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ARCADE

Aligning Research & Innovation for Connected and Automated Driving in Europe

D3.1: Technical thematic areas: challenges and scenarios

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Contents

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Executive Summary

ARCADE is to coordinate consensus-building across stakeholders for sound and harmonised deployment of Connected, Cooperative and Automated Driving (CAD) in Europe and beyond. The Thematic Areas (WP3) work on content creation leading to consensus-based positions, needs and scenarios. As defined in the Project Plan, this report is addressing the corresponding scenarios and challenges regarding the layer of “technology & vehicles”, in parallel with the reports on “systems & services” and on “users & society”.

Derived from the preceding project CARTRE, four scenarios were defined (0, A, B and C). Scenario 0 describes comprehensively short-term issues. Scenario A “Disruption through market-driven services” and B “Authority driven with focus on collective transport” are deeply looking into the development of shared mobility services and public transportation as well as policies and the role of transport authorities. Scenario C is comprehensively looking into privately owned automated vehicles.

The thematic areas of vehicles and technologies are defined in ARCADE to be:

- In-Vehicle Enablers (driving functionality, technologies like AI and V2x but also components, EE Architectures and safety and security concepts)
- Human Factors (studying human behaviour in relation to particular environments, products, behavioural models, interaction design and test procedures)
- Connectivity (between vehicles, with other vehicles and/or the infrastructure for automated driving in terms of safety, traffic efficiency and comfort)
- Deployment (bringing technology to users and society, facing the innovation lifecycle, fears and expectations)

After analyzing challenges and enablers in the different scenarios, key actions per area have been identified:

In-vehicle Enablers: Harmonize definition of operational domains and functionalities, develop technologies supporting vehicle’s own understanding of these domains, standardize perceptions systems, develop technologies for fail-operational architectures, robust and scalable perception systems as well as validation concepts and methods, research technologies to maintain system integrity and well-functioning once in the field.

Human Factors: Collect real-world experience, research integrated active and passive safety with new vehicle concepts and usage, feed and inspire controlled scoped studies, standardize internal and external user interfaces, define new roles and task of operators in remote control.

Connectivity: Define Day 2 and Day 3 C-ITS services and connectivity requirements for AD functions, promote hybrid connectivity solutions, create roadmap and policy framework, standardize security in V2X technologies, and establish safety integrity levels.

Deployment: Deploy L3 further incl. studies with users, enforce large simulation studies, support L3 pilots (field operational tests) and natural driving studies, and prepare large scale L4 piloting programs on highways and in urban environment.

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This deliverable together with the deliverables on “systems & services” as well as “users & society” is the baseline of the further ARCADE developments in year 2. The methodology of the project will provide the opportunity to iterate the discussions in all of the subjects treated in the present document as well as any new subjects that might evolve from future discussion.

The next steps, plan for ARCADE WP3 year 2, will focus on additional scenarios, approaches, impacts and proposed steps; two joint stakeholder network workshops; thematic input for the EUCAD symposium at TRA in April 2020 in Helsinki and consolidation of the year 2 input to the thematic areas and provide input to the knowledge base (WP4)

These steps will lead to three updated reports at the level of Society, Systems and Services and Technology and Vehicles (September 2020).

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1 Introduction

1.1 About ARCADE

ARCADE is an EC-funded Action that supports the commitment of the European Commission, European Member States and the industry (cf. the Amsterdam Declaration, GEAR 2030 final report, EC Communication on automated mobility[1], High-Level Structural Dialogue on connected and automated driving) to develop a common approach to development, testing, and validation of Cooperative and Automated Driving (CAD) in Europe and beyond.

The mission of ARCADE is to coordinate consensus-building across CAD stakeholders to develop this common approach. ARCADE involves 70 consortium and associated partners (to date) from 22 countries within and outside EU, who form the backbone of the Joint CAD Network of experts and stakeholders. This Network is composed of organisations from the public, industry and research sectors, stakeholder associations or individual experts, and was first established by the CARTRE Support Action (2016-2018).

In an annual cycle, ARCADE positions the Joint CAD Network (WP2) and Thematic Areas (WP3) centrally. The Network brings together the CAD stakeholder community at national, European and international levels while thematic areas work on content creation leading to consensus-based positions, needs and scenarios. The Knowledge Base (WP4) consolidates the CAD knowhow baseline and serves as a one-stop shop overview of CAD-related information. WP1 coordinates the project. These main activities are depicted in **Error! Reference source not found.**.

The main expected results of ARCADE are:

- Knowledge Base including CAD European, national and international R&I projects, roadmaps, regulations, standards and testing methodologies.
- Better understanding of challenges, enablers and research gaps on 12 thematic areas related to CAD and recommendations for next steps and actions.
- Exchanges and harmonisation of R&I approaches across EU, US, Japan and other countries outside Europe.
- Awareness raising and promotion of national, European and international CAD R&I activities and results.

ARCADE capitalizes on CARTRE legacy, including tools developed by the project such as the CAD website (https://connectedautomateddriving.eu), the work done in the thematic areas and of course, the Joint Stakeholder Network, which ARCADE will leverage and further grow.

[1] COM (2018) 283

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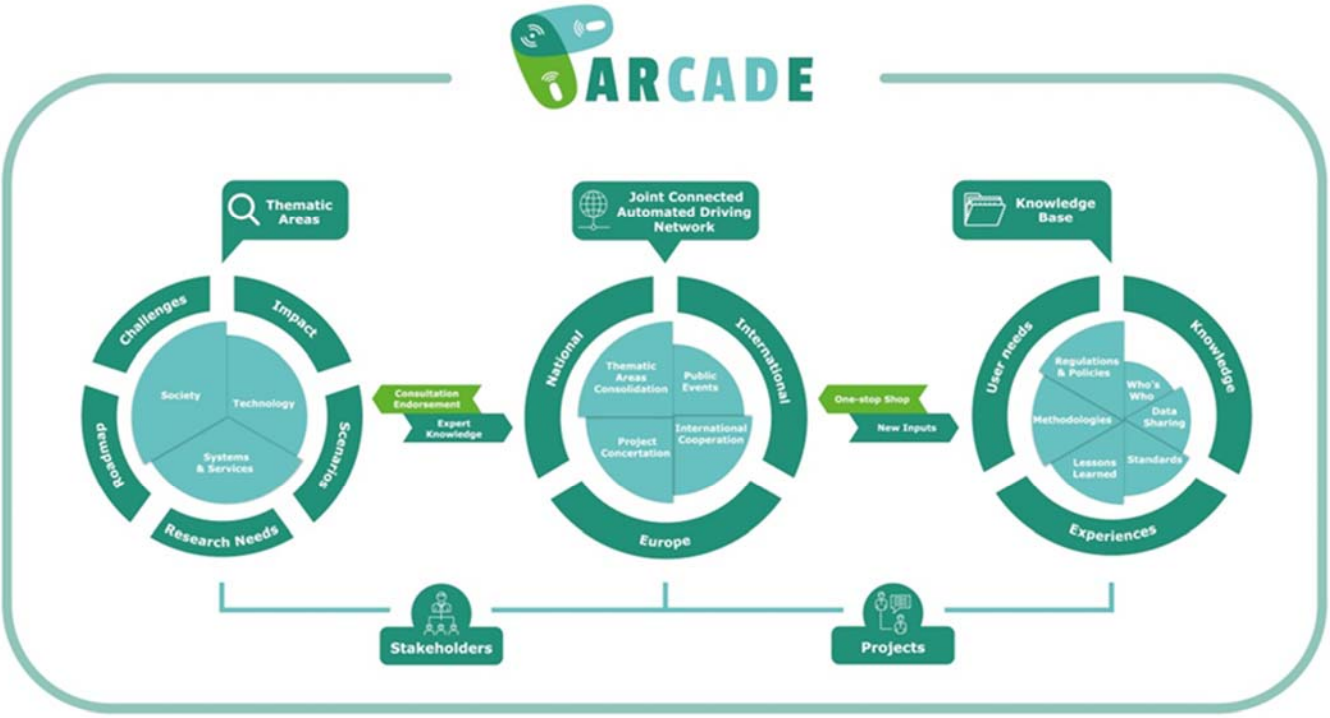

Figure 1: ARCADE main activities

1.2 Purpose of the document

Work package 3 deals with the thematic areas and has the goal to deliver the research content. At the end of year 1, ARCADE provides three reports in parallel, one by each task combining work from several thematic areas. The structure of all 3 reports is similar. The focus for year 1 is for all 3 tasks on challenges and scenarios: what is blocking fast and good introduction of CAD or may create a negative impact? What should be solved to create a positive impact? In what diverse ways could CAD evolve in the period up to 2035? Year 1 Deliverables are the first step with scenarios as a means to better reach the full bandwidth of research. It does not mean that the selected scenarios are a prognosis of the reality in the future, they only show the possibilities. This first version will be enhanced during Year 2 and 3 by additional aspects and updates to the current content.

This document addresses these challenges and scenarios for the layer of “technology & vehicles”.

