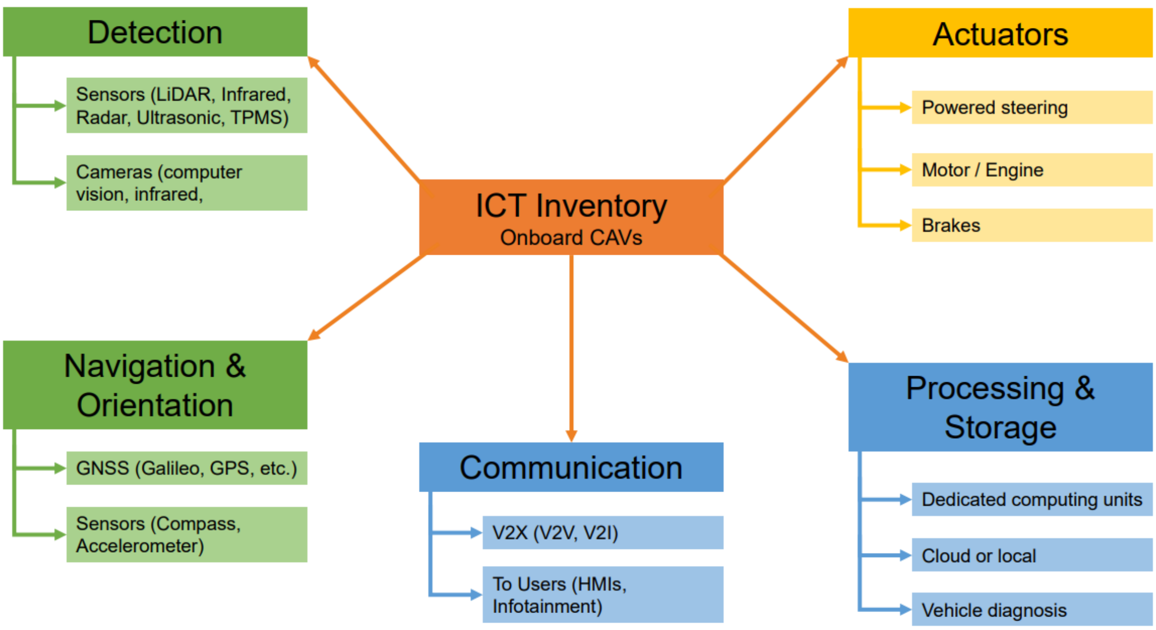

Figure 5-1 ICT Inventory overview (Source: Etelätär 2021)

The five categories can be further grouped into three supra-categories: those that the vehicle uses to obtain data through various sensors and antennas (namely Detection, Navigation & Orientation), those it uses to make decisions and evaluate situations (namely Communication, Processing & Storage), and lastly those turning these decisions into action by changing the speed or direction of the vehicle (Actuators).

5.2 Key Areas

In total six in-vehicle ICT key areas have been identified when it comes to challenges to the wider market uptake of CAVs and user acceptance. They are studied and their current state-of-art is documented in this sub-section.

They are the following: Cyber security, Safety issues, Privacy protection and data storage, Human-Machine-Interfaces (HMI), On board connectivity and Technology-Savviness. All of these areas currently experience a rapid evolution in development and research and should be taken into account in the design of any CAV, as they represent the interface between connection, automation and humans.

In-vehicle CAV ICT developement

- Cyber security
- Safety issues
- Privacy protection and data storage
- Human-Machine Interfaces (HMI)
- On board connectivity
- Technology-Savviness

Figure 5-2 Key areas to widen market uptake of CAVs.

5.2.1 Cyber security

One of the main concerns with the wider integration of ICT in high-level automated CAVs is security, and more in particular, the cyber-security of both the in-vehicle technology as well as the V2X communications, which enable the vehicle to make intelligent and informed decisions in accordance with more powerful servers in datacentres outside the vehicle

[6]. There are different kinds of attack vectors which can be targeted at a CAV's ICT; some examples follow:

- Rogue updates: unauthorised software updates containing malicious code,
- Password attacks, with techniques such as phishing or man in the middle to get access to the credentials for the vehicle's managing platform,
- Spoofing attacks, sending malicious information to the vehicle's sensors or through the network,
- DoS attacks, denial of service attacks that may overload the vehicles network or sensors,
- Exploits in the vehicle or server's code that grant the attacker access to the system.

Attacks can be local, physical, through the network the CAV is connected to or through another network. They can focus on different attack surfaces, which are different for each vehicle, an example can be seen

Figure 5-3 **Error! Reference source not found.**[2].

