



PUBLIC SUPPORT MEASURES FOR CONNECTED AND AUTOMATED DRIVING

Final Report

Tender No. GROW-SME-15-C-N102
within the Framework contract No. ENTR/300/PP/2013/FC

Written by SPI, VTT and ECORYS
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Acronym Glossary

AV	Automated Vehicles
C&AD	Connected and Automated Driving
C&AV	Connected and Automated Vehicles
CEF	Connecting Europe Facility
C-ITS	Cooperative Intelligent Transport Systems
EC	European Commission
H2020	Horizon 2020
ICT	Information and Communication Technology
IOT	Internet of Things
IPCEI	Important Project of Common European Interest
ITS	Intelligent Transport Systems
OEM	Original Equipment Manufacturer
TRL	Technology Readiness Level
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-everything
VRU	Vulnerable road users

Executive Summary

This document is the Final Report of the study on “Public Support Measures for Connected and Automated Driving” developed within the Framework contract no. ENTR/300/PP/2013/FC.

Studies have emphasised that the market size for Connected and Automated Driving (C&AD) is increasing, with revenue estimates from autonomous driving, connected services, and safety measures reaching €147 billion by 2022. It is clear that C&AD has a significant market potential in the near future.

The countries involved in this study include EU Member States, specifically France, Germany, Italy, Spain, Sweden and the United Kingdom. Outside of Europe, the study includes the USA, Japan, South Korea and China.

This study analyses the strategies, funding programmes, standards, regulations and value chains for C&AD in the selected countries. It aims to review and analyse C&AD technologies and to assess the effectiveness of existing EU support measures for the sector. Furthermore, the study provides a clearer picture of the EU’s current position compared to its third country counterparts in the C&AD sector.

The study was conducted through three major tasks: (1) Comparative analysis of public support measures, programmes and regulations put in place in the USA, Japan, South Korea, China and the EU; (2) Comparative assessment of technological and commercialisation readiness level of automated and connected driving in USA, Japan, South Korea, China and the EU; and (3) Assessment of the existence of a global level playing field and of the effectiveness of instruments available for supporting the development of C&AD.

Key findings

Several key findings were identified which are categorised under the following nine topics.

- 1. General strategies for promoting C&AD.** Several EU Member States have implemented regulatory initiatives, mainly focusing on the rules and conditions for testing C&AV on national roads. This is linked to a strong concern in ensuring strict legal conditions during vehicle testing and to guarantee the safety of drivers, passengers and pedestrians. However, and while efforts are being made in this direction, there currently lacks a more comprehensive strategic policy framework for the development of C&AD in the EU (which would allow a clearer definition of long-term goals, priorities and actions). Many EU countries have to make strategic choices in terms of public investment to comply with EU-defined budget rules. Thus, their investment capacity in the C&AD sector is limited. This limits the country’s own competitiveness and parity to other countries in the sector and the EU’s competitiveness compared to other leading players. However, the EU is determined to gain position, and has shown pro-activeness in developing a strategically comprehensive framework for the sector.
- 2. Major research and large scale industrial programmes/ projects co-financed with public funds from 2011-2016.** The EU as a whole and individual Member States have established relevant R&D programmes (e.g. Automated Road Transport topic under Europe’s Horizon 2020 programme) to support C&AD research activities or similar. These national and EU programmes could foster increased synergies and contribute to a reduction of the current fragmentation and duplication levels. Existing projects and programmes often include both public and private funds. Therefore, considering the important resources needed to promote the development of C&AD in the EU, there is a need to further reinforce the leveraging effect of public financial support to implement projects. Recently, EU-funds allocated to research on vehicles/mobility/C&AD (through, e.g. Horizon 2020, Work Programme 2016-2017) represented €200 million. The EU is on the path of developing a common political understanding and relevant actions. The Declaration of Amsterdam envisions advances in the development of C&AD in the EU, representing the political will of EU leaders in achieving C&AV. Thus, it is expected that additional funding dedicated to C&AD programmes/ projects will be available in the future.
- 3. New regulations or standards.** Many EU countries (e.g. France, Spain, and Sweden) have taken action to review the regulatory issues related to C&AD, including the testing of vehicles. Some EU countries (e.g. UK) have regulations favourable to testing and others (e.g. Italy and Germany) use a case-by-case approach. This suggests that EU Member States are at different levels in terms of development, testing and deployment of C&AD. Countries outside of the EU (e.g. USA, Japan, South Korea and China) face different limitations in terms of vehicle testing. At the EU level, this

may influence the speed at which the industry can develop and compete. Similarly, and although Member States are individually moving forward with changes in regulations, increased harmonisation in C&AD at the EU-level would be beneficial, also focusing on aspects such as cross-border testing, communication, data security and safety, and cybersecurity. Likewise, many Member States (except Spain and the UK) are signatories of the Vienna Convention, which makes it mandatory for a driver to be able to control the vehicle (Article 8). As C&AD development moves towards full automation, an amendment or re-interpretation to the Vienna Convention will be necessary to avoid problems in the development process.

4. **Legislative and infrastructure barriers to the deployment of C&AD.** Many of the EU's leading car manufacturers are developing C&AV and have made efforts to reduce limitations for testing. One approach has been the development of specialised test facilities, which allows more exhaustive testing. There are regulatory differences for testing C&AV across many Member States. Thus, there is a challenge to implement an EU-wide legal system considering many countries may have conflicting views. European road infrastructure is in variable condition across Member States, with some countries requiring more improvements than others. In principle, the main upgrades would focus on installing digital technology that would allow communication between vehicles and infrastructure. The Connecting Europe Facility (CEF) for Transport instrument, with a budget of more than €24 billion from 2014-2020 would be an important contribution, as well as complementary instruments for digital infrastructure and infrastructure at the city level.
5. **Review of the existing technologies in markets.** Many EU manufacturers develop world class vehicles containing state-of-the-art technologies (e.g. ADAS, travel services). The EU industry has a good reputation and competes very successfully on the world stage. However, new vehicles need more advanced sensor and decision making technologies from the ICT, photonics and electronics sectors. Currently, USA based companies are those most responsible for the development of Operating Systems (OS) for C&AD. This may be related to USA (and Japanese) technology exploitation and deployment being better planned and coordinated. A significant part of C&AD R&D activities are done internally or at a national level. This leads to some challenges for an EU wide-scale and cross-disciplinary collaboration (triple helix) and may also slow down the development of technologies. However, the EC is developing strategies to counter this challenge.
6. **Automated and connected cars/ road vehicles technology analysis.** Many EU companies are strong in ICT and telecommunications, which provides a competitive advantage for developing V2X communication. Most EU OEMs are actively developing, adopting and scouting for new C&AD technologies. However, EU companies are at a disadvantage in regard to, for example, artificial intelligence. There is a limited incorporation of soft technology factors (e.g. knowledge transfer) and industrial application of key technologies. The EU shows a somewhat conservative approach in developing new applications. This could become a challenge in C&AV technology research. The EU has failed to maintain and improve its market position in high-tech sectors. It is necessary for the EU C&AD industry to become more attractive for both EU and non-EU investors. Additional field trials and publicly funded challenges are important to enable EU companies and academics to demonstrate their technological knowledge at a global level.
7. **Technical and non-technical barriers in development of C&AD.** Different types of organisations consider C&AD development to be of high priority, and are therefore involved and collaborate on technology research at different levels. There is an increasing coordinated foresight policy at EU level. There is still some fragmentation in research technology and reduced responsiveness of research institutes to industry needs. Also, with many patents and standards in C&AD originating in the USA or Japan, non-integrated markets increase competition instead of complementary networks for research in C&AD technology. Several Member States are reviewing their road traffic regulations and legislation frameworks to support and allow the development and testing of C&AV on public roads. For improved research and vehicle operation testing, an EU-wide harmonised regulation for C&AD is required. Different bodies across the EU provide support (e.g. financial) for R&D projects. The development and deployment of C&AD requires public and private funding, which may take more time than expected even though the technology is available.
8. **Existence of a global level playing field.** ICT services providers play an increasingly relevant role in C&AD. Many USA ICT companies are investing in C&AD related activities. This reflects in the level of private investment in the USA, which also leverages public investment. The level of investment of EU ICT companies has been more limited although very good examples exist. This has created an adverse impact in the development of C&AD technology in the EU compared to other countries. In addition, the capacity for many EU manufacturers to develop C&AD technology can also depend on the speed at which the EU establishes harmonised regulations and laws. While

some non-EU countries have formal regulations for C&AD, this is not yet fully true in the EU. However, clear efforts are being made at the EU level to change this scenario.

- 9. Effectiveness of EU support measures.** The growing media coverage dedicated to C&AD and the growing number of research projects has contributed to an increased level of public awareness. Aspects related to safety and security, whether vehicle or pedestrian related, liability and other moral issues are of concern to citizens. Many non-EU countries recognize the positive impact that C&AD can have on revolutionising the automotive industry. These countries are investing in new infrastructures to support research as well as reform laws and regulations to support future commercialisation of vehicles. The EU is now working to increase its momentum and position in the sector. Harmonisation of regulations and public investment in specific infrastructure, both traditional and digital, is now being extended. Additional funding from the EU, Member States and the private sector is identified as important for the development of C&AD. Currently, and through the EC's Horizon 2020 programme, a step forward has been taken in allocating public funding (while leveraging private funds) for research activities aiming at developing innovative solutions for C&AD. The EU has made significant efforts to foster C&AD technology through the establishment of various groups/ programmes: (1) the High Level Group on Automotive Industry 'GEAR 2030', (2) The Connected and automated driving (C-ITS) Platform, (3) The Strategic Transport Research and Innovation Agenda (STRIA), and (4) Round Table on Connected and Automated Driving. The Digital Single Market and the Letter of Intent on the testing and large scale demonstration of C&AD are other concrete examples of the EU's intentions for the C&AD sector.

Policy Recommendations

Seven recommendations have been developed from the key findings identified in the study. The proposed recommendations consider the ideas of the Gear 2030 Working Group 2 and the priorities identified in the EU's ambitious Declaration of Amsterdam for cooperation in the field of C&AD. It is expected that these recommendations can be the basis of additional reflections by the relevant European authorities and organisations, Member States, the industry and all relevant stakeholders.

- 1. Establish a coherent funding strategy supporting the EU position in the global C&AD market.** A more coherent funding strategy is recommended to ensure that funding is allocated to priority areas and projects, which can support the EU's position in the global C&AD market. Key instruments include H2020 (namely contractual private partnerships or ERA-NET), Connecting Europe Facility (CEF) or Important Projects of Common European Interests (IPCEI).
- 2. Establish a coherent national and European legal framework for C&AD.** The EU requires a harmonised approach regarding various aspects of C&AD. In alignment with the item on a "Joint Agenda of the Declaration of Amsterdam" and "the Letter of Intent on the testing and large scale demonstration of Connected and Automated Driving, signed on 23 March, 2017, Rome", the EU should establish coherent national and European rules, with possibilities of being adopted by countries outside of the EU. The common framework should contribute to the removal of barriers, facilitate C&AV testing, and promote interoperability and legal consistency. It should focus on standardisation, cybersecurity and a harmonised testing methodology. It should also offer Member States and future participants the flexibility for innovation, facilitating the introduction of C&AV in the market and their cross-border use.
- 3. Develop a common European legislation on liability for manufacturers, drivers and third parties.** Liability is one of the key issues affecting both the development and deployment of C&AV. Although the existing legislation is sufficient for current automation levels, it is important to already discuss and define clear directives regarding liability at the five levels of automation, with special emphasis at full automation (level 5). It must also define the circumstances for the collection and usage of data for the assessment of responsibilities. In this case, standardisation of data should also be considered to ensure that data is stored and can be read independently of the vehicle and model.
- 4. Align and implement national and European initiatives for promoting C&AD awareness and acceptance.** Future public and private investment in the development of C&AD should focus on two key issues: promoting awareness and acceptance, and fostering interest and demand, thus avoiding the emergence of a technology which does not spark the common interest. For public

acceptance and consumer demand, safety and security are two primary concerns that must be taken into consideration.

- 5. Simultaneously prioritise investments in connectivity technology between vehicles and infrastructure and improvements to road infrastructure.** Maximising the impact of C&AV requires a simultaneous prioritisation of investments in connectivity technology and improvements to road infrastructure. Connectivity can increase the effectiveness of automated systems, and improve road safety and traffic efficiency by improving awareness and communication with the surrounding environment. On the other hand, by investing in connectivity technology at infrastructure level, autonomous driving can be improved through the provision of additional sensory resources as well as positive information redundancy. This will contribute to a more detailed environment perception and prediction, as well as a coordinated resolution of the vehicle's complex decisions.
- 6. Foster additional and continuous European and international cooperation on all domains of C&AD.** The EU's competitiveness in C&AD requires upholding the terms within the Declaration of Amsterdam, which focuses on 'Cooperation in the field of C&AD', and targets Member States, the EC and the Industry. Member States should establish additional international cooperation with other regions, namely the USA and Japan, to work towards a global framework and international standards for C&AV. Member States are called to facilitate collaboration and cooperation by adapting national regulations to remove barriers that limit the deployment of C&AV. Within the EU, a Centre of Excellence for C&AD could also contribute to cooperation in the sector.
- 7. Strengthen industrial and technological cooperation between the EU ICT and vehicle manufacturing industries.** There is an opportunity to increase the role of ICT companies in the sector and to strengthen industrial and technological cooperation between the EU ICT and vehicle manufacturing industries, creating synergetic benefits. This should be complemented by an additional effort from the EU to support the development of skills in various IT areas (e.g. artificial intelligence, deep learning, big data analytics, and high definition mapping) that are essential for C&AD and the EU's competitiveness. Efforts in this direction already exist through the Digital Single Market strategy.

With various EC initiatives and the active involvement of several DGs (e.g. RTD, MOVE, CONNECT and GROWTH), the EC is showing ambition towards the development and deployment of C&AD. This interconnected network designed among several DGs to cover the key aspects of C&AD will support the implementation and growth of C&AD. The political and private sectors' will and commitment towards the C&AD sector shows that the EU is moving in the right track to cater to its citizens through the benefits of C&AD development and deployment.

01. Introduction and Objectives of the Study

1 Introduction

1.1 Introduction to the Report

This report is developed under the Tender no. GROW-SME-15-C-N102 within Framework contract no. ENTR/300/PP/2013/FC. The objective of the report is to analyse in different countries or areas the strategies, funding programmes, standards and regulations and value chains for connected and automated driving (C&AD). It also aims to review and analyse the related technologies and to assess the support measures and effectiveness of specific EU support measures.

The countries involved in this study consist of the USA, Japan, South Korea, China and countries from the EU Member States, specifically France, Germany, Italy, Spain, Sweden and the United Kingdom. A comparative study detailed through the various tasks provides a clearer picture of Europe's current position compared to third country counterparts in the field of C&AD.

This document is the Final Report. It is structured into five sections:

1. Introduction and Objective of the study

Section 1 includes an introduction to the study; background information to the report, including a definition and classification of C&AD, important historical steps, potential market development, challenges for the traditional automotive value chain, and changes to city dynamics; and the study's objectives.

The section also outlines the methodological approach considered in the study and the problems encountered. Mitigation measures adopted to address the problems encountered are also described.

2. Operational Approach – Task 1: Comparative analysis of public support measures, programmes and regulations put in place in USA, Japan, South Korea, China and the EU

Section 2 addresses Task 1, which provides information on general strategies, public support measures, programmes and regulations for promoting C&AD. The task also identifies challenges in the automotive value chain.

Additionally, the selected EU Member States and third countries are subject to a comparative and in-depth analysis of their strategies. Task 1 is structured into four subtasks:

- Subtask 1 – In-depth analysis of general strategies for promoting C&AD
- Subtask 2 – Major research and large scale industrial programmes/projects co-financed with public funds
- Subtask 3 – New regulations or standards
- Subtask 4 – Legislative and infrastructure barriers to the deployment of C&AD

3. Operational Approach – Task 2: Comparative assessment of technological and commercialisation readiness level of C&AD in USA, Japan, South Korea, China and the EU

Section 3 addresses Task 2, which provides a review of the readiness levels of current C&AD functions and technologies, including an analysis of existing technologies, and technical and non-technical barriers in the development of C&AD. Task 2 is structured into three subtasks:

- Subtask 1 – Review of the existing technologies in markets
- Subtask 2 – Automated and connected cars/ road vehicles technology analysis
- Subtask 3 – Technical and non-technical barriers in the development of automated and connected driving

4. Operational Approach – Task 3: Assessment of the existence of a global level playing field and of the effectiveness of instruments available for supporting the development of C&AD

Section 4 addresses Task 3, which assesses the existence of a global level playing field and analyses the effectiveness of existing EU support measures. The task also includes proposals for support actions in the different areas where needs have been identified. Task 3 is structured into three subtasks:

- Subtask 1 – Assessment of the existence of a global level playing field
- Subtask 2 – Analysis of the effectiveness of EU support measures
- Subtask 3 – Proposals to reinforce existing support actions and instruments in the EU

5. Key Findings and Policy Implications

Section 5 provides a complete listing of key findings of the study based on the information gathered in the previous tasks. These key findings are used as a basis for several recommendations to improve the EU's competitiveness in the C&AD sector.