1.3 Intended audience

The document is addressed to the European Commission to give a full picture on the research themes and their challenges. It is also addressed to the stakeholder community for detailed understanding of research needs including but not limited to STRIA, CCAM and ERTRAC.

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2 Description of scenarios

2.1 The CARTRE scenarios

The preceding project CARTRE[2] determined four alternative scenarios for making expert assessment of the socio-economic impacts of automated driving [reported in Rämä et al. 2018 on which this chapter is based]. Scenarios were plausible descriptions of the future; they can be seen as stories of different alternatives for what could happen and for what the transport system could look like. All the scenarios focused on transport of people (and less on freight). The CARTRE expert assessment work covered eight impact areas and multiple KPIs in all of them.

The CARTRE scenarios were not mutually exclusive but they helped to look at different impacts of CAD from different perspectives.

The short-term scenario (scenario 1) refers to the near future (not 'tomorrow'), up to around 2025. The long-term scenarios (scenario 2, 3 and 4) are still fairly close timewise – somewhere around 2035. Current technology paths cannot be extrapolated much further without creating large uncertainty. On the other hand, since the lifecycle of development and use of vehicles is quite long, it can be expected that vehicles that are developed today are partially still on the road in 2035. The average age is 11.1 years for cars and 12 years for heavy commercial vehicles[2] which can even reach to 15 years[3]. Annually, about 20% of cars is replaced by a new one[4].

In the short-term scenario (scenario 1), the focus was on gradual extrapolation of automated services with no radical changes to the current. The same automated vehicle technologies and their maturity was assumed in all the long-term scenarios. In addition to the time aspect and maturity of technology, the development of shared mobility services and the locus of control (role of public authorities) were identified as the main differentiating factors between the scenarios. Specifically, the first of the long-term scenarios described a transport system in which automation emerges parallel to shared mobility, and the fleets of automated vehicles are market operated. The second long-term scenario pictured a future in which shared automated transportation is authority driven. In the third long-term scenario, automated vehicles are mostly privately owned and shared mobility has not succeeded. A summary of the scenarios and their main differences is illustrated in Table 1.

[2] Rämä, P., Kuisma, S. (2018). Societal impacts of automated driving. CARTRE Deliverable D5.3

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Table 1 Summary of assessment scenarios (CARTRE)

	SHORT-TERM SCENARIO (~2025)	LONG-TERM SCENARIOS (~2035)		
	Scenario 1 *Gradual extrapolation of automated services*	**Scenario 2** *Market-operated fleets of shared automated vehicles*	**Scenario 3** *Authority-driven shared automated transportation*	**Scenario 4** *Proliferation of private automated vehicles*
Automated vehicle technology	Gradual introduction of automated functions	Mature SAE L4 automated vehicles, penetration >50% in mixed traffic		
Use of shared mobility services	High interest, early adopters use	High	High	Low
Locus of control	Cautious but enthusiastic public support for automated vehicles & mobility services	Private	Authority-driven, public-private collaboration	Private

For the scenario-based assessment of the socio-economic impacts CARTRE suggested that in the short term, the impacts of automated driving would be minor or moderate. In the assessment of the long-term scenarios, the two scenarios that included shared mobility showed the more benefits from automated driving compared to the scenario with private automated vehicles.

2.2 Selection of scenarios for ARCADE

In ARCADE, we use scenarios to explore the implications for the various thematic areas in the sense of challenges, enablers and actions to be taken. Therefore, a selection of the CARTE scenarios was made that would suit the exploration best. The selected scenarios are meant to explore the variety of developments. They are not recommended or desired scenarios, just possible scenarios. As scenario 1 was used for the short term within the previous project, and time has progressed, the team agreed to use it with less priority with one comprehensive chapter and named scenario 0. With regards to scenario 4: after many experts´ dialogues, it was found that with evolving technology the views on it have changed. It states that owning AV is affordable for most people, as a base thought. When researching scientific publications on AV sensors and computers, it is common sense that a full 360° coverage of all three sensor principles (Camera, Radar and Lidar) is needed for Level 4 with a corresponding on-board supercomputer for real-time raw data fusion. This means that cost per vehicle will stay extremely high for a long period of time. That is why in this deliverable it is assumed that scenario 4 is evaluated to be very optimistic. Furthermore, the working assumption is that the role and focus of the authorities is too narrow and not any more realistic in scenario 4. That is why this scenario is only looked at in one comprehensive chapter and named scenario C.

The remaining two scenarios are named scenario A and B and are described in more detail in this report. As Level 3 Highway Automation is expected to be rolled out (as announced by many OEMs) in the first half of the 2020s and according to the ERTRAC Roadmap, this deliverable focuses on Level 4. The same automated vehicle technologies and their maturity is assumed in both scenarios. In addition to the time aspect and maturity of technology, the

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development of shared mobility services, the availability of public transportation and the locus of control (which actor controls the development most) were identified as three main differentiating factors between the scenarios (Brenden & al 2017, Milakis & al 2017, POLIS 2018). The differentiation of scenarios is for showing the possible range of the consequences of how technology will be applied to society and how systems and services are controlled. For scenario A the focus is on vehicle sharing and ride hailing for persons and goods on a more privately and individually organized system. For scenario B, the focus is on ride sharing strongly linked with an overall traffic management and public transport.

Future AD technologies are going to be built on the existing partial automation and related experience. In long-term SAE L4, functions in use include highway autopilot, urban and suburban pilot, and automated shuttles and buses in mixed traffic. The freight vehicles path includes SAE L4 HAVs (Highly Automated Vehicles) on dedicated and open roads and highway pilot platooning. It is also assumed that light goods vehicles (vans) for deliveries and services have automated L4 functionalities. The occurrence of automation differs, however, depending on the area, ODD of functions, willingness to use, adoption rates, etc. In these scenarios, we assume that SAE L4 functions are broadly available and mostly mature. Traffic will have mixed levels of automation. In addition, shared ownership and high technology solutions for vehicles may speed up the rate of fleet renewal.

2.3 Scenario 0: Short term Gradual extrapolation of automated services

Following the gradual launch of new automated functions, new cars have at least optional SAE L2 automation functions such as traffic jam assist, lane keeping assist and parking assist in addition to the SAE L1 ACC and Stop & Go assist. For freight vehicles, cooperative-ACC truck platooning is commonplace. SAE L2 AD functions for cars and SAE L3 functions were launched some time ago and are now spreading out.

This implies for the Vehicles and Technology thematic areas:

Doing the big step from L2 to L3, vehicle technology is challenged by developing laser scanners to maturity and cost-efficiency, introducing higher levels of computing power as well as establishing standards for the vehicle localization based on sensors together with HD Maps and HD-GPS.

In Human Factors There are challenges regarding mode awareness and ease of use when vehicles are able to switch between Level 0-3 out of different reasons, requested by the system or the driver.

Connectivity will see enabling as new cars are equipped with cooperative systems to enable connectivity of vehicles and C-ITS. This means that more information about surrounding circumstances, incidents and traffic are conveyed to the drivers; introduction of eCall and C-ACC truck platooning (providing information on traffic downstream) are examples. However, as system penetrations are still small, automated functions cannot be built on the assumption of connectivity.

Deployment, especially when it comes to trucks will face the challenge that Truck platooning needs to show a cost-benefit advantage for the fleet operators. In the passenger car market, cost-down is necessary to deploy L3 in the mass market.

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2.4 Scenario A for 2035: Disruption through market-driven services

In the following, Scenario A is described regarding two aspects: the development of shared mobility services and public transportation as well as policies and the role of transport authorities.

2.4.1 Development of shared mobility services and public transportation

Shared mobility services have broken through and became mainstream. Shared mobility Services include ride sharing, vehicle sharing and ride hailing, possibly covering several mobility modes. They are reliable and convenient in most cases. Fleets of shared and automated vehicles are market operated. Operators are competing against each other for customers, and different levels of service are available. Premium subscribers gain access to better and faster services than basic subscribers. These privately-operated fleets of vehicles have partly replaced traditional public transportation, especially on short distance trips and in densely populated areas.

Shared mobility is mainly based on the provision of vehicles and services, giving less attention to multimodal travel and integration with public transport services are not really multimodal, as cooperation is not optimized, travel chains do not cover all modes well. New services and business models for public transportation are continuously being developed in parallel with private mobility services. An increase of driverless buses is reducing the costs of bus travel.

2.4.2 Policies and the role of transport authorities

Since market-operated fleets of shared and automated vehicles competes and complements traditional public transportation, road authorities aim to promote social equity by regulations and subsidies to ensure a minimum level of mobility services to all people. Transport authorities affect market-operated transportation through regulations and subsidies that clarify responsibility issues and encourage private operators towards lower emissions, increased road safety and intelligent use of urban space. Privately owned vehicles are not subject to a special policy.

2.5 Scenario B for 2035: Authority driven with focus on collective transport

In the following, Scenario B is described regarding two aspects: the development of shared mobility services and public transportation as well as policies and the role of transport authorities.