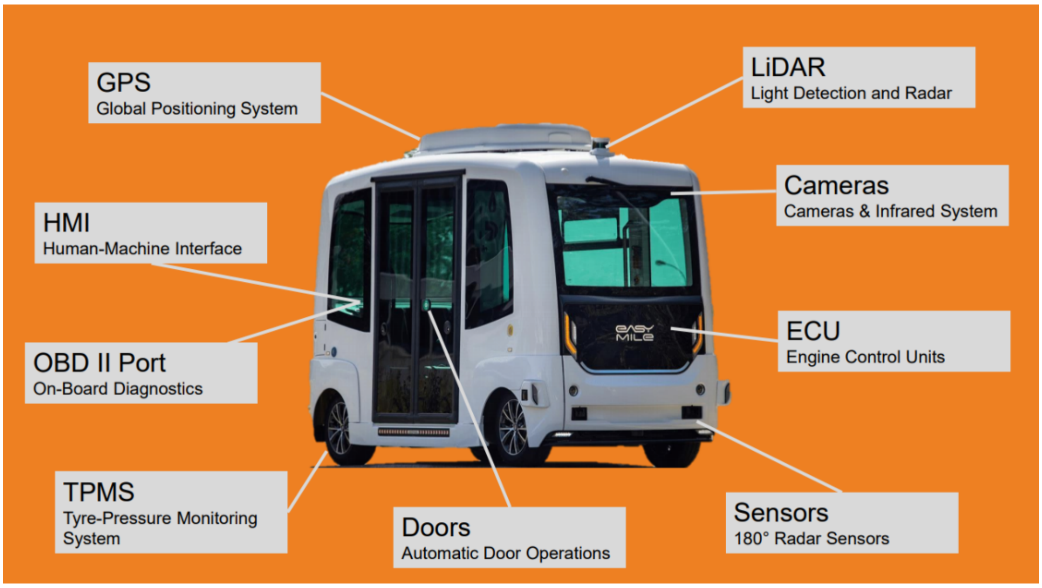

Figure 5-3 Attack surfaces for ICT in CAVs (Source: Etelätär 2021)

These attacks can achieve one ore multiple of the following tasks:

- Cyber-physical vandalism, where the objective of the attack is to cause harm,
- Ransomware, making damage or disrupting the systems and asking for a ransom to make the system operational again,
- Data theft, where attackers steal the data collected by the ICT tools.

Traditional risk assessment and security measures such as the Automotive Safety Integrity Level (ASIL)[5] do not suffice in accurately predicting and defending communication channels between the vehicle and its surrounding infrastructure on their own. Since, differently from a regular cyber-attack on sensitive data, human lives and wellbeing are at stake, this issue is of greatest importance and the inadequacy of available solutions contributes in large parts to the delayed uptake of CAVs. New tools and standards must be created, tested and implemented, which ensure that CAV ICT system security is proactive, flexible, resilient and communication-layer agnostic.

Two kinds of systems in use today can be recommended to ensure higher CAV ICT security:

1. Common Vulnerability Scoring System (CVSS)[6]: for long-term CAV deployments and general security control. They are based only on historical data and help in analysing single scenarios through reverse-engineering. The system is restrained to available data and cannot assess new risks spontaneously. Threshold CVSS scores still need to be established and audited by regulatory bodies to ensure high and consistent security.
2. BN cyber-risk classification model[7]: for short-term and spontaneous risks. It can aggregate both known and potential vulnerabilities and analyses both hard- and software components of each CAV first individually and finally as a whole system. This classification model is more dynamic, and its parameters are adaptable on a daily basis **Error! Reference source not found.**.

[5] https://en.wikipedia.org/wiki/Automotive_Safety_Integrity_Level. Retrieved Jun 14, 2021.
[6] https://en.wikipedia.org/wiki/Common_Vulnerability_Scoring_System. Retrieved Jun 14, 2021.
[7] https://www.researchgate.net/publication/320836744_Bayesian_Network_Models_in_Cyber_Security_A_Systematic_Review. Retrieved Jun 14, 2021.

Going forward, several critical functions of CAVs need to be protected, especially if they have to do with safety critical issues like connectivity, automation or data protection. Preventing these areas from being attacked by hackers is crucial going forward. A combination of legislative, technical, risk-based, methodological and governance aspects seems to be the most promising [6]. Furthermore, risk assessment tools should be further refined and could be rendered mandatory and integrated into any ICT tool.

The wider use and integration of new technologies, for example the 5G network, brings forth new challenges, which need to be addressed and updated constantly.

5.2.2 Safety issues

According to the American National Highway Traffic Safety Administration (NHTSA), 90% of crashes in traffic are caused by human error.[8] It can be expected that due to the removal of the human factor the number of accidents shall drastically decrease as more CAVs share the road with regular vehicles and other road co-users. Furthermore, they can contribute to the safety of entire communities by reducing travel time, congestion, and the waste of resources [4][6].