Figure 1 presents the full conceptual framework of the study. This includes the various outputs (i.e. reports) of the study during the project timeline, and how the study's various tasks are framed within this framework.

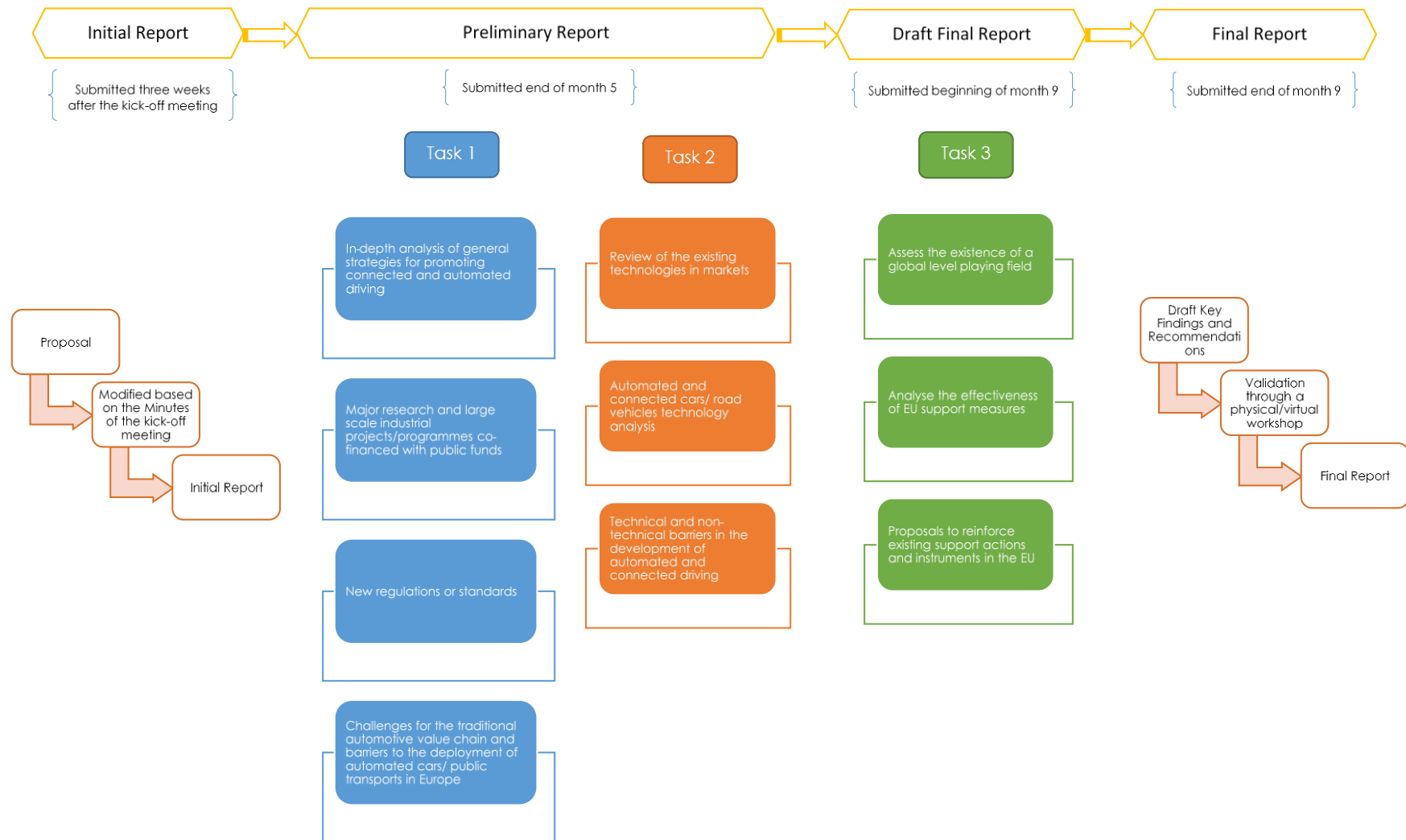


Figure 1. Conceptual Framework of the Study

1.2 Background

Automated driving covers a wide range of technologies and infrastructures, capabilities and contexts, use cases and business cases, and products and services. Automated driving should be seen within the broader context of new developments in automation and connectivity enabled by new technology and systems in mobility and elsewhere.

Connected and automated driving (C&AD) refers to a set of systems that enable vehicles to travel without direct human operation. Using artificial intelligence and other technologies, **connected and automated vehicles (C&AV)** are able to exchange information wirelessly with other vehicles, infrastructures and third-party service providers.

C&AD is expected to have a significant economic impact worldwide. There are estimates of an impact of €71 billion by 2030 in the UK alone [1], while other studies point to a global market of €170-180 billion just for car connectivity in 2020 [2].

1.2.1 Definition and Classification of C&AD

Connected driving

Connected driving is the term used to describe technologies that allow vehicles to connect to each other, to infrastructure and to other parts of the transport network. In addition to what drivers can see around them and what vehicle sensors can detect, connected driving allows the transport system to share information to improve decision making. Thus, these technologies can improve road safety not only by avoiding collisions, but also improving traffic flows and reducing congestion and environmental impacts.

C&AD is integrated in **Intelligent Transport Systems (ITS)**, in particular through **Cooperative Intelligent Transport Systems (C-ITS)**. EU Directive 2010/40/EU¹ defines ITS as systems where information and communication technologies are applied in road transport, including infrastructure, vehicles and users, traffic and mobility management, as well as interfaces with other modes of transport. Furthermore, according to the European Commission (EC), the definition of **cooperative systems** in road traffic is *"road operators, infrastructure, vehicles, their drivers and other road users will cooperate to deliver the most efficient, safe, secure and comfortable journeys. The vehicle-vehicle and vehicle-infrastructure cooperative systems will contribute to these objectives beyond the improvements achievable with stand-alone systems."*

A recent study from the Business Innovation Observatory [3] identified seven different product categories for connected cars:

1. Mobility management (for improving traffic flow, such as advanced navigation systems, traffic assistance and parking).
2. Vehicle management (for fuel management and maintenance information).
3. Entertainment (such as embedded WLAN hot spots, music/video streaming, social media integration and smartphone interface).
4. Safety (crash avoidance, such as blind spot warning systems and forward collision warning systems or warning systems for icy roads, traffic jams or adverse weather conditions).
5. Autonomous driving² (operational assistance or autopilot in heavy traffic, lane keeping warnings, automated parking systems and adaptive cruise control systems).
6. Well-being (fatigue detection systems and alert calls for medical assistance).
7. Home integration (enable functionality within the house).

The USA Centre for Automotive Research³ categorised connected car technologies as follows:

¹ Directive 2010/40/EU of the European Parliament and of the Council of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport. <http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32010L0040>

² 'Autonomous' and 'automated' are two words that are often used interchangeably in the C&AD industry.

An autonomous vehicle is one that is completely independent, not subject to any outside control. In the automated highway system, autonomous vehicles do not need any additional input from the infrastructure beyond what is currently in place. Whereas automated vehicles involve some level of coordination between the vehicles and the roadway infrastructure. In this system, the vehicle is not entirely independent. This could mean vehicle-to-vehicle (V2V) and/or roadside communications.



Crash Elimination: Crash-free driving and improved vehicle safety could change the concept of a vehicle as we know it.



Reduced Need for New Infrastructure: Self-driving can reduce the need for building new infrastructure and reduce maintenance costs



Travel Time Dependability: Convergence can substantially reduce uncertainty in travel times via real-time, predictive assessment of travel times on all routes.



Productivity Improvements: Convergence will allow travellers to make use of travel time productively

Automated Driving

Automated driving refers to the advanced vehicle systems that can assist or replace the driver tasks. In 2014, SAE, a USA-based automotive standardisation body, released a six level classification system of automated driving, based on the amount of driver intervention and attentiveness required [4].

- **Level 0:** The automated system has no vehicle control, but may issue warnings.
- **Level 1:** The driver must be ready to take control at any time. The automated system may include features such as adaptive cruise control, parking assistance with automated steering, and lane keeping assistance Type II in any combination.
- **Level 2:** The driver must detect objects and events and take control of the vehicle if the automated system fails to respond properly. The automated system executes accelerating, braking, and steering. The automated system can deactivate immediately upon takeover by the driver.
- **Level 3:** Within known and limited environments (such as freeways), the driver can safely turn their attention away from driving tasks.
- **Level 4:** The automated system can control the vehicle in almost all environments, excluding severe weather. The driver can only enable the automated system when it is safe to do so. When enabled, driver attention is not required.
- **Level 5:** Other than setting the destination and starting the system, no human intervention is required. The automatic system can drive to any location where it is legal to drive.

The SAE standard provides a common taxonomy and definitions for automated driving in order to simplify communication and facilitate collaboration within technical and policy domains (Figure 2).

³ Centre for Automotive Research (CAR). <http://www.cargroup.org/>

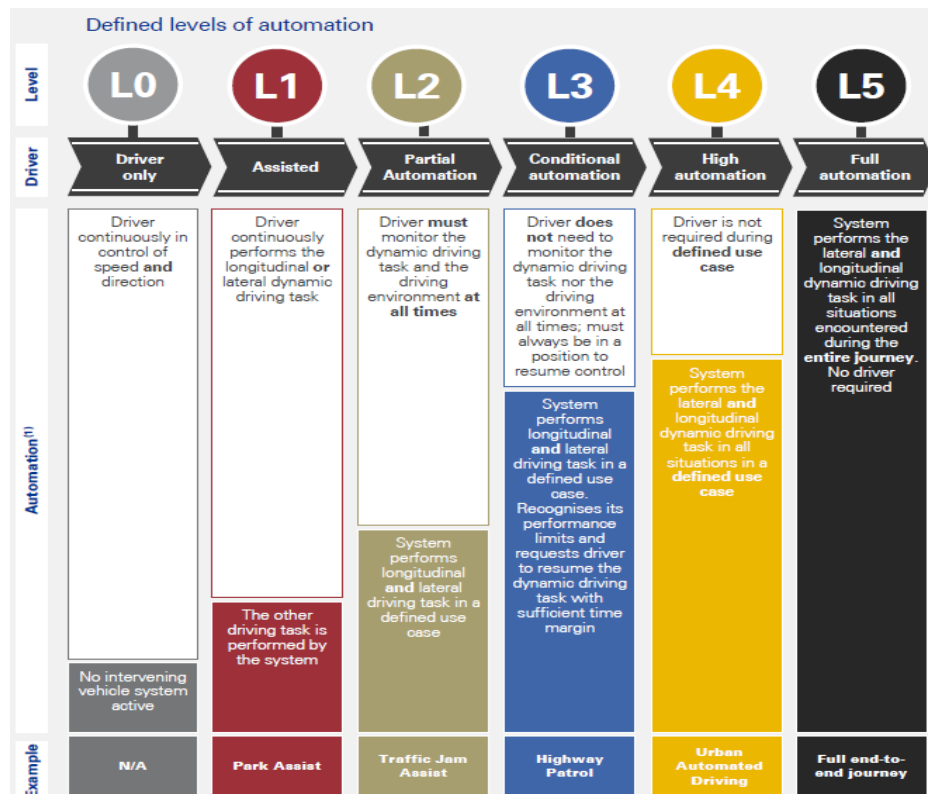


Figure 2: Defined Levels of Automation

It should be noted that for C&AV technologies, many of them overlap. For instance, to have a fully automated vehicle, the vehicle must also be a connected vehicle [5]. In this sense, reviews of such technologies are increasingly considered together.

1.2.2 Important Historical Steps

The objective of eliminating human control at the steering wheel began several decades ago. Initial research focused on creating highways and roads capable of moving cars from one point to another. This was the case at the New York World's Fair in 1939-1940, when General Motors showcased a design that included an automated highway system. It visualised trench-like tracks that enabled cars to travel without the need of human drivers.

This idea was then picked up by America's Electric Light & Power Companies. They ran an advertisement in 1957 showing how highways could be made electric and that cars would be connected and ride on them. The picture of a family on the highway playing a board game in a self-driving car has since been an icon for the exploration of automated driving. In 1958, General Motors and RCA developed a prototype of automated highways in which cars used magnets to track steel cables embedded in the roads.

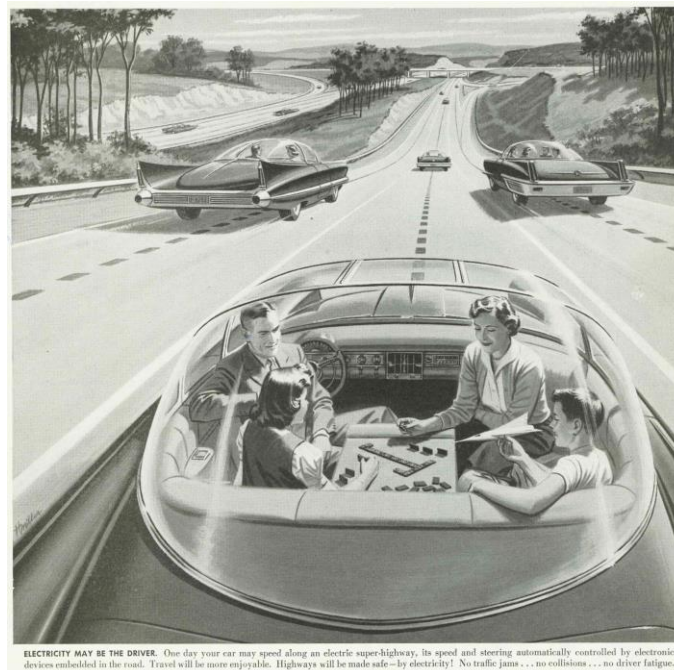


Figure 3: Driverless Car of the Future, advertisement for "America's Electric Light and Power Companies (Source: Computer History Museum⁴)

In 1977, Tsukuba Mechanical Engineering Lab of Japan created the first intelligent car using two cameras capable of recognising white road markings to navigate using signal processing. During the period of 1986 to 1995, the European Research Initiative funded the €749 million Programme for a European Traffic of Highest Efficiency and Unprecedented Safety (PROMETHEUS)⁵. It was the largest automated driving project to date. In 1994, the project showcased an automated van capable of driving in normal traffic, changing lanes, and overtaking other vehicles.

With the emergence of the internet and GPS, there was a rapid development of C&AD in the 2000s that touched almost every aspect of driving. It started in 2003 when Toyota offered the first intelligent parking assist system using parking sensors as an optional extra in its Prius hybrid. This was the first intelligent car available to the public. In 2004, the Defense Advanced Projects Agency (DARPA)⁶ launched a competition to boost developments for autonomous military vehicles. Although that year no participant completed the 150-mile course (i.e. 241 km) through the Mojave Desert, five vehicles completed the course the following year.

In 2010, the University of Parma's VISLAB⁷ was the first automated driving research entity to successfully run an intercontinental driving test by sending four autonomous vehicles on a 100-day journey that covered nearly 16,000 km from Parma to Shanghai. In the same year, Google X⁸ (Google's R&D company, now called 'X'), announced they had been developing self-driving cars and have travelled more than 225,000 km. Their self-driving vehicle prototypes can already be seen on the streets of California and Texas.

Since then, level 0 and level 1 features such as parking distance control, lane change assist, adaptive cruise control, park assist, and emergency brake assist have become a common feature in contemporary models of almost all major automotive manufacturers, including General Motors, Ford, Mercedes-Benz, Volkswagen, Audi, Nissan, Toyota, BMW, and Volvo.

The swift development of C&AD innovation during this period led to a public concern that the technology was ahead of the law. In 2011, Nevada became the first USA state to allow the operation of autonomous vehicles on its roads. It created a precedent that other states began to follow. As of

⁴ Where to? A History of Autonomous Vehicles (Computer History Museum, May 08, 2014).

<http://www.computerhistory.org/atchm/where-to-a-history-of-autonomous-vehicles/>

⁵ PROMETHEUS. <http://media.daimler.com/marsMediaSite/en/instance/ko/The-PROMETHEUS-project-launched-in-1986-Pioneering-autonomous-driving.xhtml?oid=13744534>

⁶ DARPA. <http://www.darpa.mil/>

⁷ VisLab. <http://vislab.it/>

⁸ X (Google X). <https://x.company/>

January 2017, thirteen states and Washington D.C. had passed legislation related to autonomous vehicles.

In January 2014, Induct Technology's Navia shuttle became the first self-driving vehicle to be available for commercial sale. A year later, a car designed by Delphi Automotive became the first automated vehicle to complete a coast-to-coast journey across North America. It travelled from San Francisco to New York under computer control for 99% of journey.