2.5.1 Development of shared mobility services and public transportation

In this scenario, there is a system of driverless vehicles providing demand-responsive public transportation for selected routes. There has been a proliferation of commercially explored automated public transportation systems (e.g. busses, shuttles, pods, delivery). The main private operators of public transportation have invested in creating these systems, which have been subsidized by the public sector. The main use of the systems is for access and egress of major public transport hubs and for lower-density areas. Most of the people have accepted and been used to sharing trips and vehicles. Travel chains are well functioning and intermodal.

2.5.2 Policies and the role of transport authorities

Shared and automated mobility is part of the integrated planning process, which is based on public-private collaboration. Transport authorities are proactive and, ensure social equity. They also keep strategic control of the transport network. Privately owned vehicles are being

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discouraged, both centrally and locally for example through road price charging and parking charges. Physical and digital infrastructure has been built in (part of) the strategic network.

2.6 Scenario C for 2035: Privately operated fleets and low governance

This scenario is focused on private ownership of a highly automated vehicles, similar to today's ownership situation. The cost of the vehicles will rise due to expensive sensor systems required for SAE L4 vehicles. In this scenario, , people do not want to use shared automated vehicles together with strangers and without a driver present. Thus, sharing remains marginal, not many systems have broken the barrier to being commercially explored by private companies, and public companies are not adopting them. Authorities have not been able to get public acceptance to govern the use of private automated vehicles, especially in urban areas. Policies focus on reducing emissions, managing urban space effectively, and increasing the safety of automated vehicles.

This implies in comparison to Scenario A and B for the Vehicles and Technology thematic areas:
As the application of technology doesn´t change, no different challenges and enablers can be identified for in-vehicle enablers and human factors. As fleet business will not evolve to a significant market share, connectivity requirements can be seen on a lower level and deployment will face less challenges.

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3 Scenario detailing for technical thematic areas

Scenarios A and B take into consideration the work that was carried out in ARCADE thus far with several stakeholder workshops. These stakeholder workshops aimed at identifying possible bottlenecks and challenges, and enablers related to different scenarios.

In order to have a thorough understanding of the scenarios described above from a technical point of view, the following ARCADE thematic areas gave input to this deliverable:

- **In-Vehicle Enablers** focus on the building blocks for all AD vehicles and applications: the driving functions from sensing to driving, environment models and driving strategies, technologies like AI and V2X but also localization, components such as sensors and actuators but also for communication, EE Architectures, safety and security concepts, monitoring and data recording concept, maintenance and technologies for updates in the field.

- **Human Factors** is the study of human behaviour in relation to particular environments, products, software, hardware as well as services and an important field for all introduction scenarios of different types of automated vehicles. Human Factors include among other things human behavioural models, harmonized interaction design and Human Factors related test procedures.

- **Connectivity** between vehicles with other vehicles and/or the infrastructure is considered as an important factor enhancing further the benefits of automated driving in terms of safety, traffic efficiency and comfort.

- **Deployment** is the crucial kick-off-phase of bringing technology to the users and the society, thus facing the innovation lifecycle, fears and expectations, but also the phase-in aspects to ensure a smooth transition from current mobility to the new mobility of Connected and Autonomous Vehicles.

One of ARCADE's main objectives is to further develop the work carried out in CARTRE relating to the thematic areas. In order to do so, a single approach was defined for WP3 and the three different thematic area groups: technology, systems and society related.

Important note for the understanding of the structure of this Deliverable:

Scenario A is used to describe all aspects of Vehicles and Technology, represented by the above mentioned four thematic areas. In order to avoid doubling parts, Scenario B only highlights the difference to Scenario A. No significant difference between the scenarios was found with regards to relations of ongoing activities outside of ARCADE. Therefore, the activities are described in chapter 3.2.3 for both scenarios.

3.1 Scenario A: Disruptions through market driven services

The impact of market-driven services could allow the mobility ecosystem to further develop in terms of technological advances. Various stakeholders competing against one another might attract users by providing them with a wide selection of services. On the other hand, having no concrete regulation in place could lead to a fragmented and vulnerable environment in which users' rights are overlooked.

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Scenario A predicts that there will be disruptions through market-driven services. For this reason, several bottlenecks and challenges were identified that touch upon the technical -related thematic areas. Consequently, enablers corresponding to the bottlenecks and challenges are proposed and analysed.

3.1.1 Bottlenecks and challenges

In-Vehicle Enablers

In Scenario A, the high demand for shared mobility services is leading to various concepts of automated vehicles (cars, shuttles, and buses) operated mostly in fleets. The high competition to operate these services and fleets in urban and non-urban areas leads to a very broad set of services, coming in various options available to end-customers. This represent various challenges for all technologies currently embedded in the vehicle to reach automation, which extends to new technologies like V2V, V2X that are needed to support the integration of single vehicle automation into fleet systems. Regarding bottlenecks and challenges of 'Physical and Digital Infrastructure', the reader should also refer to ARCADE Deliverable 3.4.

Driving functions: The high competition to operate fleets of automated driving passenger cars, shuttles or buses and mobility offer services in urban and non-urban areas leads to high requirements to the embedded systems enabling the driving functions. Driving functions will have to become as transparent as possible for passengers/drivers to maximize positive transit experience/free time. This affects the complete chain from sensors to actuators, from perception to actuation functions. Those driving functions are strongly depending on the Operational Design Domain (ODD) within which an operator will intend to run AD vehicles. Common understanding of those ODD and harmonization across European countries is still a challenge so far.

Sensors: Experience gathered from various European and national public funded projects shows that defining the most efficient sensor sets and sensing technology mix for automated driving applications is still a major challenge. Part of this challenge is for example due to: conflicting requirements between sensor sets for low speed, urban speed, high-speed applications; operation of sensors under harsh conditions, insufficient sensing resolutions, safe degradation concepts. There is no one standard solution. Standardization of sensor interfaces still needs to be consolidated to avoid having sensors describing the vehicle surrounding and the driver/passenger state in their own incompatible "dialects". Cybersecurity will become a major challenge also applicable to perception systems. Concepts will be needed to prevent data manipulation leading to taking wrong driving decisions due to corrupted understanding of a traffic scene.

Perception: Implementing and validating algorithms addressing the complexity of scene understanding remains one of the greatest challenges to overcome. Robust and reliable scene understanding under extreme conditions has been improving, but still there are major challenges, especially when one tries to extract knowledge about possible intentions of traffic participants to conclude on appropriate driving decisions. This complexity is even increasing when considering urban applications. This leads to a huge set of requirements applicable to a high number of perception systems variants needed to cover various applications. The speed and the robustness of perception algorithms have a direct impact on traveling experience: providing deep understanding of the environment surrounding the vehicle enables a more robust and faster driving decision-making and motion planning, which in turns enables a faster

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and robust transit for the passengers in the automated driving vehicle. European funded projects like AVENUE showed that robustness over this function chain is an important criterion for user acceptance. Systems taking inaccurate driving decisions or even stopping operation due to poor understanding of vehicle's environment are directly interacting with the user's transit experience. Advanced solutions involving intensive data fusion and computing of validated AI based algorithms are still to be deployed, tested and validated successfully. Higher robustness, reliability, but also safety computing power and validation are the main impacted requirement areas here. They are expected to strongly evolve in the next decade.

Decision making, planning: The diversity in traffic situations in the ODDs to be covered by CAVs running in fleets still needs to be clearly described and harmonized. This need is amplified by the evolution of ODDs due to sensor, perception and AI developments, and the differences of ODDs for vehicles from different OEMs. Beyond this standardization need, better modelling is required to provide more meaningful and valid domain information. The amount and level of information needed to describe a traffic situation efficiently with a reasonable amount of data is still research topic at the moment and developing those models with the help of a-priori knowhow and develop methods to update those models after detecting new situations are considered as a key challenge to make better Decision making and planning functions.

Actuation: Robust and cost-efficient motion control and redundant actuation systems are also required; they translate on the road all decisions made by the vehicle intelligence and will have to cope with the various automation levels.

AI/Machine learning: AI and Machine Learning are affecting the whole driving function chain, from sensors, sensing to scene understanding and decision-making. In spite of great capabilities of AI based algorithms, current methods to train and validate those algorithms have their limits. Due to those limits, effective usage of AI based algorithms in vehicle driving function chain is still rather limited to keep a safe and explainable system behaviour level. Validating that those algorithms work with needed accuracy and transparency is still an unsolved problem needing a lot of future research and cooperation between research and industry (see also ARCADE Deliverable 3.4, chapter 3, Big data and artificial intelligence).

Communication: Fleets of shared and automated vehicles will require high interactions between vehicles within the fleet itself, but also between fleets, and with other external systems operated by service providers, service users, and other instances. Secured and safe communication between systems embedded in a given vehicle and other instances is a key challenge. In complex driving situations, CAVs will typically need this communication to be able to cooperate in their driving and solve the complex situation, this most likely in multi-brand configurations with very high requirements towards information correctness and latency. In some situations, operators in remote control centres will most likely have to take control and send driving commands to automated vehicles, which leads to similar requirements regarding the technologies embedded in the vehicle to support such communications. Standardization of this communications will be required.