However, the general public's perception paints a different picture: most first-time users of CAVs report feeling nervous and hesitant when talking about the adoption of these new technologies. Some of the major concerns include fear of system failure and malfunctioning of the technology, system breeching, unoccupied moving vehicles, autonomous commercial vehicles and security concerns, both physical as well as cyber-attacks. Most users find it hard at first to give over the control of the vehicle and seek a sense of safety in being able to intervene in case of emergencies. Clearly, users today indicate an unwillingness to completely rely on CAVs [3].

One major concern in the safety of ICT solutions in CAVs is the legal liability and insurance requirements of owning a CAV [5]. In case of an accident or crash, users are not sure whether the vehicle manufacturer, who built and installed the ICT solutions in the vehicle can be held liable or whether they can be held accountable themselves. Furthermore, no binding obligations concerning maintenance and inspections of the ICT of CAVs have been defined.

[8] https://www.nhtsa.gov/. [Retrieved Jun 14, 2021].

On average, men feel more confident and safer while using or purchasing a CAV than women, which is partly due to the fact that they tend to purchase and use CAVs earlier in life than female road users [3]. These insights point towards the conclusion that users' perception of safety increases together with the amount of experience they have gathered onboard a CAV. Furthermore, the use of Human-Machine-Interfaces (HMIs) can greatly reduce the feeling of discomfort in CAV users, as it removes the element of uncertainty for CAV passengers, providing them information on the manoeuvres or events happening around the vehicle.

The safety concerns and considerations for CAVs today are mostly satisfactory and they are not expected to increase the number of accidents or threaten traditional traffic flows significantly. A special attention should be paid to the interoperability of CAVs in complex transport networks in the future. However, one of the most important factors in ensuring a wider acceptance of CAVs in the general population is to overcome a massive distrust in regard to safety concerns of these technologies. A large divide between perception of safety conditions and their reality can be found today. The key tools to battle this are information campaigns, a wider integration of CAVs into public transport as well as clearer legislature & insurance laws [9] and finally the encouragement to use CAVs privately. It has proven particularly effective to ask people who seem sceptical of the technology to try it in real-life themselves. Finally, a focus should lay on rendering CAV technologies more accessible for people with disabilities and ensure that these services are safe and easy to use for them.

5.2.3 Privacy protection and data storage

The sensors integrated in CAVs generate a large amount of data every time they are operating, and due to the complexity of the necessary calculations performed by the ICT tools, they are often offloaded to a more powerful server. Not only do these vehicles rely on the large and constant streams of data between the vehicle and the mentioned servers, but this data transmitted also often contains a high percentage of personal information linked to the vehicle, which requires special data protection and raises privacy concerns [6].

These concerns are not unfounded, as the gathered data could give different stakeholders deep insights into the user's driving habits, mobility patterns, trip purposes and locations [6] as well as the causes and severity of accidents caused by the failures of these ICT tools. Due to the large amount of information gathered (a fully autonomous vehicle can generate up to 7.4 Tb each day [2]), an efficient storage system is required to handle the datasets economically and solutions for real-time processing as well as a quick and smooth flow of data to ensure short reaction times can be further improved **Error! Reference source not found.**.

Subsequently, data collected, requested and emitted by the CAV should be rendered anonymous when possible and always encrypted to protect user's privacy aboard any CAV. Finally, data storage duration and conditions are still unclear as well as who should have access to these datasets [6][7].

However, storing these large datasets is still important because they can also help to interpret the information received through ICT within the CAV quickly and make informed decisions in critical situations. They help the vehicle to estimate potential outcomes such as collision scenarios or the cost of an accident [7]. Furthermore, the gathered data can help to optimise traffic flows and offers potential for new business models **Error! Reference source not found.** as well as improving existing vehicles.

To ensure that privacy concerns are addressed correctly, and all data is stored and processed safely, new policies for data ownership and data security are urgently needed and should be implemented before vehicles with higher levels of automation hit the private market. Of course, the minimum of data and privacy protection needs to follow the European Regulation 2016/679 (General Data Protection Regulation), but this could be further extended. For example, the American National Highway Traffic Safety Administration (NHTSA) published a policy guidance document, which further calls for the storage of crash data and the correct treatment of this data [14]. Furthermore, the handling of this data can be further improved, for example by using software such as Hadoop and improving the security of server gateways onboard.

Each vehicle needs to be linked to transparent, simple and clear terms & conditions, that ensure that each user understands the kind and extent of data collected during their ride.

Finally, information campaigns can help to overcome distrust of the general population concerning privacy concerns upfront.

5.2.4 Human-Machine Interfaces (HMIs)

In general, HMIs, are used as tools to display the information the ICT tools need to communicate to the users of a CAV. They can use device-specific indicators such as perceived effectiveness, perceived usefulness, or perceived efficiency [14].