In 2015, Daimler and Mercedes-Benz began testing the Highway Pilot system with the future Truck 2025. This was the first autonomous truck capable of reaching 80 km/h while tested on a section of a German autobahn. This development opened the possibility for commercial applications of automated driving.

1.2.3 Potential Market Development

It is expected that the market impact of C&A vehicles could be very big. The current phase of development in automated vehicles has already been considered the biggest innovation in automotive industries since the invention of the car itself. It could help to reduce road fatalities as 90% of road accidents result from human error. New transport services may also emerge, especially when vehicles are provided with connectivity in addition to automation (e.g. traffic safety-related warnings, traffic management, car sharing, new possibilities for elderly people or impaired people). Drivers can expect more individual comfort and convenience, which is likely to be one of many motivation factors for upcoming automated driving. In the long term, automation could have a revolutionary impact on travel behaviour and urban development. It could also result in new business models, such as shared mobility, which could lead to a strong decrease of vehicles on our roads.

It has been reported that by 2020, nearly 10 million cars will have automated driving features installed, and that a fully autonomous vehicle will be in production in 2019 [6]. Another study has put the market value of both partially and fully autonomous car at \$42 billion USD (€39.7 billion) in 2025 [7]. This shows the substantial market potential of C&AD in the coming future. The market potential of C&AD has been recognised by various automotive key players such as Volkswagen, Ford, General Motors, BMW, Toyota, and Tesla. These players have poured millions of dollars into the research and development of automated vehicles.

According to some studies, 30 to 40 percent of the value in the automotive value chain will pass through digital platforms in the near future. Since the nature of C&AD heavily relies on ICT development, big names in the IT industry like Google, Apple, and Baidu have launched intensive research in search of reducing human control behind steering wheels. Internet-based car sharing service providers such as Uber, NuTonomy, and Didi Chuxing have also shown great interest in self-driving car technologies. Uber's CEO has suggested that if Tesla can produce half a million cars in 2020, these would all be bought to transform the entire Uber fleet. NuTonomy has planned to release its self-driving taxis in Singapore by 2018 and an additional nine cities in 2020.

C&AD may introduce significant changes to manufactures' business models and an increasing offer of mobility services. With the change in the cost structure of mobility, which in turn enables shared autonomous mobility services, C&AD could change the perspective of individual ownership of vehicles. Mobility services based on self-driving cars fleets are already proposed by Uber, Car2Go and other providers. Automotive manufacturers (e.g. Ford), have announced their plans to provide mobility services with fully autonomous Ford vehicles by 2021 [8]. This development illustrates a need of a new business model for transportation and mobility in general. Shared mobility services will significantly decrease the number of vehicles on roads, resulting in less congestion and increased fuel efficiency. Therefore, there is a possibility that with the development and deployment of C&AD, individual ownership of vehicles will gradually decrease [9].

One report on C&AD shows the potential revenue from autonomous driving, connected services, and the safety measures industry reaching \$155.9 billion USD (€147 billion) by 2022 [10]. This is a 24.3% increase from the projected revenue of the C&AD industry in 2017, predicted to reach \$52.5 billion USD (€49.7 billion). This report shows that C&AD is a sector that has a huge market potential in the next 5-10 years.

Another report revealed that the technology developers providing the software for connected driving alone could generate \$87 billion USD (€82.4 billion) opportunities in 2030. The same report also suggests that while the United States and Europe led early development of connected driving, China will have a 35% share of the automated vehicles sold in 2030, creating revenues of \$24 billion USD (€22.7 billion), against \$21 billion USD (€19.9 billion) for the USA market and \$20 billion USD (€18.9 billion) for Europe [11].

Furthermore, this area holds promise for addressing global trends like urbanisation, higher sustainability standards and an ageing population (e.g. through increasing safety, improving fuel efficiency, reducing congestion and supporting inclusion in mobility). Thus, there is also a high potential for societal benefit.

1.2.4 Challenges for the traditional automotive value chain

Despite the aforementioned potential market development, the deployment of C&AV in Europe poses challenges to the traditional automotive value chain, namely the transition from contemporary to automated driving. While there is a degree of uncertainty regarding the future of the industry, it is likely that car manufacturers will have to adapt to new technologies.

Many automotive executives expect major changes in their organization's business model because of future changes in mobility preferences related to C&AD. C&AD creates the conditions for sharing cars and for new mobility concepts. If sharing cars becomes more popular, this could have a direct impact on the sales figures of newly developed cars: they may decrease due to a reduced demand for personal cars.

The influence of automation, connectivity, and electrification will affect the perception and experience of the consumer. The demand for car connectivity is increasing quickly and the competition for connected customers will intensify. This will require automotive players to shift or expand their business model towards offering new services and functionalities. Competitors must find a set of services that offer the most value from a consumer's perspective. Creating alliances with software companies (and potential competitors) like Google, Apple, or Microsoft could be crucial for the success of automated car manufacturers. Offering new services can be regarded as a unique selling point. [12]

Making automated cars affordable for the common consumer is also a challenge for the industry. Nowadays, only premium car brands offer automated functionalities. If manufacturers cannot lower the costs of C&AV, the adoption/deployment of the technology may be slower. Investments towards mass production of equipment may be a prerequisite for a successful introduction of CA&V in the market. The question remains whether manufacturers are able or willing to invest while there is still uncertainty about the future direction of the industry.

A large part of this uncertainty on future business models can be summarized in two factors: (1) the degree of automation and acceptance [13] (desired by society) and (2) the willingness to share vehicles [12]. Four possible scenarios can be considered, according to the two aforementioned factors. In short, if the willingness to share cars is high, the demand for automated cars is also high. With the possibility of shared automated vehicles in the future, manufacturers have to reconsider their strategy. Shared vehicles will also affect the taxi and public transport industry. This will further limit the potential market for C&AV. The resulting level of automation will also have an impact on a manufacturer's investment strategy: a higher level of automation will require a higher initial investment to facilitate innovative developments.

1.2.5 Changes to city dynamics

Cities and the urban city structure are closely connected with the development of its transport system. It is almost impossible to design the future of cities without acknowledging the configuration of its transport system. According to the US Department of Transport, there are three major differences between smart and connected cities compared to traditional cities. First, smart and connected cities contain and use intelligent infrastructure that can sense the environment and are capable of sending and receiving data. Second, these cities use new analytical processes that have been facilitated by the progress in ICT. Lastly, smart and connected cities increasingly require a smart grid that increases efficiency in electricity transmission. [14]

C&AD also plays a significant role in existing and smart and connected cities in several ways. First, it offers the possibility of significantly changing the usage of vehicles from individual ownership to shared ownership, shifting the perspective of cars as public properties, and contributing to the emergence of new mobility services. The management of vehicles as a public utility would allow the efficient integration of automated vehicles with collective public transport systems, resulting in a mobility based on an efficient and intelligent combination of all modes. [15] Taking this into consideration, for small and medium-sized cities, it is conceivable that a shared fleet of self-driving vehicles could completely eliminate the need for traditional public transport, considering the value of comfort and less waiting time associated to C&AV compared to conventional public transport.

Shared vehicles fleets would also increase the quantity of space in a city in several ways. First, C&AV are designed to be able to manoeuvre more effectively and would result in less space needed to drive on roads and highways. Second, with the usage of shared automated vehicle fleets, there is a reduction in the need for parking spaces in the city. [16] The reduction of space required for vehicles would free up public space, which could be used to improve the liveability of urban environments with re-qualification of public spaces for pedestrians, bicycles, etc.

From a data point of view, vehicles' continuous broadcast of their location, speed, and other data would give cities' traffic management system real-time data on traffic conditions that are more detailed and accurate than data available today. This would allow continuous monitoring of traffic conditions and would allow traffic managers to effectively solve problems in a swift manner, contributing to safer and more liveable cities.

1.3 Objective of the Study

A high level of competition exists not only between companies, but also public authorities seeking to support competitiveness at the technological and legal level. Since Europe has a strong automotive industry, European and Member State authorities are among the public authorities implementing such measures. However, there are several challenges that need to be addressed in order to optimise the delivery of such support.

Firstly, the development of C&AD features shows that ICT are increasing in vehicles, which has a significant impact on the automotive value chain. Likewise, the development of C&AD presents new challenges to ensure its competitiveness (previously separate technology and legal areas are blurring and new collaborative structures need to be established). The automotive and Internet of Things (IoT) value chains are becoming increasingly entangled and road vehicles are often considered as increasingly becoming a 'thing' in the Internet of Things. [17]

Secondly, the EU comprises a diversity of Member States. This presents the danger of support being fragmented, including inefficiencies such as the duplication of efforts or even the occurrence of gaps in support. In order to build sufficient critical mass to maintain European leadership in this area, there is a need to determine optimum ways to combine private and public investments at EU, national and regional level. While existing collaboration platforms exist at specific levels (e.g. through ERTICO⁹, the iMobility Forum¹⁰ or the C-ITS platform¹¹), the KET High Level Group proposed automated and connected driving as an Important Project of Common European Interest (IPCEI).[18]

This study aims at providing contributions that help address these challenges. For example, the study will provide an understanding of existing support outside the EU (in the four third-countries addressed), which may indicate gaps in support. It will also look to identify financial, technological and regulatory barriers which may be hindering European industrial and technology competitiveness in the sector. In this way, the study will provide useful input for the elaboration of a potential IPCEI in C&AD.

This study is developed at a time where there is an increasing amount of information that speculates that mainstream C&AD may be achieved relatively soon. This may be possible by creating spaces where safe vehicle operation can be guaranteed, such as in limited areas designed in cooperation with city planning. For example, the application of C&AD and vehicle platooning technologies would facilitate platooning on dedicated roadways, with the lead vehicle operated manually and the following cars driven automatically. C&AD at low speeds in limited areas and automated parking would also be possible. Figure 4 represents how daily life would be affected and respond to a C&AV ecosystem [19].

Considering this preamble, the overall objective of this study is to **explore and analyse the existing and planned public support measures offered by Europe's main competitors (namely the USA, China, Japan and Korea) in the field of C&AD, covering the entire value chain and including all different activities which are needed for full automation and connected driving.**

⁹ ERTICO. <http://ertico.com/>

¹⁰ iMobility Forum. <http://ertico.com/projects/imobility-forum/>

¹¹ C-ITS Platform. https://ec.europa.eu/transport/themes/its/c-its_en

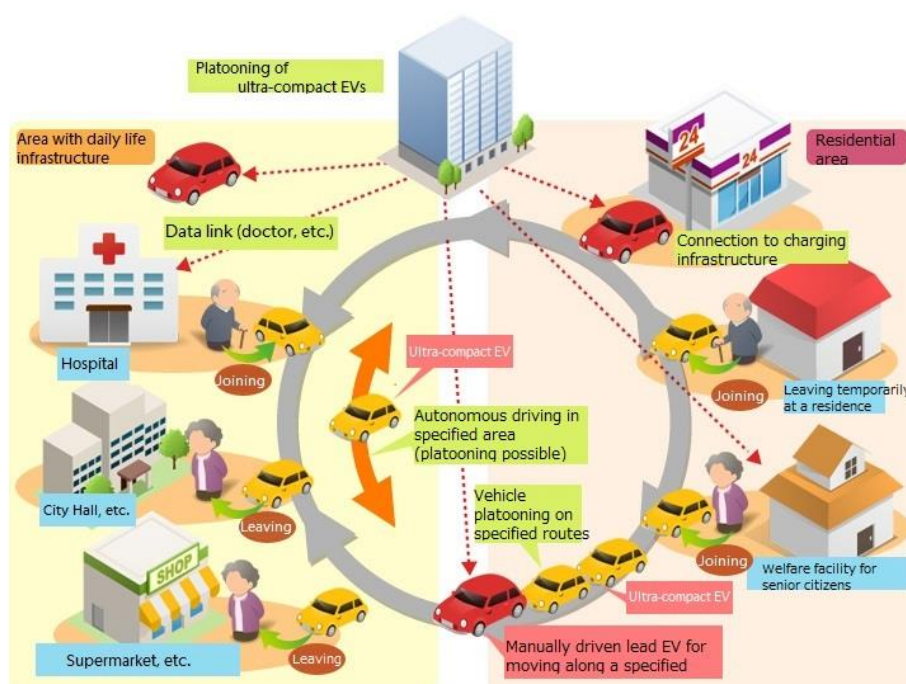


Figure 4: Area with daily life infrastructure

Source: Japan Automobile Research Institute (JARI)

Several programmes at national and EU level related to C&AD are already running, which show a strong global competition in this sector. This study will contribute to a better understanding of the evolution of similar programmes outside the EU and gaps between the EU and these competing countries. Results will contribute to the identification of financial, technological and regulatory barriers that could inhibit the competitiveness of EU projects related to C&AD.

The analysis of public support measures offered by third countries will help assess future challenges for the EU automotive sector in regard to the elaboration of projects on C&AD that support re-industrialisation and increase the EU's global competitiveness [20]. Moreover, it will provide useful input for the elaboration of a potential IPCEI in C&AD.

This main objective will be achieved through the provision of the following specific objectives:

1. Develop a comparative analysis of public support measures, programmes and regulations put in place in the EU and Member States, and in the USA, Japan, South Korea, and China.
2. Assess the technological and commercialisation readiness level of C&AD in the EU and Member States, and in the USA, Japan, South Korea, and China.
3. Assess the existence of a global level playing field and the effectiveness of instruments available for supporting the development of C&AD.
4. Develop useful recommendations for application in future activities based on the results obtained and validate the key findings identified in the study with experts.

1.4 Methodology of the Study

This section outlines the approach applied in the execution of the tasks to achieve the objectives of the study. Desk research, questionnaires and interviews constitute the three major components of the methodology. Furthermore, details on establishing the stakeholder list, efforts to maximise participation in the questionnaire, structuring the questionnaire content and aggregating and reporting information gathered from questionnaires are explained.

1.4.1 Desk Research Approach

A broad literature review was carried out considering the tasks and subtasks identified for the study. Given the complexity of C&AD, other important areas such as electronics, ICT and the digital economy were also considered.

As C&AD is a dynamic sector, secondary information gathered from desk research available until January 2017 has been included in the analysis. However, the Letter of Intent on the testing and large scale demonstrations of Connected and Automated Driving, dated March 23, 2017, is also included in the study considering its importance for the EU's position and progress in C&AD.

The desk research approach and complementary analysis was based on selected EU Members States¹² (i.e. France, Germany, Italy, Spain, Sweden and the UK) and four key third-countries (i.e. USA, Japan, South Korea and China). Where relevant, it also mentions other countries that have made considerable developments in specific areas of C&AD, such as the Netherlands and Singapore.

To note that Poland was originally included as part of the study. However, as the desk research resulted in a very limited number of studies and activities in C&AD for the country, it was decided to not be included in the full study.

As is evident in the following chapters, a dedicated subsection on the collection of information from desk research is provided for Task 1 and Task 2. This subsection is followed by a detailed description and comparative analysis of each country studied. Finally, a comparative SWOT analysis of the EU compared to other third-countries is developed.

1.4.2 Questionnaire and Interview Approach

A questionnaire was administered in the study to obtain insight on how support is perceived from different perspectives (e.g. various types of beneficiaries or policy-makers), to access information that could not be obtained in physical documents, or to confirm information previously gathered. This section describes some general aspects that relate to the study questionnaire.

Selection of those to whom the questionnaire is administered

A questionnaire was administered to individuals from organisations with different roles (e.g. companies along the C&AD value chain, researchers, policy makers, funding organisations and regulatory bodies). The stakeholder list also includes those directly involved, such as the beneficiaries of funding, the national or regional governing authorities, as well as those that are generally involved in the sector. Access to these individuals was possible through existing expert groups, associations, networks and projects. In addition, experts from GEAR 2030¹³, 23rd World Congress on Intelligent Transport Systems 2016 Melbourne¹⁴, ACEA¹⁵, CLEPA¹⁶ and LinkedIn Group – Autonomous Vehicle Technology¹⁷ were also contacted.

In terms of geographical focus, the study provides in-depth analysis for countries in which a clear strategy for C&AD and significant support measures have been found. For example,

¹² The seven EU member states have been selected to be representative of the EU and henceforth, the term EU has been used inter-changeably with these seven EU member states.

¹³ GEAR2030. https://ec.europa.eu/growth/sectors/automotive/policy-strategy_en

¹⁴ 23rd World Congress on Intelligent Transport Systems 2016 Melbourne. <http://www.itsworldcongress2016.com/>

¹⁵ ACEA – The European Automobile Manufacturers' Association. ACEA represents the 15 Europe-based car, van, truck and bus manufacturers. <http://www.acea.be/>

¹⁶ CLEPA – The European Association of Automotive Suppliers. CLEPA brings together more than 100 of the world's most prominent suppliers for car parts, systems and modules and more than 20 national trade associations and European sector associations. <http://clepa.eu/>

¹⁷ LinkedIn Group – Autonomous Vehicle Technology. <https://www.linkedin.com/groups/8507026/profile>

Member States such as France, Germany, Italy, Spain, Sweden and the UK are particularly important. Regional activities are included within the specific countries involved. The Member States selected are justified according to five specific points:

- Geographic spread across Europe;
- Highlighted activity in C&AD;
- Evidence of government policy and programmes with regards to C&AD;
- Overall strong automotive industry;
- Evidence of sufficient data availability for analysis.