Localization, Maps: CAVs require precise localization systems and HD Maps. Precise, accurate and robust localization of ego vehicle and other traffic participants or objects is still challenging, as it includes data from cameras, radars and lidars as well as GNSS and HD maps. Also, reliable and precise localization of information received by connection to other

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traffic participants and the infrastructure is still very challenging. This is needed, however, to confirm which vehicle is communicating what from where and make an understandable link between the information and where in the ego vehicle's surrounding environment this information is relevant. Similarly, European funded projects like AVENUE showed that differences between road conditions in the field and on HD Maps quickly becomes challenging even for geofenced applications. Robust update and update validation mechanisms for Maps, definition and standardization of Maps layers, certification procedures for map contents are required to reduce the gap between Map content and real condition. Concerning (see also ARCADE Deliverable 3.4, chapter 3, Physical and Digital Infrastructure).

New functions: The competition between operators for customers and the trend to offer different levels of services; in addition to continuous extension of the ODDs, leads to an increase of additional new functions to be integrated within the vehicle. At a first glance, these functions are not directly involved in the driving of the vehicle itself, but they will be required to fulfil the sold services in the mobility packages. A big part of it will most likely be systems for interactions with users, vehicle customization according to passenger profile, entertainment. These functions will have to find their implementations in embedded systems in the vehicle.

EE Architectures: The amount of functions to be integrated in the vehicles in order to fulfil needed services will augment rapidly. The systems embedded in these vehicles will have to support this quantity and diversity. The efficient integration of increasing numbers of complex electronic control units in robust fail-operational EE architectures remains a key challenge. As automated technology advances and safety systems become more complex, more points of failure can develop. To reduce the odds of a failure becoming a problem redundancy concepts for sensing, actuation is required. Appropriate data bus communication system able to cope with amount of data exchange within vehicle will be required. Successful trade-off between embedded technology needed to reach functionality and overall computing power, power consumption, and overall costs will be a key bottleneck to solve for broad deployment.

Vehicle Use in field, Lifetime, Maintenance: Overall, CAVs will be used much more intensively than non-automated ones, leading to new lifetime requirements for vehicle parts and embedded systems. Fleets of CAVs also means users will not be the owner of the vehicle anymore and will potentially have little incentive to be involved in any ways in its maintenance. Evaluating the state of a vehicle in the field will become a key to provide a high-quality service. Advanced diagnostics and maintenance systems will be needed to evaluate current "health status" of the vehicles, to report information about the various components and functions embedded, but also about status of passenger's room. Those maintenance systems will trigger maintenance operations and be in permanent connection with the operator's fleet management system. Understanding events, incidents and accidents affecting the vehicle integrity, requires to be able to gather sufficient amount of the needed vehicle internal data to reconstruct the situation and analyse what happened, and decide what to do next. Doing this in robust manner is still very challenging. Standardization over stored and exchanged information is required. The amount of software embedded in the automated driving vehicles will increase dramatically, to avoid long timeouts for fleets vehicles due to maintenance, SW updates over the air will be required. Updating SW over the air, validating this update, across a pool of vehicles is a serious challenge only partly solved at the moment. Solutions to secure the communication of these update from provider up to vehicle, and security concepts to

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prevent or recognise hackers to use these maintenance principles are still technical challenges.

Development Process
The complexity of the technology is so immense that there is a risk that many different development approaches in industry and start-ups will result in extremely fragmented solutions whose security and applicability is difficult to control (see also ARCADE Deliverable 3.7, chapter 3, Safety validation and roadworthiness testing).

Human Factors

The role of the human is changed in scenario A from an active driver to a person who can sometimes be more considered a passive user or a remote controller of an automated vehicle. Human Factors therefore play a central role in the introduction of those new vehicles and sometimes related services. In scenario A, vehicles might not be owned by individuals, but shared. This means that users use a variety of vehicles from different providers and need to gain an appropriate understanding of the interfaces and functionalities when calling, dispatching, boarding, entering and using the vehicles. Thus, all challenges related to Human-Machine Interaction (HMI) alignment and standardization are of high priority. In addition, all comfort and safety related features of the AV play a central role in the interaction with on-board users.

For all vehicles, operating in more than one automation levels e.g. in different ODDs, driver state assessment technology and harmonized design strategies are needed to ensure proper engagement levels and safe transitions of control, especially when mode automation levels are introduced in the same vehicle. The design itself should clearly induce the engagement level needed by the driver depending on automation mode (e.g. by how lateral support feature is controlling the path). In order to ensure correct driver engagement, new driver state sensing might be needed (e.g. eye and head tracking, body position, driver and system torque differentiation, proximity sensors to pedals and steering wheel controls, intoxication).

The interaction design should be intuitive within the same vehicle as well as between brands and vehicle types and no excessive training or pre-drive instructions should ideally be needed for safe use. Training and information campaigns for users but also general public could be considered, e.g. for increased adoption and to avoid general misconceptions due to wrong expectations (see also ARCADE Deliverable 3.7, chapter 3, User awareness, societal acceptance and ethics, driver training). Interaction design indicating state, intention and action of the AV to other traffic participants (manually driven vehicles as well as VRUs) through vehicle movement profile and possibly additional output devices will be a challenge. It is important to take into account different vehicle types (e.g. multi-mode vs single-mode vehicles) as well as different ODD (e.g. urban vs. motorway scenarios, public road vs. confined areas) and how/if the interaction design might differ due to these factors.

Different user groups need to be taken into consideration for all Human Factors related research and development of AV as the user groups are extended to users that were excluded from personal mobility (children, elderly, disabled people). New seating configurations are suggested in many concept vehicles which introduce new challenges related to e.g. passive/integrated safety, motion sickness etc. Human adaptation e.g. loss of driving skill is a major challenge.

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When more automation is introduced in vehicles human factors challenges might be transferred from a driver inside the vehicle to remote operators in so called control tower settings as well as for people dispatching and summoning vehicles from a closer distance. The operator rooms need to be designed according to Human Factors principles to ensure safe operation. The job description for people working in logistics hubs have to be re-defined if they will be expected to take over manual control in certain situations. What information will be needed to create proper situational awareness and avoid increased workload etc.? The precise role description of remote operators needs to be defined as well as how to handle possible interaction with both an on-board system as well an on-board driver/passenger depending on vehicle type. Further, aspects of human expectation and needs on routing algorithms of the AV and willingness to pay (e.g. willingness to pay less if the AV takes a long detour) need to be explored and addressed. A definition on how and when to transfer control to the remote operator needs to be defined. Additionally, special minimal risk manoeuvres need to be defined since the interaction or remote driving will be for punctual use and only in specific cases.

Connectivity

Connectivity is generally considered as an important enabler to ensure fast introduction of CAD. It improves safety, efficiency and comfort in transport. Fleets of shared and automated vehicles will require high interactions between vehicles within the fleet itself, but also between fleets, and with other external systems operated by service providers, service users, and other instances. The main challenge is to ensure robustness and redundancy, availability of communication channels and quality of service (QoS) for the needs of AD. Performance and resilience of connectivity are important elements especially for safety critical applications.

Secured and safe communication between systems embedded in a given vehicle and other instances is here a key challenge. Therefore, the goal is to have tamper-proof connectivity, limiting cyber-attacks, while at the same time respecting the privacy of the end users. An important factor is trust among the different entities exchanging information, thus building a connected and trusted ecosystem.

In complex driving situations, CAVs will typically need this communication to be able to cooperate in their driving and solve the complex situation, this most likely in multi-brand configurations with very high requirements towards information correctness and latency. In some situations, operators in remote control centres will most likely have to take control and send driving commands to automated vehicles, which leads to similar requirements regarding the technologies embedded in the vehicle to support those communications. Thus, in connectivity another key aspect is to ensure interoperability between the different communication technologies (hybrid connectivity) as well as the usage of standardized Cooperative Intelligent Transport Systems (C-ITS) messages and message sets (e.g. for manoeuvres).

Deployment

Costs of the technologies, and thus of the vehicles is the biggest challenge for a quick deployment and could even mean that higher Levels of Automation could come to privately owned vehicles only in a small premium segment in the 2020 decade. The perception from road users, the potential fear to new technologies and to changes in the traditional driving

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system is also a key challenge to deployment. Training and education could be a big challenge in the case of professional drivers, somehow even more complex for private citizens.

For a successful deployment it is crucial that there is a standardized procedure for homologation independent of the respective OEM or supplier. In recent times, different approaches have been or are being developed in research activities and industry in order to come closer to the goal of a harmonized validation method for autonomous driving: The Whitepaper “Safety First for Automated Driving” and the so-called OICA “Multi Pillar Approach” as industrial input to a future UNECE Regulation (see Enablers to speed up process 3.1.2).

An additional challenge is the agreement among stakeholders on technological solutions to be deployed and regulated. Some solutions maybe proprietary (but need to be approved by regulation) some other need to be standard. This choice can severely delay the process. An example is cooperative ITS in EU and US, currently in standby (V2X vs C-V2X). Specifically, for connectivity, this challenge is big on both scenarios (A and B) because generally all vehicles need to communicate (not only the fleet) in order for V2X to give its full benefit. Generally, the impact of this factor depends on the CAD aspect considered. As a whole, in Scenario A different technological solutions could be applied to the different fleets (still, however, they need to be approved by the Public Authority); Scenario B the Public Authority may delay in the choice (having direct responsibility on the fleet).”