Passengers and co-road users who interact with any CAV are dependent on additional information concerning the status of the ICTs onboard in order to be aware of any detailed situation context. If the needed information is communicated adequately and at the right moment, the feeling of trust, safety and control of the humans interacting with the vehicle increases substantially and it is vital to ensure safe navigation. To ensure quick communication, the design of any HMI onboard a CAV should be as simple and direct as possible, and it should be mostly voice-activated to cater also to vulnerable passengers and digital migrants. The most important moments for this exchange of information are those when the CAV switches for example from full automation to partial automation or when the human driver takes back control over the vehicle [15][16].

The design of HMIs needs to take into account several different factors and questions, such as the content and design of the information perceived, the understanding of this information, the timing and priority of information. All of these factors need to concede with several important transparency standards, which further raise the confidence and trust in the autonomous and connected system. Finally, four different characteristics of HMIs are of interest: usability, accessibility, functionality, and adaptability, which should be rated individually for each HMI to spot potential shortcomings or oversights. Future HMIs must also meet the seven principles of Universal Design.

To further improve the quality and acceptance of HMIs as ICT tools, they could be subjected to a Cognitive Work Analysis (CWA), which is used to evaluate complex sociotechnical work systems and could help in excluding HMIs which are not suitable. Another similar option could be the Lyons Model [16]. HMIs also need to be rendered more adaptable and accessible, depending on the user type (e.g. a child, an elderly person, a blind person, a deaf person, etc.) and accessible to persons with various different impairments or constraints to avoid the exclusion of different user groups from the optimal design of HMIs. Lastly, the communication between CAVs and pedestrians needs to be further explored and sophisticated. As the research shows, many pedestrians are insecure because they cannot predict the direction the vehicle might take due to lack of eye contact with a driver [18].

5.2.5 On board connectivity

The connectivity of on-board ICT is becoming increasingly important, and it can be estimated that by 2026, any newly produced car could be connected to its environment [17].

Some vehicles offer this connectivity to its passengers as an on-board service, for example by generating an in-car Wi-Fi hotspot or allowing them to access Web services through an interface. Another option is that the ICT connects directly to surrounding Wi-Fi hotspots itself, or other available subscribers' connection.

Connectivity matters – without safe, stable and constant connection to its environment, CAVs cannot operate properly and create a negative experience for their users. One major issue today is a missing solution for simple and quick software updates of ICT tools onboard of vehicles. Often, updates require users to bring their vehicle back to the retailer. A good alternative could be external updates, which could be installed by plugging a laptop or tablet into the vehicle at home. Furthermore, adequate solutions for remote areas without proper coverage need to be found to ensure that CAVs do not "strand" due to missing network connection. Finally, it would be worth to further discuss whether to allocate a dedicated frequency range on the spectrum for V2X communications.

5.2.6 Technology-Savviness

The level of technology savviness of CAVs users has a large impact, not only on how they perceive the vehicle itself and the ICT onboard but also determines in general what kind of transport choices they make in the wider picture. People with lower technology savviness may require help to use certain transport modes or might prefer using vehicles which make as little use of technology as possible. For example, smartphone users have most probably used location and navigation technologies before boarding a CAV and have therefore already been able to gather some experience with these technologies. Therefore, they might have a higher trust in it than other users who have not owned a smartphone or used navigation apps before [19].

Some researchers found that users with low levels of tech-savviness are not more concerned about ICT than those who feel more confident using technology [19].

The consensus today is that voice-controlled ICTs onboard of CAVs are the best solution both for the usability of people with low tech-savviness level as well as most vulnerable passengers, as they offer an intuitive alternative. Users are not required to overview, understand and select information but are rather guided in a familiar way. Furthermore, if any kind of visual cues like dashboards are needed, it is recommendable to keep them as simple and straight-forward as possible by using intuitive, minimalistic designs and avoid the use of jargon or foreign language [17].

6 Management of CAV developments placing user interest at the centre and stimulating local economy

6.1 Introduction

Present management of CCAM research and technology developments lacks insights on how the integration of increased public awareness and user acceptance could lead to improved CAV products and developed CCAM services. PAsCAL aims to identify possible new forms of CCAM service provision that lead to higher levels of inclusion, economic growth and sustainability in line with public policy objectives. PAsCAL will develop guidelines and recommendations for the following key areas:

- Integration of users' acceptance in CAV development;
- Improved mobility and transport network efficiency and CAVs;
- Usage of CAV development to support local industry;
- Increased use of CAVs and effect on social inclusion;
- CAVs and environmental sustainability.

The deployment of CAVs – when fully integrated in the whole transport system and accompanied by the right support measures and synergies between driverless mobility and decarbonisation measures – is expected to contribute significantly to achieve among other the following societal policy objectives:

- Safer transport leading to achieve the so-called Vision 0 i.e. no road fatalities on European roads by 2050 [21];
- Better accessibility for everyone respecting social inclusion;
- Sustainable mobility by reducing road emissions.

The key areas are shortly described in the following sub-paragraphs.