Maximising participation through questionnaire and interviews

Efforts were made to encourage participants to express their opinions by providing them with clear information about the purpose of the questionnaire, its duration and the themes covered. Particular attention was given to reassure stakeholders that confidentiality and data protection would be applied, with only the consortium having access to data, and no identifiable evidence released or reported that could be associated with a specific individual. In order to facilitate the process of interviewing, virtual interviews (either by telephone or other communication tools such as Skype, GoToMeeting, or others) were performed. Since the stakeholder list included high-level experts with limited time availability, the project team also gave participants the opportunity to choose giving an interview or completing the questionnaire. This contributed to an increased response rate and improved the quality of the study as the information was used to complement information previously collected.

Questionnaire content/ structure

The questionnaire was structured according to key topics related to C&AD. The questions, divided into eight main sections, focused on strategies, regulations and major projects/programmes that have been implemented in the USA, China, Japan, South Korea and EU countries. The questionnaire included structured and unstructured questions, which gave experts the opportunity to make more detailed comments on key topics. Questions were agreed in advance with the EC.

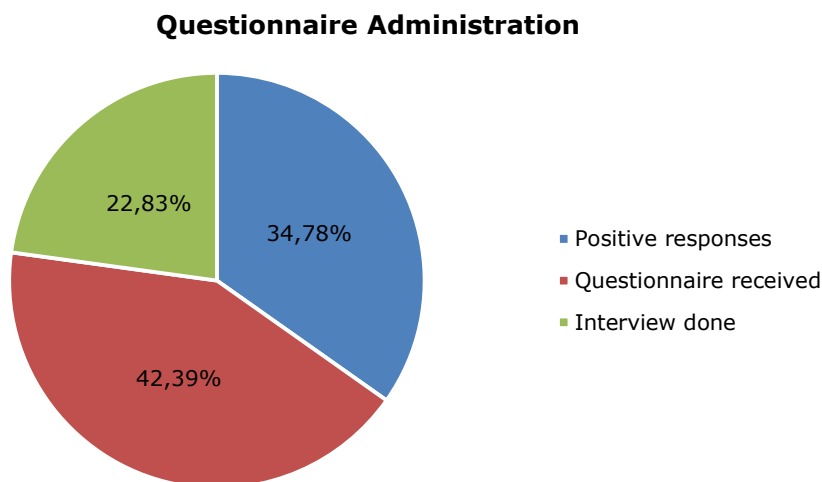


Figure 5: Status of Questionnaire Administration

Some responses are categorised as “positive responses” since some experts expressed interest in contributing to the study but were unable to contribute with an interview or questionnaire. Instead, these experts provided reference documents or contacts instead.

The questionnaire includes questions from the three tasks of the study and on topics/issues from each of the subtasks. This approach increased the amount of time required to complete the questionnaire and was identified as a barrier by potential respondents to providing a full response.

1.4.3 Identifying the recommendations and their validation

A screening of the main existing policy actions at national and EU levels (i.e. Tasks 1 and Task 2) and a critical analysis of these actions has helped identify policy gaps in relation notably to what EU’s main

competitors are doing. Following the analysis of the information gathered through secondary research and through questionnaire and interviews, recommendations to support the competitiveness of the EU C&AD sector as well as the future assessment of support measures have been developed.

Validation of the draft recommendations and supporting key findings was possible through a workshop held in March 2017 and involving various experts.

02. Operational Approach – Task 1

2 Operational Approach – Task 1: Comparative analysis of public support measures, programmes and regulations put in place in USA, Japan, South Korea, China and the EU

Task 1 focuses on the provision of an in-depth analysis of the general strategies to promote the development of C&AD put in place in the EU Member States (i.e. France, Germany, Italy, Spain, Sweden and the UK) compared to the selected third countries (i.e. USA, Japan, South Korea and China).

Regarding the EU, the study has researched the key challenges that the traditional automotive value chain will face over the following decades. This includes changes in the business model of the automotive sector and potential barriers, such as societal resistance (e.g. taxi, car sharing or insurance industries) and/or critical infrastructure requirements prior to the deployment of automated cars/ road vehicles.

The analysis identifies, describes and carries out an in-depth analysis of major research and large-scale industrial projects/programmes co-financed with public funds in the last five (5) years, and other public measures put in place to facilitate C&AD in these countries. The analysis, where possible, makes a reference to the main sub-segments concerned, the typology of beneficiaries, the relative importance of the budgets involved, as well as the intensity of the aid and the kind of financial incentive used (e.g. grants, loan, and fiscal incentives). The contributions from experts derived through questionnaires and interviews are also included in the analysis.

The whole value chain is covered (from TRL1 to TRL 9) as well as all different activities necessary for full automation and connected driving (including testing infrastructure, big data platforms, etc.). New regulations or standards put in place by national or regional authorities are identified and presented in detail. This task was carried out through an in-depth literature review, desk research and interviews.

The task ran concurrently with Task 2, for the first 5 months of the project, and used the same methodological tools (i.e. desk research and an in-depth literature review).

Task 1 includes 4 subtasks:

- Subtask 1 – In-depth analysis of general strategies for promoting C&AD
- Subtask 2 – Major research and large-scale industrial programmes/projects co-financed with public funds from 2011-2016
- Subtask 3 – New regulations or standards
- Subtask 4 – Legislative and infrastructure barriers to the deployment of C&AD

Task 1 identifies the key results regarding the four abovementioned topics together with the underlying key assumptions as well as any methodological challenges. For each sub-task, the methodology included data collection and analysis in an iterative manner to minimise information gaps and maximise accuracy. Existing literature was screened and relevant information was identified. Information gathered was verified (e.g. through comparison of sources or eventually direct contact with the responsible entity) and analysed for information gaps. Information gaps were addressed via additional desk research. The analysis of information considered the key areas of support for competitiveness in order to identify gaps in support compared to third countries as this is a basis for Task 3.

The comparative analysis identifies the possible consequences of the support (or lack thereof) by comparing the situation in different contexts. This can highlight important drivers from which suggestions for improvement can later be derived or identify problematic areas that can be investigated in greater detail and where conclusions are difficult to make.

A SWOT analysis is included in every subtask to provide systematized information on the development of C&AD in the EU compared to its main competitors. Experts' opinions and perspectives obtained from the questionnaire and interview are also described within the SWOT analysis. This is done to improve the explanation and create the basis for gap analysis, as well as recommendations that are presented at the end of this study.

2.1 Subtask 1 – In-depth analysis of general strategies for promoting C&AD

Subtask 1 includes an analysis of European, Member States and third-countries' general strategies for promoting C&AD. The manner in which these public support measures impact the uptake, demand and competitiveness of C&AD in these countries is also discussed. The analysis is based on official documents and other relevant resources.

The information reviewed is used as a basis for the development of a comparative analysis, which is complemented by a detailed SWOT that analyses the EU compared to the third-countries. Information collected from experts is also used in the analysis.

2.1.1 Review of existing strategies that can influence competitiveness

In order to understand how existing strategies can affect the competitiveness of C&AD, information from these strategies is analysed and discussed according to specific factors. These factors include initiatives to promote better public awareness and acceptance, improved market conditions, technology development, skilled labour supply, sustainability and regulation. Where possible, these factors are also complemented with aspects of governance systems.

Information from the EU and Member States is compared to the third-countries to highlight gaps/inconsistencies in support, and also to provide an analysis on the consequences of different factors of competitiveness. The analysis helps identify areas in which international collaboration efforts may promote global competitiveness. Table 1 presents an analysis of some of the general strategic documents for promoting C&AD.

Table 1: Review of existing strategy documents for promoting C&AD

Country	Analysis findings
USA [21], [22], [23], [24]	<p>The US Department of Transportation's National Highway Traffic Safety Administration (NHTSA) announced a national programme on vehicle automation. They defined fully automated or 'self-driving' vehicles as <i>"those in which the operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking, and are designed so that the driver is not expected to constantly monitor the roadway while operating in self-driving mode."</i> In September 2016, the NHTSA and US Department of Transport published a Federal Automated Vehicles Policy that acts as a guideline for C&AD development in the USA. This report adopts the SAE International (SAE) definitions for levels of automation:</p> <ul style="list-style-type: none"> • At SAE Level 0, the human driver does everything. • At SAE Level 1, an automated system on the vehicle can sometimes assist the human driver conduct some parts of the driving task. • At SAE Level 2, an automated system on the vehicle can actually conduct some parts of the driving task, while the human continues to monitor the driving environment and performs the rest of the driving task. • At SAE Level 3, an automated system can conduct some parts of the driving task and monitor the driving environment in some instances. However, the human driver must be ready to take back control when the automated system requests it. • At SAE Level 4, an automated system can conduct the driving task and monitor the driving environment, without the human needing to take back control. However, the automated system can only operate in certain environments and under certain conditions. • At SAE Level 5, the automated system can perform all driving tasks, under the same conditions that a human driver would perform them. <p>As of 2016, twenty States had introduced legislation related to autonomous vehicles. The United States Department of Transportation (USDOT) has been a leader and strong supporter of research, development, adoption and deployment of intelligent transportation systems (ITS) around the country. The USDOT's Intelligent Transportation Systems Joint Program Office (ITS JPO) is at the forefront of the development and promotion of C&AD. The ITS JPO coordinates the Federally-sponsored research conducted across the USDOT's various agencies and programmes. The USDOT also develops and issues regulatory and policy rulings to foster the growth of C&AV and other ITS technologies. However, there is still a challenge of harmonising the fragmentation across the 50 states, which raises questions on who regulates and how it should be done. The NHTSA is working in this direction and has presented a model</p>

Country	Analysis findings
	<p>policy that can be adopted by all states.</p> <p>The ITS Strategic Plan 2015-2019 (ITS-SP) presents the next set of priorities, strategic themes, and programme categories under which ITS research, development, and adoption activities will take place. It was developed in consultation with different stakeholders, internal and external to the USDOT, such as the National Highway Traffic Safety Administration. The ITS-SP defines two primary strategic priorities: (1) Realizing connected vehicle implementation, which builds on the significant progress made in recent years around design, testing, and planning for the deployment of connected vehicles across the USA; and (2) Advancing automation, which focuses on the research, development, and adoption of automation related technologies as they emerge.</p> <p>The strategic plan also defines strategic themes, which focus on the expected outcomes of new technologies and systems as they are developed, tested, and eventually adopted. Five themes have been defined and are aligned with the strategic priorities:</p> <ul style="list-style-type: none"> • Enable Safer Vehicles and Roadways by improving crash avoidance, performance measures, and other notification mechanisms; commercial motor vehicle safety considerations; and infrastructure-based and cooperative safety systems. • Enhance Mobility by exploring methods and management strategies that increase system efficiency and improve individual mobility. • Limit Environmental Impacts by better managing traffic flow, speeds, and congestion, and using technology to address other vehicle and roadway operational practices. • Promote Innovation by fostering technological progress and innovation across the ITS Programme; continuously pursuing a visionary/exploratory research agenda; and aligning the pace of technology development, adoption, and deployment to meet future transportation needs. • Support Transportation Connectivity through the development of standards and systems architectures, and the application of advanced wireless technologies that enable communication among and between vehicles of all types, the infrastructure, and portable devices. <p>Lastly, the ITS Strategic Plan 2015-2019 defines categories that provide the necessary structure for research, development, and adoption of ITS technologies. These categories reflect modal and external stakeholder input about the areas where attention, focus, and resources should be devoted. Six programme categories have been defined, with the following focus:</p> <ul style="list-style-type: none"> • Connected Vehicles: Adoption and deployment of the system. • Automation: Automated road vehicle systems and related technologies that transfer some vehicle control from the driver to the vehicle. • Emerging Capabilities: Future generations of transportation systems. • Enterprise Data: Data capture from stationary sensors, mobile devices, and connected vehicles, which expands into research activities involving the development of mechanisms for housing, sharing, analysing, transporting, and applying those data for improved safety and mobility across all modes of travel. • Interoperability: Ensuring effective connectivity among devices and systems. • Accelerating Deployment: Advancing the work from adoption to wider-scale deployment in coordination with several other DOT agencies.
Japan [25], [26], [27], [28]	<p>The Japanese Government is fully committed to achieving C&AD. The Ministry of Land, Infrastructures, Transport and Tourism (MLIT), Ministry of Internal Affairs and Communications, Ministry of Economy Trade and Industry, and the National Police Agency are working together to promote ITS. Together, these four entities worked to develop Japan's ITS roadmap and research and development plan in July 2012, aimed at reducing traffic congestion by 2020. The Roadmap includes the study of accuracy and contents of vehicular travel information and verification of its effects (by 2014); the review and implementation of measures for full-scale prevalence of Green ITS services (by 2020); and the review of vehicle-to-infrastructure cooperative systems for developing an auto-pilot system on expressways (from 2012 to 2020).</p> <p>The Japanese MLIT has stressed the importance of communication between vehicles and infrastructure for the introduction of C&AV. Thus, MLIT introduced the "ITS spot" technology in 2009, which consists of three basic services that are made available as an all-in-one system by high speed, high volume road-to-vehicle communications. The three services are:</p>

Country	Analysis findings
	<p>(1) wide-range road traffic information, where car navigation systems can search different road options and select the fastest route based on available information; (2) safe driving support, where ITS spots provide road traffic information regularly, including traffic safety issues; and (3) electronic toll collection (ETC), where ETC services can be enjoyed with a compatible car navigation system. These ITS spot services have already involved 16 automobile, navigation systems and on-board unit manufacturers.</p> <p>The first public road test of an automated vehicle on a Japanese highway was conducted in November 2013 with Prime Minister Shinzo Abe in the car. The Nissan Leaf was approved for use on the public road in September 2013.</p> <p>In 2014, Japan launched the Cross-Ministerial Strategic Innovation Promotion Program (SIP), a nation-wide project for science, technology and innovation led by the Council for Science, Technology and Innovation. The SIP focuses on 10 themes that address the most important social problems in Japan and look to contribute to the recovery of the Japanese economy. One of the 10 themes focuses on Automated Driving Systems (ADS).</p> <p>Within ADS, five levels of automation distributed amongst four stages are used to describe Japan's current status in automated driving. In 2014, Japan was at Level 1 (part of the Safe Driving Support Systems stage), where available technology provides acceleration, steering or breaking over a limited period of time. According to the ADS timeline, Japan expects practical adoption of Level 3 (automated driving systems providing all operations, with the driver only acting in emergencies) to be a reality by the first half of 2020s, with Level 4 (no requirement for driver intervention) being achieved during the second half of 2020s.</p> <p>Japan's ADS theme encompasses different fields of technology needing additional developments, such as road-to-vehicle/ inter-vehicle communications, advanced map information, signal information, traffic restriction information, and information related to driving conditions. It also focuses on other activities, including creating predictive information through ITS, improving sensing capabilities, developing driver models through performance analysis, improving system security, and investing in international cooperation and standardization.</p> <p>According to the ADS programme director, Hiroyuki Watanabe, the programme's ultimate goal is to eliminate traffic-related deaths. As this is a global concern, the programme also wants to move forward with international standards and the global public acceptance of this technology. ADS aims to build the safest traffic infrastructure in the world through public-private cooperation by developing a next-generation urban transportation system that includes public road systems. Hiroyuki Watanabe has mentioned that it is of significant importance to create a research structure that includes the participation of national and local governments and private enterprises for improving regional traffic management and for implementing practical next-generation transportation systems. Japan has great confidence in automated driving and expects that these vehicles will be available in the very near future, as early as 2020 for the Japan Olympic Games.</p>
South Korea [29], [30], [31], [32], [33], [34]	<p>The South Korean government projects smart vehicles as the next growth engine of the country, as it combines two strong industries: vehicles and IT. Innovation-related strategies are developed and launched under the cooperation of the Ministry of Education, Science, and Technology (MEST), linking universities and research institutes, and the Ministry of Knowledge Economy (MKE) linked to the industry. MKE has the responsibility of attracting Foreign Direct Investment (FDI) for many industries (including vehicles), as well as to promote the development of several high-tech industries, such as semiconductors and IT. In addition, the Institute for Information Technology Advancement (IITA), a support institute of MKE, provides strategic intelligence to the IT sector.</p> <p>Other ministries have been involved in measures related to smart cars. The Korean Ministry of Land, Infrastructure and Transport (MOLIT) launched 'The seventh National Transportation Safety Basic Plan (2012–2016)' in September 2011, with approximately €600,000 of funding. One specific goal of the Plan focused on reducing traffic mortality to 3,000 in 2016 (compared to 5,200 in 2011).</p> <p>Moreover, the Motor Vehicle Management Bureau, under MOLIT, included Automated Vehicle (AV) as one of the New Growth Sectors in 2016. A dedicated division – Advanced Motor Technology Division – has been installed, together with the AV Expert Forum. A dedicated Commercialisation Support Policy was launched that aims to reach partial commercialisation by 2020, and securing world-class technology by 2026. The Policy aims to promote AV for safety improvement and a new growth source, through four pillars of support: institutions, infrastructure, technology and industry. The Government and experts consider that AV will</p>