3.1.2 Enablers to speed up processes

In the following, enablers to speed up the process are described regarding In-Vehicle Enablers, Human Factors, Connectivity, and Deployment.

In-Vehicle Enablers

Possible enablers for the in-vehicle technical themes are described in the following section:

Driving functions

- Common understanding and definition of ODD and harmonization across European countries.

Sensors

- New sensor types and further development of sensor technologies (e.g. sensors with audio detection system, MEMs and solid-state lidars), failure tolerant systems, fail operational and degradation concepts, higher sensing resolutions, robustness increase against harsh conditions and at the same time cost optimized for targeted application complexity.
- Standardization of sensor interfaces to facilitate integration.
- Protection of sensors against hacking to provide non-corrupted information.
- Harmonization and standardization of sensor interfaces.

Perception

- Perception systems able to secure fast, robust and reliable scene understanding even under harsh conditions (for example correct road signs recognition in all locations under all conditions). Systems able to predict the behaviour of an object on the road based on its classification.
- Perception systems able to generate knowledge about what is happening within the vehicle, to generate understanding about the state of the passengers and the engagement level of the driver.

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- Cooperation between research, OEMs, TIERs to define common and appropriate validation methods, and especially expand the usage of simulation to cover some part of the validation of perception systems.

Decision-making, planning

- Robust domain models containing domain information that is more meaningful. Robust dynamic physical and behavioural models of objects in traffic scenarios, including à priori knowhow in those models, and developing methods to update those models after new situations.
- Extensive use of explainable AI, robust integration of non-traffic-rule-compliant traffic participants, robust methods to distinguish between real non-traffic-rule-compliant dangerous situations and situations where ego vehicle has to take a non-traffic-rule-compliant to solve a driving situation.
- Robust estimation of vehicle's own capabilities at a given time, and consideration of critical setups in this estimation like trucks with trailers.
- Robust understanding about the ODD in which the vehicle is currently evolving.

Motion control and Actuation (steering, braking, and accelerating)

- Fail operational actuation architectures, with affordable redundancy concepts support the various automation levels.

AI/Machine learning

- Harmonized training and validation concepts and methods for AI Based algorithms
- Advanced AI & data fusion control units.

Communication

- Robust, secure and safe Integration of information from infrastructure or from other vehicles into function chains (Perception, Decision making)
- Cybersecurity concepts, securing the integrity of all components of the vehicle
- V2V further development and standardization
- Definition and Standardization of remote driver roles and capabilities, security concepts for remote control.

Localization, Maps

- Precise, accurate and robust localization of ego vehicle and other traffic participants & objects. Reliable and precise localization of information received by V2V from other traffic participants. Robust integration of those low latency localization information into function chain (Perception, Decision making systems).
- Real time update of HD maps available, robust update and update validation mechanisms for Maps, definition and standardization of Maps layers (including GNSS, Galileo), certification procedures for maps contents.

EE Architectures

- Appropriate Data bus communication system able to cope with amount of data exchange within vehicle.
- Scalable, safe and fail-operational Architectures at realistic market costs.
- Robust software architecture standards to fulfil highest safety, availability and reliability, e.g. redundancy requirements.

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- Successful trade-off between embedded technologies needed to reach functionality and overall computing power and power consumption.
- Harmonization on the understanding of system redundancy required to fulfil functions within a given ODD.

Vehicle Use in field, Lifetime, Maintenance

- Successful transformation of the automotive sector into a software driven industry complexity, functional growth, continuous software online updates and cyber-security.
- SW updates over the air: Develop SW architectures and mechanisms to enable seamless SW updates in vehicle, Develop Methods for validation of those SW updates after market introduction.
- Speed up "time to market" for early market deployment of new solutions.
- Production and end-of-line tests, quality assurance tests and certification.
- After-market sector and after-market products and services, maintenance concepts, calibration, diagnostics, field-support, fleet monitoring.

Development Process

- Define Methods and tools for affordable and feasible validation. Define standards, methods and tools to share testing scenario for safety, for security, to support validation a function, component and vehicle level. Defined tailored approaches for validation and certification of a system within a geofenced area.
- Develop usage of virtualized testing and release, with simulation and vehicle in the loop to enable a shift of validation effort from in-vehicle to simulation. Develop standards and tools to support usage of simulation for validation (see also Deliverable 3.7, chapter 3, Safety validation and roadworthiness testing).

Currently, there are two complementary industry initiatives aimed at establishing standards for the validation and successful deployment of autonomous vehicles: The Whitepaper SaFAD to establish an industry standard and the OICA Multi Pillar Approach to establish a regulatory standard.

- **Whitepaper "Safety First for Automated Driving" (SaFAD):** In July 2019, 11 industry partners (Audi, BMW, Daimler, Fiat Chrysler, Volkswagen, tiered suppliers and key technology providers) have published a white paper entitled 'Safety First for Automated Driving' (can be downloaded on their homepages). The whitepaper covers all relevant safety methods for Level 3/4 SAE automated driving and introduces a traceability system, which extends from the primary goal – being safer than the average driver – right down to the individual safety objectives of the various components. The objective of this publication is to systematically break down safety principles into safety by design capabilities, elements and architectures. Furthermore, it summarizes the V&V methods in order to demonstrate the positive risk balance of automated driving solutions compared to the average human driving performance. With Level 3 and 4 automated driving systems still under development, this publication represents guidance for potential methods and considerations in the development and V&V as a precondition for deployment.

- **OICA Multi Pillar Approach:** The Multi Pillar Approach is an OICA (Industry) Certification Approach that is widely accepted in industry and distributes the tasks of Certification to different pillars. It is currently being supported by worldwide OEMs in the Geneva

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Regulation bodies. Its goal is to develop a standardized certification process for autonomous driving that has industry-wide validity. The approach is based on the assumption that the validation of autonomous driving is not partly possible but is based on different pillars: Audit and Assessment, Virtual testing, Physical certification tests, and Real-world test drives. Due to the high complexity of autonomous driving, use cases must be validated on all pillars to ensure that autonomous vehicles are considered safe and can be homologated.

Next to these two industry driven approaches there are several methodologies created by research projects. All approaches are following a scenario-based validation methodology with a scenario-based database as a core element.

Human Factors

Possible enablers for Human Factors are described in the following section:

- Increase standardization work towards safe, harmonized design strategies for drivers and passengers via in-vehicle input, output devices and actuators as well as with surrounding road users (VRU, people in adjacent vehicles, pick-up scenarios for driverless vehicles). Avoid detailed regulation with regard to specific design implementations to allow for constant improvements. Consider different design strategies depending on road type, vehicle type etc.
- Increase work on driver state assessment methods and technologies which can capture inattention due to drowsiness, boredom, intoxication as well as body position, proximity to driver controls (if any) etc. More extensive proof of feasibility in real world conditions as well as design solutions on what to do when e.g. a driver/passenger is unfit to take over control.
- Development of training and information campaigns for users but also public which can complement good, intuitive vehicle design instead of compensating for un-intuitive design solutions.
- Increase focus on passive safety aspects such as human body modelling for alternative body positions (e.g. rotatable and reclined seat).
- Increase inclusion of wider range of user groups (e.g. children, elderly, disabled people) especially when designing for mobility services.
- Increase research and development of remote-control concepts including definitions of requirements and limitations.

Connectivity

Communication technologies are evolving rapidly. This future evolution includes, but is not limited to, the emergence of 5G and higher networks (“Mission critical services”), evolution of ITS G5, hybrid connectivity (convergence). It is important for speeding up the uptake of connectivity in AD to integrate swiftly all available communication technologies which exist or will pop up, e.g. LTE-V2X/C-V2X, as well as cybersecurity and standardization progress:

- Robust, secure and safe Integration of information from infrastructure or from other vehicles into function chains (Perception, Decision making).
- Cybersecurity concepts, securing the integrity of all components of the vehicle.
- V2X further development and standardization.
- Definition and Standardization of remote driver roles and capabilities, security concepts for remote control.

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Another key aspect is the data exchange between the different stakeholders e.g. OEMs, NRAs, NAP, TMC, ITS Service Providers.

It is important to understand the role of connectivity: how to use connectivity? For which purpose? etc. in turn to ensure a certain level of performance for AD functions deploying connectivity. With today´s focus on Day 1-1.5 services it is not yet defined which services need to come next. There is no agreement on Day 2 or 3 as well as on hybrid use cases and the needs for connectivity. A step by step approach to define these future use cases will boost deployment.

A European solution with a European governance, both policy and market driven, is needed. There are technical, economic and legal frameworks that are necessary to make use of these connectivity technologies. Policy is needed for level playing field, but the market advances if there is competition.

The frequency band allocation for automated driving is another topic we need to tackle: For example, in Japan there is a 10MHz band reserved for automated driving.