CCAM and local economy, networks, social inclusion and sustainability

- Co-creation process in CAV developement
- Effect of CAVs on mobility and transport
- Stimulation of local economy
- CAVs and social inclusion
- CAVs and environmental sustainability

Figure 6-1 Key areas of CCAM and local economy, networks, social inclusion and sustainability

6.2 Key areas

6.2.1 Integration of users' acceptance in CAV development

Usually, businesses in general are developing their solutions in research and development laboratories, only accessible and open for internal staff. However, to be able to increase user acceptance of CAV development or any kind of related technological development, a more open and dynamic approach is needed to develop sustainable solutions. Therefore, more and more organisations are including external stakeholders and end-users into their design process for new products and services. End-users are being integrated in the creation process to source and test designs. This involvement of external stakeholders in the creation process of a service or product is called co-creation. This is key to ensure that services and products remain relevant in the market, which is constantly changing. Co-creation is enabling to pool existing talent and resources across sectors and develop products to keep them at the front of the race [Web 13].

Co-creation and end-user involvement relate to a cooperative process where the involved stakeholders, and particularly the end-users, can influence the experimentation from its ideation phase. Co-creation aims at aligning the objectives of the parties involved and enhancing the participation of the end-users in the development of the final products and services, as a result - increasing their acceptance of the developed innovation and, thus, the chances of their uptake [22].

Co-creation can have several benefits [22]:

- Developed product/service integrates first-hand opinion and requirements of the end-users, therefore has a better fit for purpose characteristics and benefit of the higher acceptance rate and roll out perspectives.
- Product/service developers gain access to the end-user data and feedback which further accelerates the innovations' uptake and acceptance.
- Stakeholders could go through the innovation iteration cycles earlier in the product/service development process.

During the development of a new CAV products and services, potential end-users can be incorporated in the testing phase by being interviewed, surveyed and/or observed about how they are using the test CAV. The earlier the end-user is involved in the product/service development process, the more added value its participation can bring to the final output.

One step further, i.e. applying the Universal Design principles to any CAV design process, will bear the potential to increase their adoption by the greatest number of citizens, in particular those who cannot currently use a private vehicle independently. In addition to its social implications and impact, Universal Design is therefore key towards manufacturers reaching out to new commercial prospects.

However, end-user and citizens engagement can be experienced as a challenge in each phase of the innovation development. Surveys among citizens and test panels in respective areas can have benefits, however, often lead to only partial consultation and involvement. Actual collaboration with end users and/or citizen empowerment as to say to provide the final responsibility and decision with the citizens is rarely happening [22]. Therefore, Living labs (further described in 6.2.3) principals in CCAM testbeds and large-scale demonstration enable co-creation with end-users and citizen engagement processes to further raise the trust in the developed innovation and its acceptance [22].

Providing good practices examples of actual collaboration with end users as well as citizen empowerment might help to improve the uptake of innovations and solutions.

6.2.2 Improved mobility and transport network efficiency and CCAM

The introduction of CAVs will shape the future of road transport and is expected to increase efficiency of usages of the present transport and mobility network. Even if the impacts of CAVs still require further research, already some preliminary estimations have been made in different studies (e.g. [3]; [23]; [24]).

Based on the findings in these studies, Raposo et al. [25] provided an analysis of specific CAVs impacts on mobility, safety and environment and is explaining the fundamentals of how the road transport system could respond to CAV technologies. CAVs can have positive as well as negative impacts on mobility.

The introduction of CAVs in the mobility and transport network can lead to a decrease in congestion due to e.g. less delays that result from accidents. In addition, it can lead to an increase of road capacity due to platooning and in an increase of users, by offering an inclusive mobility (e.g. for young, elderly and disabled people). The goal is to create more user-centred, all-inclusive mobility, while increasing safety, reducing congestion and contributing to decarbonisation [25]. On the other side, CAVs can lead to an increased congestion to a higher travel demand and a lower usage of public transport.

Another important factor are the costs related to mobility and transport. The introduction of CAVs could lead to a significant reduction of transport costs. This includes a reduction in car ownership costs; parking costs (if cars can be parked in less space and located in less expensive land); insurance and crash costs (if crashes are reduced) as well as labour costs of taxis and commercial vehicles as drivers are no longer needed. On the other side, there could be an increase in costs due to higher vehicle equipment costs and a higher need of infrastructure equipment (including higher maintenance costs). From the side of public stakeholders, there could be a decrease in revenues, like parking revenues for cites.

Moreover, CCAM could introduce new services and offer new ways to respond to the increasing demand for mobility. This could encourage shared mobility services, integrated with public transport, and 'mobility as a service' platforms. Moreover, CAVs could involve a change from car ownership to mobility on demand services, which could offer the same level of service than the one offered by car ownership but at much reduced cost ([25] [26]).