Country	Analysis findings
	<p>have a positive impact on reducing traffic fatalities, creation of jobs, and improving living standards.</p> <p>A 'National ITS Master Plan' was first developed in 1997 and presented basic directions for the efficient development of ITS projects. In 2000, a 'National ITS Master Plan 21' for 20 years was prepared, running up to 2020. The Plan includes goals, systems, procedures and directions for project development, and also basic directions and financing plans. The Plan consists of seven ITS service sectors, 18 services, 62 unit services, and presents goals and strategies in three steps. Jointly with the Intelligent Transport Society of Korea (ITS KOREA), MOLIT launched the ITS Master Plan 2020. The priorities covered by this programme consist of five core issues, namely: (1) people-centred city, (2) dynamic global city with a strong job market, (3) vibrant cultural and historic city, (4) lively and safe city, and (5) stable housing and easy transportation, community-oriented city. With regard to the transportation aspect, it allocates approximately 3.25 billion EUR and aims to reach zero traffic accident deaths by 2030 through three stages: (1) vehicle-to-infrastructure (V2I) based on safety on expressways; (2) V2I and vehicle-to-vehicle (V2V) based on safety in metropolitan areas; and (3) V2V + vehicle-to-pedestrian (V2P) based on safety in urban areas.</p>
China [35], [36], [37], [38], [39], [124]	<p>The Ministry of Science and Technology (MOST) in China, together with a number of other Ministries and authorities, established the National ITS Coordination and Management Team and Office in 2000, aiming to jointly plan and manage R&D of general technologies, as well as strategy development for sectors such as road, railway, water transportation, civil aviation, among others.</p> <p>Following this step, a number of national research centres linked to Ministries and public research institutes and universities were established, such as the National Intelligent Transport Systems Centre of Engineering and Technology (ITSC), The Centre of National Railway Intelligent Transportation System Engineering and Technology (RITS), and the Centre of National Traffic Management Engineering and Technology.</p> <p>The Chinese Government sees automated driving as a reality by 2020. As China is not a signatory of the Vienna Convention, it was able to start deployment of autonomous vehicles earlier than most countries. Yet, no specific regulations on autonomous cars have been issued. Near Beijing, in the city of Tianjin, first tests with driverless GM EN-V 2.0 vehicles took place in 2014. It has also been reported that Baidu, the Chinese internet search engine group, started developing a 'highly automated' car in 2014. It has also been reported that the Research Institute of Highway Ministry of Transport will work jointly with Baidu on issues relating to intelligent driving, transportation safety, research into laws and regulations and technology standards. Baidu is one of a few organisations to have been given permission by the government to test automated driving in China. And, given the level of congestion in cities across China, the market for the technology could be vast.</p> <p>Although this joint effort is important, multiple ministries have responsibilities on the supervision of C&AD. This reduces clarity over who regulates what and in what way. Thus, it is considered that China still needs to develop a national framework for autonomous vehicles. Moreover, it is believed that this framework can also help with the limitations on road testing, legal liability, development of technical standards and awareness on AV, among others.</p>
France [40], [41], [42], [43], [44], [45]	<p>The C&AD sector is considered a core sector-based initiative for the industrial development in France, encompassed within the New French Industrial Plan (prepared in 2013). Previous to this Industrial Plan, France prepared groundwork on Intelligent Transport Systems (ITS), highlighting several ITS policies in France (e.g. road information, environmental protection, driving aids, etc.).</p> <p>In the New French Industrial Plan, the Autonomous Vehicles Plan (AVP) is a roadmap for the sector that gathers high level representatives of key stakeholders from the French car industry (e.g. Renault/Nissan). The AVP aims to consolidate the French position in three distinctive aspects related to the C&AD sector: (1) being a testing field for AV, (2) being a Centre of Excellence for related C&AD technologies, and (3) being a major player in critical system safety domain.</p> <p>The AVP expects to focus, up to 2020, on the full deployment of shared fleets, shuttle platooning or intelligent parking of vehicles on private and industrial roads. From 2020 onwards, it will focus on open road deployments (such as in highways or peri-urban itineraries). The AVP addresses almost the entire C&AD innovation value chain (from TRL 2 to 9). Up to 2015/2016, priority has been given to designing the regulation/standards and safety frameworks, and setting the conditions for launching technological research and large scale</p>

Country	Analysis findings
	<p>experimentation projects.</p> <p>A cross-cutting policy and strategic priority for France within the C&AD sector is to promote the involvement of private sector players, both in terms of investment and research, and ultimately for a collaborative public/private approach to the sector.</p> <p>The French government is an essential actor in actively supporting the development of C&AD in France. The core activities of the French government in the national C&AD policy framework are related to deploying research support schemes, either for basic or applied research, and preparing mechanisms such as private-public partnerships.</p>
<p>Germany [45], [46], [47]</p>	<p>Germany's main public policy instrument is the "Strategy for Automated and Connected Driving" adopted by the government in 2015. The strategy sets three core objectives: (1) consolidate Germany as a leading provider of the C&AD sector, thus creating a regulatory framework that enables research, development and production related to Mobility 4.0 technologies; (2) turn Germany into a leading market in C&AD, both in the production of C&AV, as well as in the use of these vehicles; (3) deploy C&AV in real situations, based on two structural scenarios: (i) highly automated cars in less complex traffic environments; and (ii) fully automated vehicles in low-speed and complex traffic environments.</p> <p>The Strategy identifies the impacts that the C&AD sector could potentially have in terms of traffic efficiency, road safety and emission reductions. It also highlights that C&AD may ultimately lead to a more competitive automotive industry in Germany, and acknowledges Germany as a leading place for business innovation. The Strategy acknowledges the cross-cutting nature of the C&AD sector and defines five generic priority areas: (1) Infrastructure: including digital infrastructure and standards for intelligent roads; (2) Legislation: including international and national regulatory framework, driver training, type approval and technical inspection; (3) Innovation: the "Digital Motorway Test Bed" initiative; (4) Interconnectivity: including mobility data and spatial data, interlinking of traffic signs and high-precision map systems; and (5) Cybersecurity and data protection, including standardization measures.</p> <p>This Strategy is coordinated and strategically monitored at State secretary level (Federal Ministry of Transport and Digital Infrastructure) with close coordination between the Federal Ministry of Transport and Digital Infrastructure and other Government departments. The Strategy establishes a Programme group and specific teams, as well as an "Automated Driving Round Table" (ADRT), composed of experts from public and private sectors that will actively support its implementation.</p> <p>The "Report on the Need for Research", published by the ADRT, defines the basic and applied research priorities and needs for C&AD. In line with the five aforementioned priority areas, it further identifies four research clusters under which research needs are grouped: (1) human-machine interface; (2) function, safety and validation; (3) road infrastructure and traffic; (4) social aspects.</p> <p>In parallel to the National Strategy, several States also have significant ambitions in developing C&AD technology and may have their own strategies and activities beyond the Federal level.</p>
<p>Italy [27], [48]</p>	<p>Following Directive 2010/40/UE, which set the general framework for ITS diffusion at the European level, Italy identified ITS systems as an innovative measure for the transport sector and for promoting the economic growth of the country. An interministerial Decree was enacted by the Italian government in February 2013, and served as the operational and methodological basis for the development of the National Action Plan (NAP) for ITS, later published in 2014.</p> <p>The NAP defines four priority settings: (1) optimal use of data concerning roads, traffic and mobility; (2) consolidation of ITS-related services for traffic management and goods transportation management; (3) application of ITS for road and transport safety, and (4) connection among vehicles and transport infra-structures. These four priority settings are aligned with those initially defined by Directive 2010/40/UE.</p>
<p>Spain [45], [49], [50]</p>	<p>Spain does not have a single ITS-related policy framework. Two different ministries (Ministry of Transport and Public Works and Ministry of the Interior) have competences in the area and transport-related public entities of the Autonomous Communities may also have responsibilities in this domain. Thus, for ITS, the following policy instruments are of relevance:</p> <ul style="list-style-type: none"> • Infrastructure and Transport Strategic Plan (SPIT): SPIT acknowledges ITS as

Country	Analysis findings
	<p>an important instrument/tool to facilitate technological and institutional cooperation for the management of transport-related infrastructures.</p> <ul style="list-style-type: none"> • National Plan for ITS Consolidation: This Plan sets the conditions for a full-scale deployment of ITS addressing: (1) road safety; and (2) traffic management improvement (and, as a result, improving mobility and reducing environmental impacts). The Plan contains 14 priorities, which can be grouped into the following topics: (1) improvement to road safety (including, for example, driving aid systems and vehicle-infrastructure and vehicle-vehicle cooperative systems); (2) improvement of systems and information services for users (including, for example, traffic data capture); (3) improvement of access to electronic administration; (4) support to intermodality; (5) improvement of the competitiveness of Spanish transport companies; (6) creation of a Spanish ITS architecture. • Strategic Plan for Road Safety (SPRS): SPRS sets the Spanish priorities for traffic-related topics up to 2020, focusing on two main goals: (1) road safety; and (2) sustainable mobility. Most of the performance indicators defined for SPRS are related to the first goal, including aspects related to the reduction of fatalities. ITS is regarded as a tool to achieve specific objectives related to: (1) protection of vulnerable road users; (2) safe mobility in urban areas; (3) safety of motorcycle drivers; (4) improving road safety on conventional roads; and (5) improving driver's behaviour for alcohol drinking and speeding. • Spanish Strategy of Sustainable Mobility (SSSM): SSSM encompasses five fields, one titled "territory, transport and infrastructures planning." Within this field, the progressive implementation of ITS is set as a priority to meet the following goals: (1) improve the safety of the passengers or merchandise affected by transport and traffic; (2) optimise the exploitation of transport resources; and (3) harmonise and standardise definitions of compatibilities between systems and presentation clarity for the user. • Royal Decree 662/2012: In addition to adopting the EU Directive 40/2010 on ITS-deployment, it also establishes additional clauses on personal data protection.
Sweden [45], [51], [52]	<p>The Swedish Transport Agency has launched a pilot study aiming to understand the need for legislation modification in order to allow for automated driving. The result of the study suggested that: (1) the public sector needs to be more engaged and more proactive in terms of developing self-driving vehicles, and (2) needs to create the necessary infrastructure and regulations.</p> <p>Although no specific testing regulations have been specified, testing is allowed in Sweden. Private and public players have urged for clear legislations to be launched regarding conditions under which testing can be carried out, namely to facilitate a number of test schemes, such as "Drive Me" (scheduled for the beginning of 2017).</p> <p>C&AD has been further explored through the "Drive Sweden" initiative, which not only looks at automated driving and mobility from a technological and scientific lens, but also considers it an innovation and revolution of the life style, social development, and a platform for engagement of public and private sectors. The Swedish government aims to foster the next generation of mobility through the programme, whose partners have been engaged in more than 10 projects related to smart mobility.</p>
United Kingdom [45], [53], [54], [55]	<p>The UK government has a long history of building a strong automotive innovation environment. In 2013, the R&D investment in the sector reached approximately €2 billion. The same year, the UK National Infrastructure Plan led a review of relevant legislations and regulations to make sure that automated vehicles could be tested on UK roads. The review was done alongside a proposal to invest approximately €15.5 million in collaborative R&D projects for C&AD technologies in the UK.</p> <p>The UK has provided a leading testing environment for CAVs. It has been proved to be able to "test anywhere" in the UK, which greatly facilitates the demonstration and deployment of CAV. Due to its challenging and diverse traffic, road and weather conditions, the UK is considered an ideal location for testing and developing CAV technologies.</p> <p>The UK's efforts in the sector have continued through the latest review led by the Department for Transport (DfT): "The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies". The objective of this review is to ensure the implementation of relevant measures for highly and fully automated vehicles to be tested on UK roads. The result of the review showed that the existing legal and regulatory framework would facilitate</p>

Country	Analysis findings
	<p>real-world testing of automated cars in the UK, as long as a test driver was present to ensure their safe operation and that the car follows road traffic laws.</p> <p>Although new regulations are not necessary at this stage, amendments and improvements/further clarification are considered to be necessary. This has included the definition of various terms (e.g. "safe use of vehicles"), requirements of appropriate insurance and the role of the test driver to ensure safety during testing, the publishing of a Code of Practice for the setting of standards for manufacturers, organisations and test drivers (including requirements for test drivers, data recorder, and vehicle technology, cybersecurity, and road infrastructure standards), and encouraging and supporting the provision of education materials on testing for the public.</p> <p>In addition to the legislation on testing, the UK has also started to amend regulations concerning production and marketing of C&AV which are foreseen to be completed by 2018.</p>
<p>EUROPE [56], [57], [58], [59]</p>	<p>Europe has launched several initiatives and strategies for promoting C&AD. One of the most relevant initiatives dates back to December 2008, when the EC adopted an Action Plan for the Deployment of Intelligent Transport Systems (ITS) in Europe. The Action Plan aimed to accelerate and coordinate the deployment of ITS in road transport, including interfaces with other transport modes. The Action Plan identified six priority areas: (1) optimal use of road, traffic and travel data; (2) continuity of traffic and freight management ITS services on European transport corridors and in conurbations; (3) road safety and security; (4) integration of the vehicle into the transport infrastructure; (5) data security and protection, and liability issues; and (6) European ITS cooperation and coordination. The Action Plan aimed to mobilise Member States and other stakeholders, as well as combine resources and instruments to deliver added value to for the EU.</p> <p>Another initiative was Directive 2010/40/EU on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport. This initiative was supported by DG Mobility and Transport (lead), DG Communications Networks, Content & Technology, DG Research & Innovation, DG Enterprise and Industry and DG Climate Action. This legal framework was adopted in 2010 to accelerate the deployment of innovative transport technologies across Europe, as well as coordinating the implementation of ITS in Europe. As part of this framework, the EC was required to adopt specifications (i.e. functional, technical, organisational or services provisions) to address compatibility, interoperability and continuity of ITS solutions across the EU. The directive defined four key priority areas: (1) optimal use of road, traffic and travel data; (2) continuity of traffic and freight management ITS services; (3) ITS road safety and security applications; and (4) linking the vehicle with the transport infrastructure. The Directive presented six priority actions: (1) the provision of EU-wide multimodal travel information services; (2) the provision of EU-wide real-time traffic information services; (3) data and procedures for the provision, where possible, of road safety related traffic information; (4) the harmonised provision for an interoperable EU-wide eCall; (5) the provision of information services for safe and secure parking places for trucks and commercial vehicles; and (6) the provision of reservation services for safe and secure parking places for trucks and commercial vehicles. As part of this Directive, Member States had to submit to the EC a report (by August 2011) on their national activities and projects regarding the aforementioned priority areas, a five-year plan (by August 2012) with information on envisioned national ITS actions, and reports (by August 2014) on the progress made since the initial report.</p> <p>As recently as 2016, the European Commission adopted a European Strategy on Cooperative Intelligent Transport Systems (C-ITS). The objective of the Strategy is to facilitate the convergence of investments and regulatory frameworks across the EU, in order to support the deployment of C-ITS services as early as 2019. Among other points, this includes the adoption of a suitable legal framework at the EU level by 2018 to guarantee legal certainty for public and private investors, to make EU funding available for projects, the continuation of the C-ITS Platform, and international cooperation with other regions of the world on cooperative, C&AV.</p> <p>Also in 2016, Member States signed the Declaration of Amsterdam, an agreement on Cooperation in the field of connected and automated driving. The Declaration served as a first political message on the introduction of C&AV in the EU. The Declaration highlights the need for a shared European strategy on C&AD, identifying various shared objectives and topics for a joint agenda. Equally important, the Declaration lists various actions to be carried out by Member States, the European Commission and Industry stakeholders. Key items of the Declaration include the definition of coherent rules, the use of data, data privacy and</p>

Country	Analysis findings
	<p>protection, C-ITS communication and infrastructure, security, public awareness, common definitions and international cooperation.</p> <p>Other European initiatives, namely at a policy level, include GEAR 2030¹³ (DG GROW), which is a High Level Group set up in October 2015 to discuss the future of the automotive sector, the Strategic Transport Research & Innovation Agenda (STRIA)¹⁸ (DG RTD) and the C-ITS Platform¹¹ (DG MOVE).</p>

2.1.2 Comparative analysis of general C&AD strategies

At a macro level, Europe is mostly at par with the selected third-countries in existing initiatives that aim to promote C&AD. Europe launched strategies for ITS as early as 2008, which is at a similar level to the C&AD initiatives developed in third-countries. In 2008, Europe launched the Action Plan for the Deployment of ITS; in 2010 it launched the Directive 2010/40/EU (which required Member States to develop their national strategies for ITS); and in 2016, it launched the Declaration of Amsterdam and the European Strategy on Cooperative ITS (C-ITS). Despite these initiatives and from the review presented in 2.1.1, there is a dispersion of focus regarding C&AD at the Member State level.