Deployment

It is necessary to perform large-scale tests and pilots towards deployment of connected automation in all applications – passenger vehicles, heavy commercial freight vehicles and urban mobility vehicles – and in mixed traffic conditions for improved safety and efficient road transport. Lessons learned of deployment tests are shared, data exchange needed for this is possible, results flow back to standardization and regulations. For this reason, an enabler can be to establish a European multi-stakeholder platform to coordinate open road testing, pilots and deployment of connected automated mobility.

The alignment with the deployment of C-ITS in balance with 5G deployment is needed. Connectivity and cooperative systems are important enablers for a higher level of automation as well as the alignment with physical and digital infrastructure development. Indeed, technology penetration is key factor for cooperative systems, and a phase-in (i.e. early adoption) plan with expected benefits should be done and monitored, also considering all the other vehicles. Enabling services should be designed in order to demonstrate benefits to also with limited number of connected cars/fleets. Considering this, digital infrastructure plays a key role as enabler in early deployment, provided that it is interoperable (same standard), harmonized and efficient in cross-border scenarios.

Concerning new services business models need to clarify their data management and their integration with digital and physical infrastructure. There is the need of an aftermarket for needed parts and maintenance. Recalibration and delta-validation concepts are scaled to system complexity. The mapping of automated function to automation / cooperation levels has to be improved for passenger cars, trucks, buses and all applications.

Taking into account socio and regional differences within EU, technology should always work, 360° vehicle awareness is a must. It is important to change acceptance to adoption, which also implies explaining automation to the user, convincing him/her of the CAD benefits including the driver and/or user awareness of the level of automation and the expectations on when it is automated and when it is not.

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Showing and demonstrating the benefits to the public to ensure/reach adoption of CAD. Communication on how it works should be done at several levels, depending if the audience is the general public, professional drivers, etc. This could be done by experience, allowing a certain amount of people to try/test/drive the vehicles, then finding ways of multiplying this effect (since we cannot make every citizen to test/try the CAD). Ethics should be scientifically clarified on the base of concrete questions regarding the technology and their use cases and kept out of user tests.

The technology should be affordable, and integrated in non-premium vehicles, to be able to reach mass rollout and the higher benefit for society. Also, a system of incentives to include automated functions in all cars and then providing funding as well as promoting by regulation could support the rollout. Concerning the support/funding mechanisms, these should also take into account the new shared mobility services.

Furthermore, traffic management in urban environments could be an enabler (cities could be an easy deployment case, since they could improve traffic flow and reduce congestion).

Regarding the road infrastructure no big changes are expected for 2030 in the physical infrastructure. Rather, changes are expected in the digital infrastructure. HD mapping (multi-layered and progressive), with static features (geography and roads) and dynamic ones (traffic situation, vehicles, traffic management and regulation) are a clear prerequisite. Some of these layers will be available in the short-term, others will be gradually incorporated to the HD maps. For the adoption, the technologies will be gradually implemented with a first step, the so-called minimal viable product, which is the minimal service that will allow to enter the market with the technology. Possible starting points for introducing the CAD technologies and improving society adoptions are small ODDs (e.g. trucks for professional drivers, car sharing schemes relocating cars by night) (see also Deliverable 3.4, chapter 3, Physical and Digital Infrastructure).

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3.2 Scenario B: Authority driven with focus on collective transport (difference to Scenario A)

3.2.1 Bottlenecks and challenges

In-Vehicle Enablers

In scenario B, authorities play a stronger role in supporting the deployment of automated driving for collective transportation. This leads to a more focused roll out of automated driving technologies and applications and will lead to a different ecosystem, within which services provided by operators are somewhat more framed by authorities or road operators and less impacted by open market trends compared to scenario A. Public-private partnerships will operate those services, and will have stronger incentive to get comparable, standardised technical solutions. The grade of standardization for those technologies will be strongly driven by authorities. It could possibly reach higher levels earlier, if authorities request similar solutions e.g. for first/last mile, for interurban combined transport of people and goods. At the same time, those standards will be pushed potentially at various pace in various target countries, meaning that several standards will be relevant in parallel for solution providers (analogy with emission standards).

All challenges listed for Scenario A are still valid in Scenario B, but from in-vehicle enablers point of view, scenario B somewhat changes the main factors influencing the diversity of technical solutions to be covered by in-vehicle enablers and the market in which they are sold.

Driving functions, sensors, perception, decision making, planning, actuation: Authorities driving AD deployment with focus given to collective transportation and decision making (in a time interval) will be reflected in the requirements coming to sensors, perception, decision-making, planning and actuations. Collective transports are quite specific to a specific area, this could lead to new distribution of AD system variants.
On the other hand, there will be room for some leading solutions to establish themselves as benchmark. Those solutions are likely to be taken over by several cities. Defining the most efficient AD Setup, like sensor sets and sensing technology mix adapted to those automated driving applications will be even more critical to enable a quicker rollout into high volumes, if most of big cities request these solutions.

AI/Machine learning: Authority driven roll out means more attention will be paid on regulations applicable for the release of AD Systems. This may increase and request earlier application of adequate validation methods which are still not available for AI based algorithms. The harmonisation of AI-based technologies is easier in this scenario and comes along naturally (see also Deliverable 3.4, chapter 3, Big data and artificial intelligence).

Communication: A higher focus on collective transportation means AD vehicles will have to be not only connected to their fleets or other brand's fleets, they will have to be more interconnected with the rest of the transportation system. That could be a new challenge, being felt in the form of a difficult integration of the new information to be understood by the AD vehicles which in this case will be generated by new stakeholders outside of automotive industry (see also Deliverable 3.4, chapter 3, Physical and Digital Infrastructure).

Localization, Maps: Emphasis on collective transportation is likely to induce a large set of different AD systems interacting with other transportation system using common maps and relying on precise localization so that intermodal transportation remains possible. Challenges listed in Scenario A remain valid (see also Deliverable 3.4, chapter 3, Physical and Digital Infrastructure).

EE Architectures: Emphasis on collective transportation will have to be reflected in EE architectures selected for AD vehicles. Vehicles will be shaped to fit with required capacities and take the form of shuttles or buses. Number of passengers per vehicle will be higher. Maximum speed applicable to run those vehicles will follow those defined in urban centres. Those factors will all influence the emerging of efficient EE Architectures.

Vehicle Use in field, Lifetime, Maintenance: In this scenario AD Vehicles will be used somewhat differently compared to scenario A but the challenges listed in scenario A remain valid

Human Factors

The challenges do not differ from scenario A, priorities in rollout may be different, but this aspect is out of scope of the current document.

Connectivity

When a dominant public transport relies very much on connectivity technologies, also in terms of safety, privacy and security, robustness and redundancy in connectivity are even more important.

In the same sense, interoperability and compatibility of the solutions between the different actors is more important in this scenario.

In addition, the requirements of remote operation will be much more dominant and most likely the defining factor for quality of service, bandwidth etc. of all connectivity technologies.

Geographical limitations of the network could also be a defining factor for cities and their possible automation zones / shared spaces.

The necessary increase of the level of control for this scenario is a big challenge for the operations led by authorities.

Deployment

The pressure on costs of technologies and vehicles will be much higher and a main cost per service factor. Level 4 automation in this scenario could come to these different sizes of road transport units with a faster rollout und higher volumes.

The perception from road users, the potential fear to new technologies and to changes in the traditional driving system is an even bigger challenge to deployment, but in this scenario a common task of authorities, developers, producers and service providers. Development and operations could be organized similar to today´s big tech companies.

A new big challenge will be for authorities and service providers to sort out between necessary standardization for cost reduction and speed vs. individual framework of the specific county and city.

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3.2.2 Enablers to speed up processes

In-vehicle enablers

In addition to the enablers listed for scenario A, stronger consolidation of standardization activities at EU level is a key enabler.

Human Factors

The enablers are the same as for Scenario A.

Connectivity

The enablers mentioned in 3.1.2 are also valid here. Emphasis is on facilitating the data exchange and close collaboration among the different stakeholders, since we are dealing with wider and more holistic implementations of AD supplementing existing Public Transport (PT) services.

Deployment

In this scenario it is even more crucial to team up between all stakeholders and have a good common understanding between industry, road operators, communication providers and authorities about the way to bring driverless vehicles in cities to reality. Most important is a stepwise approach in two dimensions:

For the driving task (safety approach of European industry) the steps should be:

1. development engineer (vehicle under development)
2. highly educated safety driver (vehicle in user test)
3. onboard operator (vehicle inherent safe)
4. teleoperator (vehicle fully usable)

For the use cases (to be seen as an example, many variations possible) the steps should be:

1. not in mixed traffic
2. reduced application in test area in mixed traffic (e.g. parking facilities, trucks in confined areas, buses when approaching and leaving a station, small urban test areas)
3. full application in test area (larger urban surrounding)
4. full application in mixed traffic

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3.3 Relations to ongoing activities outside of ARCADE

The following section lists relevant projects that are related to CAD, in particular to the Technologies & Vehicles layer of thematic areas. For each, relevant challenges that are currently being worked on in the projects are outlined (see connectedautomateddriving.eu).