One fundamental factor of the introduction of CAVs into the road transport system is the increase or decrease of the travel demand and road capacity. Travel demand can vary in two directions: on one side a increase in travel demand and vehicle miles travelled (VMT) or on the other side a decrease in VMT. As a potential consequence of CAVs making road travel cheaper, more comfortable, more efficient and accessible to new user groups, travel demand could potentially increase. This demand could corresponds to the demand of these new users groups and their induced demand resulting from capacity improvements enabled by CAVs, which is called the “rebound effect” (see Figure 6-2). Figure 6-2 also that there could be an increase in travel demand (increase in VMT) due to an increased urban sprawl, automated taxis (Automation Level 4) and a lower user of public transport. A decrease in travel demand such as the decrease of VMT could follow as a consequence of a shift to a shared mobility system, which reduces vehicle ownership.

Influencing Factor	Increases VMT	Decreases VMT	Likely Automation Level
Rebound effect	X		2, 3, 4
Car-sharing and reduced vehicle ownership		X	2, 3, 4
Driverless taxis	X		4
Greater sprawl	X		2, 3, 4
Substitute for intracity or intercity public transportation	X		4

Figure 6-2 Increase and decrease of travel demand due to CAVs (Source: [25])

On the other side, the supply side, road capacity could also vary in two directions. Initial stages of CAVs deployment could decrease throughput as a result of their cautious behaviour and inefficient interactions with human-driven vehicles and other road traffic participants. With a higher penetration rate of AVs coupled with vehicle cooperative features, capacity improvements are expected, since these vehicles could adopt shorter headways (e.g. platooning), provide a better traffic distribution using real time traffic information and reduce the number of disruptions to traffic flows [25].

If travel demand increases, congestion, fuel consumption/energy use and emissions might increase. The increased travel demand can be accompanied by an increase in road capacity and on the opposite an decreased travel time can lead to a decreased congestion. However, the effects on congestion are still uncertain due to the differentiations in the rates of each respective reduction or growth (of demand and supply).

Therefore it will be useful to develop short-term and long-term scenarios to work out some trends in relation to the impact on traffic flow and congestion.

6.2.3 Usage of CAV development to support local economy

Optimistic estimates have anticipated that CAVs will account for up to 75% of cars on the road by the year 2040 or that by 2030 all vehicles will be self-driven, plus electric and shared [25]. Other estimates of AVs penetration indicate a 30% penetration rate by 2040 [25]. Chapin et al. [26] includes assumptions, which indicate that AVs could account for 50% CAV sales by 2040 (with 90% private vehicles) and reach a 100% CAV sales by 2060 (with 70% private vehicles). The research firm IHS Automotive predicts that there will be 21 million CAVs on the road by 2035 (4.5 million in the US) [Web 14].

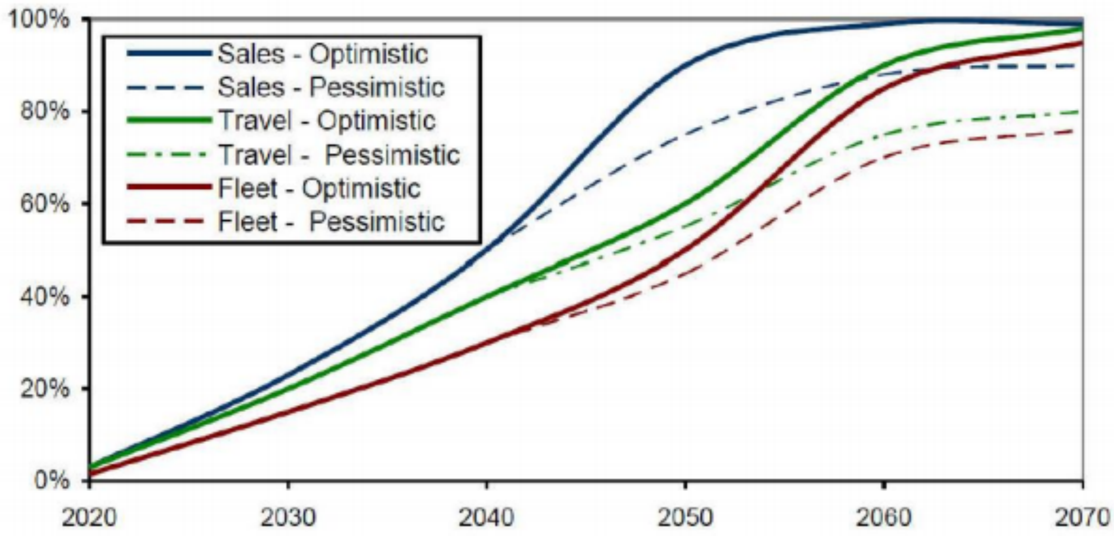

Figure 6-3 CAV sales, fleet and travel projections (optimistic versus pessimistic). (Source: [25])

In Figure 6-3, CAVs could take one to three decades to dominate vehicle sales and one to two decades to dominate vehicle travel and even at market saturation, a significant part of vehicles and vehicle travel may still be human-driven (dashed lines i.e. pessimistic projections). CAVs could represent around a 15% of the vehicle fleet by 2030 and around 45% by 2050 (red bold line i.e. optimistic fleet projection) [25]. These projection curves serve as a basis for the subsequent analysis of potential effects of automated and connected vehicles.