ITS as the backbone for C&AD

Initially analysing ITS, which can in part be considered a basis for C&AD, EU Member States (including those addressed in this study) enacted Directive 2010/40/EU and developed five-year plans for ITS in their countries. This was an important step to put *intelligent transport* on the Member States' agendas.

France's plan included the provision of tools and solutions to optimise transport modes, improve safety, mobility and the environment. Germany's plan addressed the optimum use of road, traffic and travel data; the continuity of the ITS services in the fields of traffic management and traffic information; and ITS applications to enhance the efficiency of transport, road safety and security, and environmental sustainability. Italy's plan emphasized the use of road, traffic and travel data; continuity of traffic and freight management ITS service; and the linking of vehicles with transport infrastructure. Spain's plan included 14 priorities – covering advanced safety systems, including the vehicle and its surroundings, and improving data capture and traffic monitoring services, among others. Sweden's plan focused on the development of a sustainable, secure and safe transport system, useful for individuals, companies and society; facilitating multimodal journeys and transport from door to door; and strengthening the competitiveness of the Swedish industry and contributing to new job opportunities. Lastly, UK's plan highlighted the optimal use of road traffic and travel data; continuity of traffic and freight management services; ITS road safety and security applications; and linking the vehicle with transport infrastructure.

However, these national ITS plans had limited detail on C&AD. Of the six Member States, only Italy, Sweden and UK included detailed identification of C&AD, and with a greater focus on 'connected' than 'automated'.

Outside of Europe, the USA, Japan and South Korea all have ITS plans underway. In the USA, the Intelligent Transportation Systems Joint Program Office (ITS JPO) oversees C&AD in the country, and currently has a plan ongoing until 2019. Japan has an ITS Roadmap in place as of 2011; and South Korea first proposed a 'National ITS Master Plan' back in 1997, followed by the 'National ITS Master Plan 21' in 2000, which would extend until 2020. Of the four third-countries, China's ITS strategy is less evident, despite the establishment of a number of dedicated structures to promote ITS.

Regulations to enable testing of C&AV

Despite Member States' dispersion of focus regarding C&AD, there is one area that has been addressed by the majority of Member States: the revision of legislation and/or regulations to enable the testing of C&AV. Within Europe, this has taken place in France, Germany, Spain, Sweden and the UK. The UK was the first to move forward (in 2013) with a revision in legislation and regulations to support road testing.

¹⁸ STRIA: <http://ec.europa.eu/programmes/horizon2020/en/news/towards-strategic-transport-research-innovation-agenda-stria>

It appears that the UK leads by example within the EU, providing an extensive testing environment for C&AV. This facilitates the demonstration of vehicles, which is important for future deployment. Moreover, and considering its diverse traffic context, the UK is considered an ideal location for C&AV testing. Recent regulations facilitate real-world testing, but require a test driver to ensure safe operations and that the car operates within existing road traffic laws.

In France, Germany and Italy, government authorities have recognised the importance and impact of C&AD on the national economy and have moved forward with plans and roadmaps with specific objectives focused on promoting and testing C&AV. In France, the involvement of private car manufacturers is a priority to help consolidate France's position in the sector, as well to support the testing of vehicles. In Germany, the revision of regulations is one of many key priorities for the C&AD sector. However, the fact that many German States also have their own ambitions for developing and deploying C&AD beyond the Federal level is relevant as it may contribute to fragmentation. Likewise, Spain lacks a single regulatory framework as two different ministries play a role in transport. However, regulations and various policy instruments do favour testing of AV on national roads. Sweden has assessed the need to move forward with changes to regulations to enable C&AV testing, which are expected to take effect in 2017.

In the Netherlands, the National government has plans to initiate amendments to international regulations and has launched a study on potential issues, such as liability, driving skills requirements, traffic data and the possible impact on infrastructure. This plan also included a proposal to extend exemption rules to allow the large scale testing of C&AD, which was later approved. In July 2015, the Dutch Ministry of Infrastructure and the Environment opened public roads to large-scale tests with self-driving passenger cars and trucks, further improving the development of C&AD in the country [60].

Thus, and while some Member States are further ahead than others, there is a clear overall objective of ensuring the legal conditions for testing. This approach ultimately intends to ensure higher safety standards on public roads – both for the users of automated vehicles and for the drivers of other vehicles. The national strategies tend to address concerns and challenges faced by the deployment of C&AD-related technologies in a real world context.

Outside Europe, the four third-countries are at different levels regarding legislation and regulations for testing. In the USA, the United States Department of Transportation (USDOT) is responsible for the regulatory and policy rulings for C&AD. Plans exist up to 2019 that favour the implementation of C&AD, which are based on existing progress, including at the level of testing. However, the USA faces the challenge of harmonising federal and state level regulations, and overcoming the fragmentation of its 50 states and the impact this has on all aspects of the C&AD value chain, testing included [124].

Japan is well underway in this the revision of regulations, having established a common roadmap involving various Ministries. Similar to Europe, safety is a key priority for Japan within its focus on Automated Driving Systems (ADS) and expects to have autonomous vehicles on roads as soon as the 2020 Olympic Games. South Korea has identified smart vehicles as the motor for their future growth, and has also moved forward with regulatory changes that favour C&AV. ITS in South Korea goes back as far as 1997, which shows the country's full commitment to the sector, including partial commercialisation of AV as soon as 2020. China's current legislation requires the presence of drivers in the vehicle, which impacts the introduction of C&AV. However, special exceptions are possible.

Still outside of Europe, the Singapore Land Transport Authority (LTA) has since 2015 been facilitating C&AD trials by various technology developers at designated locations. In February 2017, Singapore enacted a more rigorous legislation amendment in support of the development of C&AD trials [61].

The fact that the USA and UK have not signed the Vienna Convention, which imposes some limitations to C&AD (see Section 2.3), has likely benefited the revision of regulations and consequently helped drive the testing of C&AV. China, however, while having taken advantage of fewer constraints for C&AD, has yet to define a detailed strategy for testing vehicles.

Technology for the development of C&AD

The development of technology is imperative for the success of C&AD and is transversal to the various strategies developed at EU level. The Action Plan for ITS, the Directive, the Declaration of Amsterdam and C-ITS presuppose the need for further advances in technology. All key areas or priorities of these strategies require improved technology.

All studied EU Member States reference technology development in their ITS plans (under Directive 2010/40/EU). However, details on how technology will be developed or the specific types of technology are less evident in Member States' individual C&AD strategies.

In France, there is reference to the development of technologies in the roadmap that goes up to 2020 and beyond, but specific details are limited. In Germany, information on technology focuses mainly on the importance of interconnectivity, and the openness of mobility and special data. In Sweden, the Drive Sweden project has been the main project through which new technologies have emerged.

Considering the third-countries, most of the information that exists about technology also relates to ITS, with limited information on technology at the C&AD level (further discussed in Task 2).

Improving market conditions

There is limited focus on the improvement of market conditions for the development and deployment of C&AD, with exception to promoting changes in legislation and regulations (as previously discussed), in the national strategies being implemented. This is evident for Europe and for the studied third-countries.

However, the Declaration of Amsterdam does propose a number of objectives that can be facilitators for improving the market conditions for C&AD. These are: (1) adopting a "learning by experience" approach, including, where possible, cross-border cooperation, sharing and expanding knowledge on connected and automated driving and to develop practical guidelines to ensure interoperability of systems and services; and (2) to support further innovation in C&AV technologies to strengthen the global market position of the European industry.

Thus, it is expected that as Member States' public and private stakeholders implement the measures foreseen within the Declaration of Amsterdam, there will be an overall improvement in the respective market conditions.

Sustainability of the C&AD sector

Although there are limited references to improving market conditions, it is clear that many countries consider that cooperative intelligent transport systems and C&AD are the future of transport. Thus, it would be expected that these countries define strategies to ensure the sector's long-term sustainability. However, only a limited number of Member States have shown forethought for the market – in particular France and Germany. France's Autonomous Vehicles Plan focuses up to 2020 and beyond, namely in terms of road-deployment of vehicles. Germany, while not specifying dates, has stated that it intends to continuously invest in research to ensure the success of C&AD.

Outside of Europe, third-countries appear more focused on ensuring the sustainability of the sector. Within the USA, it is expected that research on C&AD continues to be a priority after the end of the current ITS Strategic Plan set for 2019. Japan expects to have automated vehicles operating during the 2020 Olympic Games and will likely expand on this experience. Furthermore, many of the Japanese existing initiatives aim to ensure the sustainability of ITS beyond 2020. In South Korea, the C-ITS Master Plan proposes a long-term vision for C&AD, with various actions going beyond 2030. In China, with the implementation of various dedicated structures (e.g. research centres and offices), C&AD appears to be a long-term priority. In Singapore, while the government has not set a specific target for C&AD deployment, NuTonomy has aimed to provide self-driving taxi services by 2018 [62].

Europe has developed important plans to ensure the deployment of C&AD and its long-term sustainability. Again, the Declaration of Amsterdam is an important aspect in this regard. By proposing to work towards a coherent European framework for the deployment of interoperable C&AD, by fostering cross-border cooperation, and by supporting the necessary innovation in technologies to strengthen its market position, Europe has created an important basis for the sustainability of the sector.

Public awareness and acceptance

The sustainability of the sector can only be as strong as the acceptance and interest of those that will use C&AV. There is limited evidence that Member States have invested sufficiently in engaging the public to create awareness and acceptance. Among the Member States studied, there is no indication of a specific strategy or initiative that actively involves users.

Outside of Europe, the USA and Japan show initiatives of this nature. The USA's ITS Strategic Plan has identified communication and education activities to facilitate awareness and acceptance as a priority.

In Japan, it is considered that public acceptance is just as important as the actual technology necessary to deploy C&AD. With China, it is relevant to note that despite the potential size of its market, little work has been done in public awareness.

The relative lack of initiatives for public acceptance and awareness in Europe has not gone unnoticed. Within the Declaration of Amsterdam, one of the key items of the joint agenda involving European stakeholders is to raise awareness and increase acceptance and interest in C&A vehicles and respective technologies.

Ensuring the necessary skilled labour supply

In order to develop the required technology, it is important that Europe and the rest of the world have the required skilled labour supply. However, similar to public awareness and acceptance, specific initiatives are scarce.

Outside of Europe, and specifically in South Korea, there is indication that undergraduate and graduate courses, as well as training programmes, are expected to be launched to specifically prepare autonomous vehicle technicians and experts.

Regarding specific competences, the main European challenge is related to acquiring competences and skills related to artificial intelligence, an area where some non-European competitors are strong (e.g. USA and China) are particularly strong.

Infrastructure and conditions for C&A vehicles

Once legislation has been revised, vehicle technology is matured, skills are available, and the public has accepted the idea, it is important that there is the required infrastructure to bring C&AV onto the open road.

There are some strategies and initiatives that focus on infrastructure and conditions. In Europe, only Germany has emphasized the importance of developing the required digital infrastructure for C&AD. Some Member States have also developed infrastructure for testing automated vehicles, but infrastructure still has to be developed outside of the testing framework.

Outside of Europe, Japan has introduced specific ITS infrastructure. Japan's ADS programme also emphasizes the need for the development of traffic infrastructure. South Korea is also preparing a pilot that focuses on infrastructure and communication. In China, it is considered that improvements to infrastructure are required [124], but there are limited references to strategies focused on this issue.

With C&AD the discussion of infrastructure goes beyond traditional road network. C&AD infrastructure includes all the infrastructure that guarantees the vehicle, independently of the level of automation, is able to communicate with the other nearby vehicles on the road. It includes the wireless and mobile networks that ensure the transmission of vehicle information to dedicated infrastructure, which also has to collect, process and store this information in security.

Again, the Declaration of Amsterdam is likely to put the issue of infrastructure on Member States' agendas. One of the key agreement points is vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. A further issue is ensuring the security and reliability of C&AV communication and systems. Thus, it is expected that as C&A vehicles come closer to the market, the necessary investment in infrastructure will also take place.

2.1.3 SWOT analysis of general C&AD strategies

Table 2: SWOT Analysis for EU on General C&AD strategies

Strengths		Weaknesses	
Main Point	Explanation	Main Point	Explanation
Existence of a broader policy and strategic framework based on ITS	<ul style="list-style-type: none">Despite the absence of a single framework for C&AD, all the studied EU countries have developed an Integrated Transport Systems (ITS) Plan.For some countries (e.g. Italy and Spain), establishing this framework was important for additional work in C&AD.For Europe, these broader plans may facilitate the understanding of C&AD as a cross-cutting sector and as a relevant sector to foster competitiveness, industrial development and innovation nationwide.	Absence of comprehensive and integrated strategic and policy instruments for C&AD	<ul style="list-style-type: none">Non-EU countries (e.g. Japan and South Korea) have general strategic and policy frameworks for the development of the C&AD sector.Strategic and policy frameworks allow a clear definition of long-term goals, priorities and actions for the competitiveness of the national sector.Within the EU, only Germany and France have comprehensive frameworks.The European strategic and policy framework for C&AD is rather fragmented.
Emphasis on regulations for safety	<ul style="list-style-type: none">Strategies on regulations and standards focus on setting the rules/ conditions for testing automated vehicles.European countries appear to implement a more human-centred approach to C&AD.Non-European countries appear to implement a more functional approach (economically- , industrial/ technologically- or innovation-focused).		
Opportunities		Threats	
Main Point	Explanation	Main Point	Explanation
Development of a European Roadmap on C&AV as a complementary strategy for the sector	<ul style="list-style-type: none">The absence of common strategic guiding principles for the C&AD sector has led European countries to select different priorities for the sector at the national level.Defining a common EU Roadmap for the sector would allow the harmonization of standards and procedures in EU Members States and also potentially foster the complementary integration of national policy frameworks and strategic priorities.	Budget restrictions may hinder investment capacity to boost C&AD	<ul style="list-style-type: none">The progress on research and innovation on C&AD is considered to demand a significant level of investment.Challenges within each EU Member-State can hinder their investment capacity which can ultimately affect the competitiveness of European countries in C&AD innovation.
New opportunities for the logistic and transport sector	<ul style="list-style-type: none">C&AD technology is expected to have a big impact in the logistic (e.g. loading, transport) and transport (e.g. taxis) value chain.C&AD can bring increased safety and productivity to both sectors (i.e. logistics and transports).	Segmentation of the EU market	<ul style="list-style-type: none">Member States’ interests and own capacity can cause segmentation at various levels (availability to fully change legislation, capacity to offer required road and technical infrastructure).Full deployment of C&AD will depend on each Member State’s readiness level.

STRENGTHS

Existence of a broader policy and strategic framework based on ITS

Despite the absence of a single strategic and policy framework for C&AD, many European countries, under Directive 2010/40/EU, have enacted a comprehensive framework for Integrated Transport Systems (ITS). All EU countries addressed in this study enacted the Directive and prepared five-year plans in August 2012, which would last until 2017.

As discussed in Section 2.1.2, the studied Member States all have their own plans that address various ITS issues (e.g. safety, mobility, transport infrastructure, among others). While only three of the six countries make some reference to C&AD, this is still a strength for the EU's competitiveness as the Directive put intelligent transport (a basis for C&AD) on Member States' agendas. However, outside of Europe, the USA, Japan and South Korea also have ITS plans underway. South Korea, particularly, had a National ITS Plan as early as 1997.

Thus, despite ITS (and by extension, C&AD) being somewhat 'novel' for these EU countries, one of Europe's strengths is that there is a comprehensive framework for ITS under which C&AD is addressed. For some countries (e.g. Italy and Spain), this broader framework has served as an important stepping stone for additional investments in C&AD. For Europe as a whole, this encompassment may facilitate the understanding of C&AD as a cross-cutting sector (e.g. due to the connections with ICT, mobility, transport, etc.) and as a relevant sector to foster competitiveness, industrial development and innovation, ultimately leading to the deployment of policy options.

Emphasis on regulations for safety

Member States have moved forward at their own pace with their own strategies and initiatives for C&AD. One of the issues addressed by the majority of the studied Member States is the revision of legislation and regulations, particularly on the rules and conditions for testing automated vehicles on roads.