5G-Mobix:

- The “roaming” situation in case of 5G is blocking seamless connectivity.
- Data must be able to cross the border, which is an issue of MS authorities and telecom providers.
- Proper requirements on 5G addressing specific use cases are key challenges.

ADAS&ME:

- Understand the driver on board of the AV, driver state, technologies for robust driver state detections.
- Adapt the HMI and automation levels to driver states for all AD applications and user groups.
- Mix of simulators and vehicles, range anxiety.

AUTO C-ITS:

- Security and safety concept for error free communication are challenging.

AutoMate:

- Understand the driver on board of the AV, driver states monitoring camera.
- Cooperative driving, extensive usage of i2x during driver take-over in addition to sensor-based detection.
- Role of driver and human factors: driver input for the automation that is stuck - approval/confirmation need by driver.
- Growing over confidence of drivers in the automation systems abilities to handle critical situations.

AUTOPILOT:

- Processing of the data to unleash functions, in vehicle or / and in cloud.
- Specification of middleware, definition of standards for data and device management for connectivity are important challenges.

AVENUE:

- Vehicle operating speed having high influence on Sensor set, different sensor set for low speed vs sensor for high speed
- Slow and not robust enough perception systems leading to interrupts of vehicle operation, leading to poor travel experience perceived by user. Defining Fast and robust perceptions systems is still challenging
- Achieving correct road signs recognition in all locations under all condition is still challenging, especially under bad conditions even at low speed.

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- Gaps between Road conditions readable from Maps and real road conditions remains a challenge even for geofenced application. This challenge is very acute in case of bad weather conditions.
- Validate and pass certification for all possible routes within a targeted area is challenging for geofenced applications. Re-Validation and Re-certification needed every time new routes are opened for operations.

Dreams4Cars:

- Robust Dynamic / Physical / Behaviour models of objects and traffic participants within a traffic scene are not available. Integration of à priori knowhow in those models is a challenge. Without those models, robust scene understanding, and decision-making remains very challenging.

Ensemble:

- Robust estimation of vehicle's own capabilities at a given time even more critical vehicle setups like trucks or vehicle with trailers is challenging. Accessing to such information is critical for platooning applications.
- Confirmation which traffic participant provided which information at which time and where exactly in the ego vehicle environment is still very challenging.
- Adequate sensor set for trucks, pedestrian recognition.
- Truck Platooning Human Factors for truck drivers.

ICT4CART:

- Hybrid connectivity (not only in terms of HW) is a major challenge.
- How the handover which information (in case they are contradictory) in reliable and secured manner so that a driving or other decision can be safely taken is a significant challenge.

interACT:

- Communication with the onboard user and the surrounding traffic participants.
- Recognition, consideration of AD vehicles' behaviour. AV have to behave in a human way, but human drivers may adopt non-traffic-rules-compliant driving in some situations. How to identify and handle those cases. What will be the acceptable compromise between what is technical possible, liability issue, user needs?

L3Pilot:

- A big challenge is the cost related to the deployed technology. We need to keep the cost low, and this is challenging to ensure reliable performance.

MAVEN:

- V2X message sets for future traffic management are not yet defined.
- how to manage a platoon to cross an intersection efficiently (creating, dissolving the platoons).
- Connection to the TMC needs further work.

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SimuSafe:

- Analysis and modelling of Road Users' behaviour.
- Study of usability of simulators to study human factors and behaviour.
- Includes study and simulators for Cars, Powered Two-wheelers, Bicycles, and Pedestrians.

TransAID:

- How to keep automation level high without many handovers;
- merging with mixed traffic and how to solve the coordination between connected and non-connected vehicles are important challenges;

VI-DAS:

- Driver state measuring using non-invasive sensing
- Fusion of interior and exterior situation (driving scene and the driver) to manage the hand over and hand backs when changing automation levels or ODD
- Proposed VCD format to describe in a standard form the surrounding of the go-vehicle and build easily the local dynamic map
- Training and validation AI algorithms and AD functionalities mixing simulation and real scenarios

Virtual Vehicle:

- The amount and the level of information needed to describe an ODD efficiently with a reasonable amount of data is still very challenging and a research topic. Without those models, it is difficult to have a robust training and validation of AD functions.
- Usage of virtualized testing and validation as part of the product release is still challenging. Broad, robust and efficient usage of simulation for validation, as well as standards and tools to support virtualized release and reduce validation efforts at vehicle level is still challenging.

The smart cities initiatives by governments in EU are also providing incentives to the people to share rides while commuting. For instance:

- The Smart City Wien project: the Vienna city is developing e-mobility on demand to integrate the transportation system with the e-car sharing model effectively.

To succeed, smart cities must securely integrate data from all participants (local government, citizens and industry) designing a collaborative transport system where everyone is a passenger.

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EU Projects

Name of project	Duration	Website
5G-MOBIX	November 2018 – October 2021	https://www.5g-mobix.com/
ADAS & me	September 2016 – February 2020	http://www.adasandme.com/
AUTO C-ITS	November 2016 – December 2018	https://www.autocits.eu/
AutoMate	September 2016 – August 2019	http://www.automate-project.eu
AUTOPILOT	January 2017 – December 2019	https://autopilot-project.eu/
AVENUE	May 2018 – April 2022	https://h2020-avenue.eu
Dreams4Cars		https://www.dreams4cars.eu/en
ENSEMBLE	June 2018 – May 2021	https://platooningensemble.eu/
ICT4CART	September 2018 – August 2021	https://www.ict4cart.eu
InterACT	May 2017 – April 2020	https://www.interact-roadautomation.eu/
L3Pilot	September 2017 –August 2021	https://www.l3pilot.eu/
MAVEN	September 2016 –August 2019	http://www.maven-its.eu
SimuSafe	June 2017 – November 2022	http://www.simusafe.eu
TransAID	September 2017 – August 2020	http://www.transaid.eu/
VI-DAS	September 2016 – August 2019	http://www.vi-das.eu/

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3.4 Actions to be taken

Actions have been identified in all thematic areas, with the relevant stakeholders and the level of priority. The actions have been derived for all 4 scenarios.

In-vehicle enablers

- Short-term actions from Scenario 0: Application research is needed for a European sensor program for quicker maturity and cost-efficiency, including standards for urban HD Maps and HD-GPS.
- Harmonize definition of ODDs and functionalities needed for given ODDs at EU Level through coordination projects.
- Research Action to develop technologies supporting vehicles' own understanding of ODDs (incl. maps, localization), with the target to develop concepts enable cooperation between AD vehicles.
- Coordination action focusing on the standardizations needed for perceptions systems, for example via the coordination of the standards further developments proposals resulting from EU project activities (interfaces, validations, simulation).
- Research Action to develop technologies and harmonization needed for fail-operational architectures (costs, energy, and redundancy).
- Research actions to develop further, robust and scalable perception systems, sensor sets and new sensor technologies.
- Research actions to develop concepts and methods for the validation of perception systems, sensor sets and new sensor technologies, including methods covering AI specific validation challenges.
- Research Action focusing on technologies and standards needed to maintain system integrity and well-functioning once in the field, monitor for updates.

Human Factors

- Short-term actions from Scenario 0: Continuation of standardization and application research projects necessary regarding mode awareness and ease of use.
- Collect real-world experience (pilots, FOTs) to validate research findings.
- New basic research is needed on integrated active and passive safety with new vehicle concepts and usage.
- Feed and inspire controlled scoped studies with input from open world studies.
- Standardization concerning Human Factors (also external UI).
- Definition of new roles and task of operators in remote control.

Connectivity

- Short-term actions from Scenario 0: Technology-neutral connectivity rollout support needed for quick safety and traffic flow improvements by first features, their effectiveness depending on broad rollout in the field.
- Definition of Day 2 and Day 3 C-ITS services.
- Definition of connectivity requirements for AD functions (performance, QoS, resilience, etc.).
- Promotion of hybrid connectivity solutions ensuring interoperability.
- Creation of a European Roadmap and a policy framework for connectivity.
- Standardization and enhancement trust and security in V2X technologies.
- Establishment of safety integrity levels to allow balanced decision making.

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Deployment

- Short-term actions from Scenario 0: Early standardization efforts to support an accelerating development of lower (L2 and L3) automation features, especially for trucks needed.
- For L3 piloting, studies with customers are essential for deployment. Legally, only professional drivers are allowed at the moment.
- Enforcement of large simulation studies to complement pilots for a quicker technological development. Real-world test parameters are the basis for this.
- Support L3 Field operational tests and natural driving studies after piloting.
- Prepare large scale L4 piloting programs on highways and in urban environment.

3.5 Key Actions, Prime actors and Priorities

In the table below, priority actions from the previous section are summarized with the prime actor involved.