CCAM will have a remarkable economic impact as stated in the McKinsey's "RACE 2050" [Web 15] report and according to their Auto 2030 model, which indicates that European automotive revenues based on consumer spending will almost double from EUR 850 billion in 2016 to EUR 1,400 billion by 2030. The economic value contribution is one of the core requirements to create a profitable future mobility industry and maintain relevance as a global export industry. Europe has the unique opportunity to consolidate its leading role in CCAM against rising competition in global value chains and markets. In fact, a new European Patent Office (EPO) study [Web 16] shows that Europe accounted for 37.2% of all patent applications related to self-driving vehicle technologies at the EPO between 2011 and 2017 - ahead of China (3%), Japan (13%) and the United States (33.7%) [27]. With the full integration of CCAM into the transport system, one of the expected positive impacts for industry and society will be the strengthening of competitiveness of European industries by technological leadership and ensuring long-term growth and jobs[9].

High levels of investment and newly created jobs are needed to develop new technologies and services. CAVs will have spill-over effects on many other sectors in the value chain and the new business models enabled or facilitated by driverless mobility [21].

Next to attracting the CAV industry, there are several manners wherewith local and regional public authorities can capture part of the benefits. Living labs and testbeds provide ideal environments to combine co-creation, design testing and validation for a potential upscaling and therewith support and create new opportunities for the local economy and industry.

The European Network of Living labs (ENoLL[10]) defines living labs as "user-centred, open innovation ecosystems based on systematic user co-creation approach, integrating research and innovation processes in real life communities and settings". Living labs allow co-creation and validation of the product/service with an end-user. The end-users are integrated into the ideation/co-design/validation as well as in the evaluation process. Testbeds, on the other side, allow access to physical facilities, capabilities and services required for the development, testing and upscaling of new

[9] GEAR 2030 final report
[10] https://enoll.org/about-us/

products and services. Their co-creation process includes validation and evaluation of products and services.

6.2.4 Increased use of CAVs and effect on social inclusion

CAVs could bring mobility to those who cannot drive themselves (e.g. elderly or disabled people) or to areas that are under-served by public transport. This inclusion of vulnerable users is described by the European Commission in the Joint Report on Social Inclusion [28] as social inclusion, which is defined as followed:

Social inclusion “is a process which ensures that those at risk of poverty and social exclusion gain the opportunities and resources necessary to participate fully in economic, social and cultural life and to enjoy a standard of living and well-being that is considered normal in the society in which they live. It ensures that they have greater participation in decision making which affects their lives and access to their fundamental rights.”

The European Union and its Member States support the accessibility of their citizens, since good accessibility thrives the European economies, promotes inclusion and fosters the well-being of inhabitants. The European Union particularly focuses at improving accessibility of vulnerable social groups such as the elderly, blind and partially sighted persons, children, non-drivers, people with low-income, the disabled and people living in remote or deprived regions, so to arrive at a state of affairs with a ‘mobility for all’ [29].

There is an important need for inclusive mobility solutions, which need to apply at least one of the following conditions [29]:

- A transport option is available which suits to the individual’s physical condition and capabilities (availability).
- An existing transport option reaches destinations where the individual can fulfil his/her daily activity needs in order to keep a reasonable quality of life (accessibility).
- The necessary weekly amount spent on transport, leaves a household with a residual income above the official poverty line (affordability).
- The individual doesn’t need to spend an excessive amount of time travelling (time budget).
- The prevailing travel conditions are dangerous, unsafe or unhealthy for the individual (adequacy).

Innovative mobility and transport solutions like CAVs have the potential to improve accessibility for vulnerable social groups by increasing their flexibility and independence. However, it needs to be considered that these vulnerable users might not be able to afford the use of CAVs. The high costs of these vehicles could negatively affect equity and cause disparity of socio-economic access [30]. Concerning the availability of CAVs for all persons, it needs to be considered that people with reduced mobility and partially sighted and blind people need assistance to be able to use CAVs. Especially for these vulnerable groups as well as children, travel conditions need to be safe and well-coordinated.

6.2.5 Increased environmental sustainability and CAVs

Many environmental factors could be considered in the environmental impact assessment of CAVs, like impacts on air quality, water consumption, land use change and biodiversity. As the potential environmental impact of CAVs is specifically concentrated in the choice of energy use and management of tailpipe emissions, the work within work package 8 will concentrate on the potential, CAVs have to save energy and reduce emissions, especially if they are shared and the CAV penetration rates are high [30].