It appears that the UK was the first to move forward (in 2013) with a revision in their legislative framework, with the remaining EU countries having proposed or introduced revisions afterwards. While these revisions may have come later than desirable, they clearly mark a favourable change for promoting C&AD. In fact, and as previously discussed, the UK appears to lead by example, providing an extensive testing environment for C&AD. In other Member States, and with or without the support of private entities, revisions are underway to facilitate testing. In parallel, these revisions also aim to increase safety of the driver and pedestrians. Outside Europe, the four studied countries are also equipped with a favourable national legislation and regulations for testing, with exception to China where specific regulations are not evident. A visible strength is Europe's tendency to have a more human-centred approach to C&AD in their strategies (i.e. the importance of driver and pedestrian safety through testing). This somewhat contrasts to the more functional approach (economically-, industrial/technologically- or innovation-focused) in the non-European countries, as developed in their strategies.

Experts corroborated this strength related to regulations, standards and the setup of rules/ conditions for testing automated vehicles (Question 1A.2). Specifically, more than 75% of experts indicated that 'sustainability and regulation' are either a 'very important' or 'important' item for deploying C&AD. When asked about the advantages of C&AD and for whom (Question 1A.3), 'safety', 'reduction of crashes', 'reduction of traffic incidents' or similar was referred by all respondents. Therefore, there appears to be a link between the importance of promoting sustainability, regulation and technology development while privileging the safety of citizens, whether drivers or pedestrians.

Experts (majority European), when questioned about the advantages of C&AD (Question 1A.3), also identified items related to human wellbeing: increased productivity, social inclusion (for those who cannot drive for any particular reason), greater mobility for people, among others. Environmental benefits were also identified as an advantage, although this requires focusing on the move to electric vehicles.

It should be noted that safety is also a priority for non-European countries, as demonstrated by the example of Japan and its objective of reducing traffic-related deaths.

WEAKNESSES

Absence of comprehensive and integrated strategic and policy instruments for C&AD

Non-European countries including Japan and South Korea have established a general strategic and policy framework for the development of the C&AD sector. In Japan, there is the ITS Roadmap and Research and Development Plan, which studies the accuracy and data of vehicular travel, vehicle-to-infrastructure cooperative systems for developing an auto-pilot system on expressways, and the implementation of Green ITS services. In South Korea (active in the sector as early as 1997) the National ITS Master Plan 2020 identifies the objectives, procedures and financing plans for ITS and C&AD. In the USA, despite the ITS Strategic Plan (ITS-SP) 2015-2019 having two key priorities, addressing five main themes and six programme categories, it still faces the challenge of overcoming the fragmentation of 50 states and establishing harmonised guidelines across boundaries. Thus, the USA and the EU face a similar situation: managing the interests of various states while aiming to ensure a harmonised strategy for C&AD.

These strategic and policy frameworks allow for a clear definition of long term goals, priorities and actions for increasing the competitiveness of the national sector. They also enable the identification of the comparative position and roles of different key players (e.g. government, IT operators, car makers, etc.) in the process.

In the selected European countries, and although the majority have some type of strategy for C&AD (e.g. with a focus on testing), only Germany (with the 'Strategy for Automated and Connected Driving') and France (the 'Autonomous Vehicles Plan') have identified such a comprehensive strategic and policy framework. In these two countries, and from a strategic and policy framework perspective, C&AD is addressed as a broader topic to foster innovation and industrial development. In France, for example, driverless vehicles are one of the sector-based initiatives of the New French Industrial Plan).

As described, it should be noted that the EU has also made efforts in this area, namely through the launch of the European Strategy on Cooperative Intelligent Transport Systems (C-ITS) and the Declaration of Amsterdam. The Declaration aims to facilitate the convergence of regulatory frameworks and the introduction of C&A vehicles in Europe. However, as these are initiatives from 2016, there is limited evidence of the impact this will generate.

Among the countries that present more comprehensive strategic instruments (e.g. Germany and France in the EU; Japan and South Korea outside of the EU), only the non-EU countries (except South Korea) present ideas on public awareness and acceptance initiatives. The USA ITS-SP emphasizes communication and education activities to facilitate awareness and acceptance among stakeholders. In Japan, the Director of the Automated Driving Systems programme defends that public acceptance is just as important as the technology used. In Europe, public awareness and acceptance is still an open issue.

Thus, it appears that the strategic and policy framework in Europe is rather fragmented, possibly hindering the realization of the potential benefits of cross-sector fertilization that the C&AD sector can stimulate.

OPPORTUNITIES

Development of a European Roadmap on C&AV as a complementary strategy for the sector

The absence of common strategic guiding principles for the C&AD sector at the European level (before the C-ITS Plan and Declaration of Amsterdam, both in 2016) led European countries to select different strategic planning priorities for the sector at the national level.

For example, France is committed to extensively involving the private sector in C&AD developments, and focuses on testing, establishing a Centre of Excellence for research and improving safety, thus addressing a significant part of the C&AD innovation value chain. Germany aims to position itself as a leading market provider in the sector by creating a framework that enables R&D; increases production and use of C&A vehicles; and deploys vehicles in real situations. Italy and Spain have defined data, road and transport safety, and connections among vehicles as C&AD priorities. Sweden and the UK emphasize the need for clear regulations for testing C&A vehicles.

Despite these priorities and an sporadic reference across the studied EU countries, there are limited references to stimulating public awareness and acceptance through dedicated initiatives; creating conditions for improving the market conditions to introduce C&A vehicles; training people to increase the level of skilled labour (assuming that the sector and the respective value chain will lead to new

and specialised jobs); ensuring that the sector is sustainable in the long-term; and ensuring the development of proper infrastructure.

Thus, there is a visible opportunity to build on these limitations and conditions, including them in a common European Roadmap for the sector. This common approach would not only allow the harmonization of standards and procedures in Member States, but can potentially foster the complementary integration of national policy frameworks and strategic priorities, promoting C&AD as an integrated sector at the European level, with countries deepening their specific competitive advantages in distinctive nodes of the C&AD value chain (research, technology integration, industrial development, testing, etc.).

Both the Declaration of Amsterdam and the European Strategy on Cooperative Intelligent Transport Systems (C-ITS) are an important step forward in this domain. Thus, once a single European strategy and policy for C&AD is established¹⁹, it should define the safety of citizens as a top priority, thus building on the priorities of individual Member States. It should also take into consideration European citizens' wellbeing. It should be noted that the principles of the Declaration of Amsterdam and the European Strategy on C-ITS have already taken this into consideration.

New opportunities for the logistic and transport sector

C&AD technology is expected to have a big impact in the logistic and transport value chain. It is expected that C&AD deployment in the logistic sector will affect warehousing operations, outdoor logistics operations, as well as line haul transportation. In terms of warehouse operations, autonomous vehicles are already used to support warehouse management such as loading, transport, and order picking.

C&AD also has the opportunity to be deployed in outdoor logistics operations such as airports and harbours [63]. The combination of classic forklifts, trucks and pedestrians in the yard environment can make manoeuvring difficult, dangerous, and inefficient. Therefore, autonomous vehicles may provide a great solution by executing all types of yard logistics including manoeuvring and repositioning transport items such as pallets and swap bodies.

Another opportunity is the deployment of autonomous cargo trucks on public roads and highways. One of the most important arguments for this is safety. Logistic sector companies face a constant risk of road traffic accidents as it is impossible to control all driving-related factors (e.g. another driver's error of judgment or the onset of dangerous weather conditions). Accident scenarios often illustrate the difficulty of performing a sudden manoeuvre with a large truck – these vehicles are intrinsically heavy, and may also be transporting heavy cargo. The occurrence of an accident will often result in disastrous damage to other road users.

Thus, technologies from C&AD can help drivers react faster to oncoming dangers and calculate the safest manoeuvre, taking into account the truck's current status and the driving conditions. This could drastically reduce the number and severity of accidents, and therefore self-driving vehicles have the potential to play a significant and useful role in reducing driver error and avoiding accidents [63].

In the transport sector, and while the possibility of deploying C&AD in public buses is still open [64], the immediate impact will mostly affect the taxi and shared cars sector. Uber has already launched self-driving cars services in Pittsburgh, USA. This pilot project is a big step forward in deploying C&AD in the transportation sector. Uber has stated that real world testing is critical to the success of the sector and creating a viable alternative to individual car ownership is important to the future of cities [65].

In Europe, there have been initiatives to deploy C&AD in the transportation sector. Deutsche Bahn, a German-based railway and logistics company has plans to operate fleets of autonomous vehicles that could be ordered via an app to transport its passengers from their home and bring them to public transit stations [66]. This would contribute to reducing the amount of traffic caused by passengers of the public transport system. Another European project that tries to use C&AD technology in the transportation sector is the Netherlands' WEpods. These are fully autonomous vehicles that can carry up to six people and run on a fixed route of the Ede-Wageningen railway station to Wageningen

¹⁹ Many experts expressed a need for one voice in terms of European strategy on C&AD, although they did acknowledge that Member States are characteristically different compared to, for instance, states in the US. They were of the opinion that a single European strategy would allow a greater leverage in terms of global influence of European OEMs and telecom operators.

University, and then on campus [67]. This is another example of C&AD technology being deployed in public transportation system and the opportunities it provides.

THREATS

Economic and financial restrictions faced by European countries that may hinder investment capacity to boost C&AD

The C&AD sector and the respective innovation value chain is extremely complex and comprehensive. Not only does it involve R&D, but it also includes testing, establishing regulations, and complementary and interdependent sectors (e.g. data, security, technology and infrastructure), fostering public acceptance and ensuring the sustainability of C&AD.

In countries known for their vehicle manufacturers or where vehicle production is of high economic relevance, private investment in C&AD may overcome public limitations to investment. Many car manufacturers, within their possibilities, will likely continue to follow the tendency of moving to increasingly automated and connected vehicles.

However, it should also be noted that national economic and financial restrictions may also limit the public's capacity to buy vehicles. For example, the 2007-2008 world financial crisis had an impact on many European economies. The average number of registered cars between 2005 and 2008 in the six EU countries studied was 1,950,191, and 13,152,925 for the EU-15. In the following four years (2009-2012), the average number of registered cars was 1,727,189, and 11,299,121 for the EU-15, a difference of more than 1.85 million units. To note that within the six EU-countries and the EU-15, only in 2013 was the number of registered cars superior to the previous year.

Therefore, economic and financial restrictions are a threat to the C&AD sector, from the conception and manufacturing phases to final public uptake. This threat can ultimately affect the competitiveness of European countries in C&AD innovation, particularly in comparison to the selected non-European countries. Thus, it is necessary to identify timely and sustainable measures at the EU-level that can prevail in case of unexpected economic fragilities. Furthermore, it is important that countries less exposed by these threats show solidarity to those most affected in order to maintain an EU-wide competitiveness.

In fact, more than 80% of experts indicated that they 'strongly agree' or 'agree' that public organisations and private companies should pay equal attention to C&AD development and deployment (Question 1A.4). In Europe, where national budgetary constraints are an issue for many countries (and thus public investment), joint R&D supported on private investment (with specific benefits later on to cover the investment) is a possible approach to enable a more sustained development of C&AD across Europe.

Segmentation of the EU market

As previously discussed under opportunities, EU countries have identified their own priorities in C&AD. While the Declaration of Amsterdam and the C-ITS Plan have helped refine the priorities Member States should consider, they still leave room for segmentation of the internal EU C&AD market. Moreover, this segmentation can also be inflicted by limitations deriving from the economic and financial restrictions.

While non-EU countries can approach the sector according to a nation-wide agenda, the EU must manage the interests and capacity of its various Members, which can cause segmentation at various levels.

Even though the aforementioned strategies call for an EU-wide harmonisation of regulations, countries have their own idea on how national C&AD ecosystems should be shaped. These countries may follow an EU-wide strategy and/or framework, but will still be influenced at an operational level towards their own ideal C&AD ecosystem, which existed before the formulation of a European strategy (e.g. experts from the Netherlands expressed explicit interest in national policies towards traffic management and road side infrastructure).

Member States may have limited flexibility to fully change their legislation to account for all C&AD requirements (e.g. the SAE level at which the car can circulate on national roads). Segmentation may also be felt at the level of infrastructure (further discussed in Task 2), as not all countries will have or will be able to offer the required road infrastructure, technical infrastructure (for V2V, V2I and V2X communication) or internet bandwidth and connectivity, among others.

There is a threat that there will continue to be different readiness levels across Member States. Moreover, and for all EU countries (some more than others), to achieve a desired balance of readiness for full deployment of C&AD will come at a cost for which there is still some differences among Member States.

2.2 Subtask 2 – Major research and large scale industrial programmes/ projects co-financed with public funds from 2011-2016

Subtask 2 includes an analysis of European, Member States and third-countries' large scale programmes/projects co-financed with public funds from 2011-2016.

The reviewed information is used as a basis for the development of a comparative analysis, which is complemented by a detailed SWOT that analyses Europe compared to the third-countries. Additional information collected from experts is also used to justify the performed analysis.

2.2.1 Review of programmes/projects co-financed with public funds

Table 3 provides a brief analysis of some of the programmes/ projects in the third countries and selected EU Member States. This analysis is done according to several factors, including the existence of public-private partnerships, conditions for testing and infrastructure, the focus on research, technology and innovation, and sustainability and social impact. This has allowed a gap analysis of programmes/projects being performed and an understanding of the consequences for different actors involved in the C&AD value chain. In addition, where relevant, the methods through which public support measures and funding is injected into the C&AD value chain in the target countries is further elaborated.

Table 3: Analysis of project/programmes in third countries and selected Member States

Country	Analysis findings
USA [68],[69], [70], [71], [72], [73], [74], [75]	<p>The USA has a number of projects and programmes for automated driving. In January 2016, the Government pledged \$4 billion USD (€3.79 billion) to support automated driving. The USA Department of Energy launched the 'ARPA-E NEXT-Generation Energy Technologies for Connected and Automated on-Road-vehicles (NEXTCAR) Program', which seeks to fund the development of new and emerging vehicle dynamic and powertrain (VD&PT) control technologies that can reduce the energy consumption of future vehicles through the use of connectivity and vehicle automation. The Florida Automated Vehicles (FAV) programme, led by the Florida Department of Transportation (FDOT) is helping to educate the public by engaging stakeholders, developing research and pilot projects, and creating awareness of the technologies and how they support FDOT's vision statement.</p> <p>In September 2015, The US Department of Transportation's (USDOT's) launched the Connected Vehicle Pilot Deployment Programme, a multimodal initiative to support safe, interoperable, networked wireless communications among vehicles, infrastructure, and personal communications devices. The USDOT and other organisations have developed research on connected vehicles because of the possible transformative capabilities of the technology to make road transportation safer, smarter, and greener. This programme will support the implementation of connected vehicle technology. The pilots will be initial deployments of connected vehicle technology in a real-world context, aiming to deliver near-term safety, mobility, and environmental benefits to the public. The USDOT has awarded over \$40 million (€37.9 million) to three locations: New York City Department of Transportation; Tampa Hillsborough Expressway Authority; and ICF/Wyoming for the pilots.</p> <p>Funds allocated to New York City Department of transportation aim at installing vehicle-to-vehicle (V2V) technology in 10,000 city-owned vehicles, including cars, buses, and limousines, that frequently travel in Midtown Manhattan, as well as vehicle-to-infrastructure (V2I) technology throughout Midtown. This includes upgrading traffic signals with V2I technology and roadside units with connected vehicle technology.</p> <p>The Tampa Hillsborough Expressway Authority pilot focuses on solving peak rush-hour congestion in downtown Tampa and protecting the city's pedestrians by equipping their smartphones with the same connected technology being placed in vehicles. This pilot will also measure the environmental benefits of using this technology.</p> <p>Lastly, the ICF/Wyoming project focuses on the efficient and safe movement of freight through the I-80 highway, which is critical to commercial heavy-duty vehicles moving across the north of the country. By using V2V and V2I, the Wyoming Department of Transportation will both collect and disseminate information to vehicles not equipped with the new technologies.</p> <p>The objective of these pilot deployments is to encourage partnerships involving multiple</p>