Key Actions	Prime actor	Priority
Harmonize definition of ODDs and functionalities needed for given ODDs (Specific use-case priorities)	EU, Standardization, Research, Industry	High
Define, develop, and validate robust and scalable perception systems and sensor sets, including infrastructure-based perception	Research, Industry, Infrastructure operators, Standardization	High
Develop and harmonize concepts supporting vehicle ‘s own understanding of ODDs and cooperation between AD vehicles (including; maps, localization etc.)	Research, Industry, Standardization	High
Define and harmonize concepts to maintain system integrity and well-functioning once in the field, monitor for updates	EU, Standardization, Research, Industry	high
Reach efficient integration of overall system in fail-operational architectures (costs, energy, redundancy)	Research, Industry	medium
Define and harmonize integrated safety concepts (passive, active, seating positions, crash impact, etc.)	EU, Standardization, Research, Industry	high
Reach efficient and safe interactions with external road users (mixed traffic)	EU, Standardization, Research, Operators	high
Harmonize the role of remote operators (sustain attention, control environments, etc.)	EU, Standardization, Research, Industry, Operators	medium
Develop use cases to increase inclusion of wider range of user	EU, Research, Industry	medium

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groups (e.g. children, elderly, disabled people) especially when designing for mobility services		
Development of training and information campaigns for users but also public	EU, Research, Industry	medium
Define and harmonize connectivity requirements for AD functions (performance, Quality of Service, resilience, etc.)	EU, Standardization, Research, Industry, Operators	high
Define and harmonize specification of Day 2 and Day 3 C-ITS services	EU, Standardization, Research, Industry, Operators	high
Support the standardisation and further deployment of V2X technologies locally and at European level	EU, States, Standardization, Research, Industry, Operators	high
Develop and harmonize concepts to reach (Cyber)secure and safe communications respecting privacy and various levels of trust	EU, Standardization, Research, Industry, Operators	high
Pilot and demonstrate interoperability of communication technologies / Hybrid connectivity solutions	EU, States, Standardization, Research, Industry, Operators	medium
Set up living labs to support tests and demonstration of systems and mobility concepts by including end users earlier	EU, Authorities, Operators, Industry	High
Enable L4 Pilots including cross-border applications	EU, Authorities, Operators, Industry	high
Enable L3 FOT, field operational tests including cross-border applications	EU, Authorities, Operators, Industry	high
Promote deployment through simulations of deployment scenarios, road transport & traffic management	EU, Authorities, Research, Operators, Industry	medium
Define a framework allowing customer pilots with non-homologated vehicles	EU, Authorities, Operators, Industry	medium
Develop user-oriented mobility concepts supporting society inclusion and enhancing mobility of elderly, disabled and children through real-world studies, field operational trials and naturalistic studies	EU, Research, Authorities	medium

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4 Conclusion and recommendations

Looking at research and innovation, technologies will come to the market as soon as they are mature enough to fulfil customer needs and will be applied to vehicles connected to the cloud and used. That is why the consequences of the scenarios do not differ strongly in D3.1 (Technologies & Vehicles), but with growing understanding of the capabilities of vehicles with such technology systems will be able to be defined clearer and clearer and new services will lead to new businesses around them and for the sake of their providers. This leads to slight differentiation of the scenarios in D3.4 (Systems & Services), without leading to different actions. Depending on how these systems and services are controlled and rolled out, there is clear differentiation for the individual user and his or her needs of comfort and time efficiency as well as for the society and its needs for safety and environmental efficiency in D3.7 (Society).

The priorities and actions resulting cover both specific and generic needs (see section **Error! Reference source not found.**). The recommendation to align stakeholders on common methodologies, vocabulary, data format, use case descriptions, and architectures is common to all areas, as well as the need for large-scale testing. The link with existing initiatives and EU projects has been made. It is also recommended to foster the integration of national projects and that the consolidation of results should be made through the knowledge base (WP4).

This is the result of the joint work in WP3 through the succession of sprints and workshops organized during the first year and consolidated during the September 1-3 2019 workshop. The results have been integrated in the ARCADE consolidated roadmap 2019 (D2.1).

This document will be updated annually and enriched with the results of ARCADE year 2 and 3 research. It delivers the analysis of the main challenges, enablers and actions required within different scenarios investigated during the year 1 of ARCADE.

Addressing the challenges highlighted by the technical-related thematic areas will have a considerable impact on the deployment of CAD.

In-Vehicle Enablers consist of sensing, environment models and driving strategies, technologies like AI and V2x but also localization, components like sensors and actuators but also communication, EE Architectures, safety and security concepts, monitoring and data recording concept, maintenance and technologies for updates in the field. With a harmonisation of operational domains and functionalities, all the possible user functions for passenger cars, trucks and urban mobility can be developed be using the same technological basics as fail-operational architectures, perception systems as well as validation concepts and methods. With a fast and short-term action on a European sensor research program including standards for urban HD Maps and HD-GPS including interfaces, validation and simulation on the one side and looking much more into European software skills and workforce, the main areas of competition with overseas technologies can be tackled now.

Human Factors study human behaviour in relation to environments, products, software, hardware as well as services. It is an important field for all introduction scenarios of different types of automated vehicles. It includes human behavioural models, harmonized interaction design and Human Factors related test procedures. Continuing standardization and application research regarding mode awareness and ease of use and validating these findings in real-world experience (pilots, FOTs), is key for a quick rollout of first automation functions.

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New basic research is needed on integrated active and passive safety with new vehicle concepts and usage, also being underlined with input from open world studies. Also, the completely new area of remote-control operation needs to be researched be defining these new roles and tasks in the traffic system.

Connectivity between vehicles, with other vehicles and/or the infrastructure is considered as an important factor enhancing further the benefits of automated driving in terms of safety, traffic efficiency and comfort. With Day 2 and Day 3 C-ITS services and connectivity requirements hybrid connectivity solutions should be promoted by creating a roadmap and policy framework. Technology-neutral connectivity rollout support is needed for quick safety and traffic flow improvements. Then standardization is key to enhance trust in V2X technologies.

Deployment is the crucial kick-off-phase of bringing technology to the users and the society to ensure a smooth transition from current mobility to the new mobility of CAVs. Early standardization efforts should support an accelerating development of lower (L2 and L3) automation features, especially for trucks. Also, large simulation studies to complement pilots for a quicker technological development need to be started short-term. After piloting L3, field operational tests and natural driving studies are needed to establish the state of the art and support broad rollout. Then, also for L4 large scale, piloting programs on highways and in urban environment should be established.

4.1.1 Recommendations

The recommendations for further actions are listed in **Error! Reference source not found. Error! Reference source not found.** and **Error! Reference source not found. Error! Reference source not found.**.

4.1.2 Next steps

The next steps, plan for ARCADE WP3 year 2, will focus on the following activities;

- Organise the thematic work for year 2 in 4 sprints, focussing on additional scenarios, approaches, impacts and proposed steps (T3.1)
- Perform 2 joint stakeholder networks workshops with WP2 to further consolidate, elaborate, develop and rank the key priorities as identified in the D2.1. This is planned for February and Spring 2020 (Task 2.3)
- Define additional scenarios, approaches, impacts and proposed steps for the thematic areas (T3.2, T3.3, T3.4)
- Provide thematic input for the EUCAD symposium at TRA in April 2020 in Helsinki and partially lead the sessions (WP3).
- Consolidate the year 2 thematic areas and provide input to the knowledge base (WP4)

These steps will lead to three updated reports at the level of Society, Systems and Services and Technology and Vehicles (September 2020).

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Overview of ARCADE Deliverables Year 1:

Deliverable	Topic
D3.1	Technical thematic areas: challenges and scenarios
D3.4	Systems & Services thematic areas: challenges and scenarios
D3.7	Society thematic areas: challenges and scenarios

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6 Glossary: Acronyms and definitions

Term	Description
AD	Automated Driving
AI	Artificial Intelligence
ARCADE	EU H2020-DT-ART-2018-2019/H2020 CSA project Aligning Research & Innovation for Connected and Automated Driving in Europe, GA number 824251
ART	Automated Road Transport
AV	Automated Vehicle
CARTRE	EU H2020 ART06 CSA project Coordination of Automated Road Transport Deployment for Europe, GA number 724086
CAD	Connected Automated Driving
CAV	Connected Automated Vehicle
C-ITS	Cooperative Intelligent Transport Systems
C-V2X	Cellular Vehicle-to-Everything
ERTRAC	European Road Transport Research Advisory Council
FOT	Field Operational Test
GNSS	Global Navigation Satellite System
HAV	Highly Automated Vehicles
HMI	Human-Machine Interface
HW	Hardware
ITS	Intelligent Transportation System
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
OICA	International Organisation of Motor Vehicle Manufacturers
QoS	Quality of Service
LIDAR	Light Detection and Ranging
MEMS	Micro-Electro-Mechanical System
SAE	Society of Automotive Engineers
SaFAD	Safety First for Automated Driving
TA	Thematic Area
TMC	Traffic Message Channel
V2X	Vehicle-to-Everything
V2V	Vehicle-to-Vehicle
V&V	Verification and Validation
VCD	Value Change Dump
VRU	Vulnerable Road user
VI-DAS	EU H2020 MG3.6-2015 RIA, GA number 690772

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