The potential energy and emission savings could include:

- Energy-saving driving practices (Output=energy efficient driving): One of these practices could be eco-driving, which strives to maximise energy efficiency while minimising harmful emissions. A CAV successor to current eco-driving (through such tools as advanced cruise control) could be eco-motorization, which promises larger gains in fuel efficiency. This could be achieved by digital regulation and smoothing of vehicle movements (digital systems management of vehicle fleets based on traffic smoothing algorithms), minimizing the inconsistency of human drivers [31].
- Changes in the design of vehicles (transition to electric power) (Output=energy efficient vehicles): If CAVs enable greater use of battery electric vehicles or hydrogen fuel cell vehicles, improvements in air quality could be significant. A reduction of the engine performance could lead to lower energy consumption and lower emissions [32].
- Optimisation of the transportation system, in particular platooning, (vehicles travelling close together at high speed), synchronised driving and optimised routing (Output=Reduced emissions and pollution due to smoother traffic flow): The platooning can be used to improve traffic

safety, optimize traffic flow, and reduce emissions, since vehicles can exchange data with each other and coordinate driving speed, braking characteristics and distances between vehicles. Thus, energy consumption could be reduced [33].

- Reduced need to search for parking space (Output=reduced energy consumption and pollution): CAVs can lead to a decrease in parking requirements. Fewer automobiles could free up some of the voluminous parking spaces that currently permeate cities. Public AVs could drop off passengers and either park in a satellite facility or go on to pick up other passengers. Such shared use could also reduce the
- Reduction of the number of vehicles (Output = Reduced emissions and pollution): CAVs have a potential to reduce the number of (private) automobiles, as well as to increase their occupancy, both achieved through digitally based sharing schemes. Connected and autonomous car sharing fleets with a high degree of flexibility could potentially reduce the number of vehicles on the road and reduce congestion [31].
- Reduced need for street lightning at night (Output=energy efficient infrastructures and less light pollution).

However, CAVs could also have negative impacts on the energy use and emissions [32]:

- Vehicle Miles Travelled (VMT) of CAVs could increase due to a combination of factors, and as a consequence lead to an increase in energy use and emissions. This could include an increase of use by people unable to drive and a number of trips (occupied and unoccupied); a shift away from public transport; additional VMT due to self-parking and self-fueling and longer commutes.
  CAVs can pick up their users, park, and carry out courier journeys autonomously. These additional journeys will occur regardless of whether they are private or shared CAVs.
  Time also plays an important role in choosing the mode of transport. When time during a trip with a CAV can be better or more efficiently used, users could consequently be willing to undertake more and longer trips. Such time rebound effects can be caused not only by better use of time but also by the more efficient flow of traffic. So, if an alternative mobility option becomes faster, users will accept longer journeys as the journey time will not place extra demands on their mobility time budget. However, this will lead to an increased travel demand and to more energy use.

- Shifts in mode choice: Shared CAVs are especially attractive for car owners, neglecting the fact that they could also unintendedly impact the mobility behavior of other, currently non-car, users. Some studies discuss possible mobility shifts away from eco-friendly mass transportation towards more comfortable shared CAVs offers.
  People could prefer convenient mobility on-demand services over previous alternatives such as walking, cycling, or public transport [33].
- Larger more luxurious vehicles or higher average speeds would also results in a higher energy use.

7 Conclusions and next steps

7.1 Overview of the findings

Developments in legislation, CAV technology and services are evolving rapidly. Developments are to a large extent driven by the opportunities new technologies provide, and not necessarily by the needs of individual users and/or society. However, CAVs will not drive in isolation: infrastructure, lay-out of roads and traffic management will need to change in order to arrive at a situation where CAVs become the dominant form of motorised mobility.

After having identified the different key areas, related issues and present approaches, it shows that there are discrepancies between their current situation and related needs to improve public awareness and user acceptance. Subsequently, some initial recommendations were drawn for each area wherewith public awareness and user's acceptance of CAV technologies and CCAM could be further improved. These will be followed up in the development of the 100 recommendations and guidelines that will be integrated in PAsCAL's Guide2Autonomy.

As we have seen there is a strong interaction between policies, the attributes of different technologies and services, and the needs of the users. User and societal needs may not drive technological development but full-scale deployment of CAVs and successful services will depend on public awareness and user acceptance. It was also seen that there might be conflicts between the needs of individual users and societal needs, and between the needs of different groups of users. Even needs of an individual user may be conflicting. The present set of key areas shows also that in that respect each PAsCAL recommendation and guidance needs to be carefully balanced.

7.2 Next steps

After identifying and specifying the key areas in four different thematic domains (i.e., Policies and regulatory framework; Design of new CAV technologies and infrastructure; CAV ICT developments; CCAM management and stimulation of local economy) the overall framework for the Guide2Autonomy and other dimensions can be set and finalised. The G2A will then be build. Once set up, the development of the PAsCAL recommendations and guidelines will start and integrated into to G2A..

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