Country	Analysis findings
	<p>stakeholders (e.g. private companies, transit agencies, commercial vehicle operators,) to deploy applications using data captured from multiple sources (e.g. vehicles, mobile devices, and infrastructure) across all elements of the transportation system (i.e. transit, freeway, arterial, parking facilities, and toll ways). The pilots will support an impact assessment and evaluation effort that will provide a cost-benefit analysis of connected vehicle concepts and technologies. The USDOT's goals for the programme are straightforward: advance deployment, measure impact, and uncover and address the technical and non-technical barriers to deployment in a hands-on way.</p> <p>Another example of the Government involvement in C&AD is the Dynamic Mobility Applications (DMA) programme, an initiative of the USDOT multimodal initiative led by the Intelligent Transportation Systems Joint Program Office within the USDOT Research and Innovative Technology Administration (RITA). The DMA programme aims to advance the development, testing, commercialization, and deployment of innovative mobility applications by leveraging new technologies and federal investment. The research plan envisions the development of open source applications that use multi-source ITS data to transform surface transportation management and information. It is expected that the research developed within the DMA will identify high-value applications for research and develop the tools, metrics, and concepts that form the foundation for future application development.</p>
Japan [25], [76], [77]	<p>ITS Japan is a national level project that looks to change society and has the potential to create new industries and markets. It offers a fundamental solution for various issues regarding transportation, which include traffic accidents, congestion and environmental pollution. It also deals with these issues through the most advanced communications and control technologies. ITS Japan has developed a comprehensive plan designed to integrate people, roads and vehicles in order to resolve road traffic problems (e.g. traffic congestion, accidents and environmental degradation).</p> <p>One of the important programmes issued by the Japanese Cross-ministerial Strategic Innovation Promotion Program (SIP) is the Automated Driving Systems (ADS). This programme has set national goals to reduce the number of annual traffic fatalities by the year 2018 and create the world's safest road traffic environment by the year 2020. With a fiscal allocation of ¥2.32 billion (approximately €17.3 million), this programme is tasked with developing automated driving systems, including next-generation urban transportation infrastructure. By reducing accidents and traffic congestion, Japan will achieve a major leap forward in travel convenience through C&AD.</p> <p>Additionally, the ADS Programme is supported by several funding agencies and related ministries, namely: Cabinet Office; National Police Agency; Ministry of Internal Affairs and Communications; Ministry of Economy, Trade and Industry; and Ministry of Land, Infrastructure, Transport and Tourism.</p>
South Korea [29], [30], [78], [79], [80], [81], [82], [83]	<p>ITS Korea has been designated as the National ITS Standard Organization for Road Transport Sector by the Ministry of Land, Infrastructure, and Transport (MOLIT). ITS Korea performs R&D on ITS-related technologies and collects and analyses a variety of information in and out of the country. South Korea's ITS Master Plan aims to boost technology, infrastructure building and testing/ deployment of C&AD in the country. From the first National ITS Master Plan (established early in 1997) to the latest National ITS Master Plan for 2020 (and its amendment), South Korea has experienced a number of obstacles. This is known as the "trial & error" period that has led to the development and improvement of a law and support system. Further, it defines a series of National ITS Services including electronic payment, advanced traffic information, commercial vehicle operation, advanced public transportation, advanced traveller information, advanced vehicle and highway and advanced traffic management.</p> <p>The latest plan has defined three phases for ITS deployment, from launching a project on infrastructure and services, to growth and expansion, and finally maturation and advancement. The plan targets national, regional and city level ITS systems via interaction and connection.</p> <p>To support the plan, the government has also launched the Transport System Efficiency Act that defines standards, certification of standards and quality, as well as business evaluation, among others. The National ITS Architecture 2.0, has developed seven specific ITS application areas for user services, as well as logical architecture, physical architecture and service packages. So far, the deployment of ITS has shown benefits including an increase in safety, operational performance improvement, mobility and convenience enhancement,</p>

Country	Analysis findings
	<p>environmental benefits, increased productivity, and growth expansion. It has been concluded that the advantages for developing ITS in South Korea include strong national efforts, availability of advanced IT technologies and wide range of ITS projects.</p> <p>By 2020, South Korea aims to have approximately 22,000 km of installed highways at national level and 75 Transport Information Centres (TIC) in operation. Advanced ITS Services through V2V and V2I communication are expected to be available for the 2018 Winter Olympic Games, providing traffic management solutions and operation of ITS system (movable IT infrastructure).</p> <p>At the same time, the South Korean government launched, as part of its Science and Technology Basic Plan (2008-2012), the 577 Initiative, to stimulate genuine innovation in the country. This initiative consisted of three main areas: (1) increasing the percentage of GDP spent on R&D from 3.23% in 2006 to 5% in 2012; (2) defining seven technology areas, which are further divided into critical technologies and candidate technologies, and (3) becoming one of the seven most important Science and technology power in the world. Moreover, one of the seven categories, Key Industrial Technologies, has included next-generation environmental automotive technology as a critical technology and intelligent automotive technology as candidate technology.</p> <p>To support additional research in C&AD, the K-city test bed for self-driving cars was announced by the Government in 2016, including the deployment of new technologies to test automated vehicles. K-city will include various settings with different driving conditions, from expressway to inner-city roads. A key roadmap for automated driving with C-ITS includes the testing of Level 3 (limited self-driving automation) in 2018 and the production of level 3 vehicles in 2020.</p> <p>The private sector has significantly contributed to the development and deployment of C&AD in South Korea. For example, Hyundai-Kia Motors launched a competition on automated vehicles in 2010 to drive on a 3.4 km-long course with a mix of paved and unpaved roads. The competitors need to finish nine standard missions, such as recognizing crosswalk traffic lights, parking, among others. SsangYong Motor has teamed up with the Korea Automotive Technology Institute (KATECH) for the development of automated vehicles. The main research topics focus on second-generation vehicles with lower cost sensors and how to demonstrate vehicles' safe operation in busy urban environments with potential use of GPS system, as well as on Automatic Guidance Systems (AVGS). The industrial and innovation players have set an ambitious goal: Eyes off (2018) and Mind off (>2020).</p> <p>At a global scale, South Korea has signed a Memorandum of Understanding with the USA and has been regularly meeting the counterparts to share ideas on automated vehicle technologies. Steering working groups with the EU, USA and Japan have also been actively implemented.</p>
China [33], [84]	<p>Starting from 1990, the national “863 Plan” – launched and administered by MOST – has supported autonomous driving technology for military purposes. It involves a number of key universities and research institutes, including the National University of Defence Technology (NUDT) and Harbin Institute of Technology. In the Eighth Five-Year Plan, the Nanjing University of Science and Technology, Beijing Institute of Technology, Tsinghua University, Zhejiang University, and others, initiated a research collaboration on automated vehicles technologies for military vehicles.</p> <p>During the Ninth Five-Year-Plan Period (1996-2000), a number of national, local and industry initiatives were launched to establish a national ITS plan and framework, and the R&D of application systems, leading to the foundation of public-private research.</p> <p>During the Tenth Five-Year-Plan Period (2001-2005), a number of key technology programmes focusing on ITS were launched. These programmes tackled the challenges of ITS technology and addressed practical needs. These 10 years have paved the way for the rapid development of ITS during the 11th Five-Year-Plan Period (2006-2010). Within the 12th Five-Year-Plan Period (2011-2015), this momentum was kept and resulted in a nation-wide network of expressway road transport.</p> <p>The Chinese Government has also started a pioneer car electronic tracking project involving more than 200,000 cars, aiming to clamp down on crime and irresponsible driving. The project could eventually be widened to all private vehicles in Shenzhen, where the pilot programme was started, and later throughout all of China.</p> <p>In terms of civil cars, research has followed a history of private-public partnerships. In 2000, NUDT and the FAW Group Corporation began research on the automated vehicles system on</p>

Country	Analysis findings
	<p>the Chinese brand Hongqi car. Apart from MOST initiatives, the National Natural Science Foundation (NSFC) launched in 2008 a key research programme - <i>Cognitive computing of visual and auditory information</i> – as well as an <i>Annual "Future Challenge" National Automated Vehicles Competition</i> starting from 2009, aiming at stimulating interest and research breakthroughs from private and public organisations.</p> <p>In 2013, NUDT led a team of key research institutes and universities to implement one of the Key Research Programmes under NSFC – Automated Vehicles Key Technologies and Integrated Verification Platform. This project aims to build an automated vehicles integrated verification platform that is open and of modular architecture, which will enable long-distance automated driving (2,000 km) on inner city and intercity roads under normal traffic and normal weather.</p> <p>In terms of the private sector, the main Chinese companies have started to dive into the wave of automated vehicles research, including FAW, Chery Automobile, SAIC Motor, Guangzhou Automobile Industry Group and BYD Company.</p> <p>Regarding challenges and the future, experts consider that an efficient public private partnership is of extreme importance, where the government should lead and implement policy and regulations to facilitate the framework conditions of such research. Research institutes and universities should focus on tackling key technology challenges, and the private sector should bring the technology into production and the market.</p>
Germany [27], [85], [86], [87], [88], [89]	<p>As one of the top leaders in the automotive industry, Germany has been active in maintaining their progress in the field of C&AD. The Federal government, mainly through the Federal Ministry of Transport and Digital Infrastructure, launched and actively implemented in 2013 the "Automated Driving Round Table", gathering key contacts and opinions from the industry, academia and the government for the exchange of ideas on creating optimized framework conditions for C&AD.</p> <p>A number of working groups have been created, including those on "Legal Issues", "Driver/Vehicles" and "Research". The main results obtained include having reached an agreement on a "Research Agenda" for future research programmes in the field; and creating four clusters on "Human – Machine-Interaction", "Functional Safety", "Road Infrastructure and Traffic" and "Societal Issues".</p> <p>Federal-level initiatives have been announced, including building a test field for C&AD on motor ways through the "Digital Motorway Test Bed", in cooperation with automotive manufacturers and ICT companies. One example is the test field in Bavaria, located between Munich and the area of Nuremberg. It combines innovative infrastructure and a speed transmission system, as well as the use of intelligent applications.</p> <p>In addition, a number of R&D projects have been supported by different Ministries. For example, the Federal Ministry of Economic Affairs and Energy sets foot on advanced assistance systems (ADAS) and cooperative systems. A new research programme on "New vehicle and System Technologies" was also launched, setting the framework for funding C&AD and other innovative vehicles. The Federal Ministry of Education and Research has also funded projects on intelligent vehicles and driver assistance systems, as well as links of electric mobility and automated driving.</p> <p>Another example is the "Cooperative and Highly Automated Driving", led by TÜV Rheinland Consulting GmbH, and funded by the German Ministry for Economic Affairs and Energy. As the name suggests, the project focuses on improving safety, traffic efficiency and comfort. Another example is KoHAF – Cooperative Highly Automated Driving, led by Continental. This project focuses on researching highly automated driving at higher speeds.</p> <p>Up to 2020, the Ministry for Transport and Digital Infrastructure (BMVI) will make available a specific programme with €80 million euros for R&D. Likewise, the German automotive industry, including manufacturers and suppliers, are expected to become increasingly involved in C&AD R&D, and will likely invest €16-18 billion in this field in the next three to four years.</p>
France [41], [42], [90], [91], [92], [93], [94]	<p>In September 2013, France launched 34 programmes for a new industrial conquest called the 34 plans of the Nouvelle France Industrielle (NFI) – New Industrial France. This initiative is led by the General Directorate for Enterprises (DGE) together with the Ministry for Economy, Industry and Digital Affairs (MEIN), and joins France's innovation clusters and sector-based strategy committees composed of stakeholders from different sectors. This government initiated, industry-led project aims to build "a France of smart driverless vehicles" and ensures the pioneering status of the French automotive sector in automated vehicles by</p>

Country	Analysis findings
	<p>actively removing regulatory barriers. It aims to “make the French automotive and road transport industry one of the pioneers in designing mainstream autonomous vehicles”. The four objectives further direct the action plan: (1) Study (impacts); (2) Develop (technologies); (3) Create (framework conditions); and (4) Remove (obstacles).</p> <p>The programme mainly provides testing and deployment support (funding), legal review, as well as other high-level technology support via the programme’s industrial partners (i.e. Renault-Nissan Alliance). It has been analysed that France’s autonomous vehicles technology level is between level 2 (partial automation) and level 3 (conditional automation). The plan aims to achieve affordable autonomous vehicles for all of France by 2020. More practically, as of 2015, specific R&D projects, technical experiments and technological roadmaps have been actively launched.</p> <p>In parallel, the Research and Higher Education Ministry has defined autonomous vehicles as part of the “Sustainable Mobility and Urban systems” within the National Research Strategy, drawing opinions and expertise from a number of public research organisations and private sectors. Several programmes funded by the French National Research Agency have been planned to support the implementation of the strategy.</p> <p>In addition, France, with keen interest and a strategic focus on advancing C&AD technologies through private – public partnerships, has established the VEDECOM Institute. This institute is dedicated to the research and training on carbon-free, sustainable individual mobility based on a collaboration between industries of the automotive sector, infrastructure and services operators in the mobility eco-system, academic research institutions, and local communities. VEDECOM aims to become a European innovations leader in the fields of electrified vehicles, autonomous and connected cars, and new infrastructure and services for shared mobility and energy. VEDECOM has €60 million of public funding (Inria, IFSTTAR, MINES ParisTech, UTC, etc.) and €60 million of private funding (Peugeot, Renault, Valeo, Safran, etc.).</p> <p>Regarding European level involvement, France also collaborated with the Network of Automated Vehicles, a European project connecting two domains of intensive research: cooperative systems for Intelligent Transportation Systems and Automated Driving. A number of key public and private players from France have been involved, with a total budget of €4.6 million. It aims to connect cooperative systems for Intelligent Transportation Systems and Automated Driving.</p>
Italy [27], [95]	<p>VisLab was one of the first laboratories to invest in vision technologies for vehicles and its efforts are still contributing to shape the history of vehicular robotics. VisLab is a research group at the University of Parma, which launched an R&D project that resulted in an automated van capable of driving from Italy to China through various traffic, weather and road conditions. The application of vision systems in vehicles not only requires full control of the latest vision technologies, but also to have a deep knowledge of the key issues of this environment, such as calibration, illumination, noise, temperature, power consumption, as well as cost and installation requirements.</p> <p>VisLab has also created Braive, a prototype that has been tested on the streets of Parma, which marked the technological development of automated vehicles. In addition, a number of other projects have tested automated cars and buses. For example, the PROUD project, managed to test vehicles in rural areas, urban roads and highways.</p>
Spain [27], [90], [96], [97], [98]	<p>A number of initiatives and programmes have been carried out at national and regional levels in Spain to promote automated driving technologies and to facilitate testing and framework building. At the government level, Spain has been investing in an outdoor test field for the most advanced technologies. For example, the Spanish government has supported a project enabling open road testing of an autonomous vehicles on 100 km of highway without driver input.</p> <p>The Advanced Driver Assistance Systems Research Group is part of the Computer Vision Centre based in the Universitat Autònoma de Barcelona. It focuses on combining computer vision techniques (e.g. pattern recognition, feature extraction, learning, tracking, 3D vision, etc.) to develop real-time algorithms to assist driving. The Centro Tecnológico de Automoción de Galicia (CTAG) and Dirección General de Tráfico (DGT) launched an initiative in 2010, SISCOGA, with a focus on cooperative systems. As a result, a cooperative corridor of over 100 km was built for operational tests under cooperative applications. Intercity and city scenarios in Vigo have been included, connected to the DGT and Vigo Council Traffic Management Centres.</p>

Country	Analysis findings
	<p>At the regional level, Barcelona is among the top cities in urban automated driving with the support of the city council. They have established the Barcelona Board of Cooperative and Automated Driving, aiming to create a supportive ecosystem and infrastructure for testing. The Reial Automòbil Club de Catalunya (RACC) is involved in an initiative aimed at testing cars with automated functionalities in real life conditions.</p> <p>The CVC-ADAS of the University of Barcelona has created an electric car serving as a platform for autonomous driving. Similarly, Polytechnic University of Catalonia and the Spanish Council for Scientific Research (IRI) jointly developed a smart car (IRI - Car) under the frameworks of national projects. The AI2 research group of the Polytechnic University of Valencia, funded by national project IDEMOV-IDECONA, is developing a methodology on control, planning and automatic navigation. The Institute of Biomechanics of Valencia has successfully completed the HARKEN project on detection of driver conditions.</p> <p>In terms of European projects, Spain hosted the SARTRE FP7 project on open-road platooning and testing of autonomous vehicles. Through this project, the first tests occurred on Spanish motorways. In addition, FP7 projects Citymobil and Citymobil 2 initiated demonstrations of automated driving in different Spanish cities: Castellon, Leon and San Sebastian.</p>
Sweden [27], [52], [90]	<p>One of the most relevant initiatives that the Swedish government has launched is the "Drive Me – Self driving cars for sustainability mobility" project. The project aims to end fatalities in traffic through the research, testing and application of self-driving cars. Initiated in 2014 with the necessary customer research and technology development, cars from Volvo were already running tests in the city of Gothenburg (headquarters of Volvo).</p> <p>Drive Me has gathered key Swedish partners from public and private sectors, including car manufacturer Volvo, Gothenburg City authorities, the Swedish Transport Administration, the Swedish Transport Agency, and Lindholmen Science Park. It involves all major players including legislators, transport authorities, a city authority, a vehicle manufacturer and real customers.</p> <p>Drive Me strives to understand how autonomous driving will affect both vehicle and infrastructure, as well as to analyse factors and even social benefits. Several focus areas are set, including societal and economic benefits, infrastructure requirements, traffic situations, customers' confidence, as well as drivers' interaction with a self-driving car. It foresees approximately 50 km of public roads in and surrounding the city of Gothenburg. 100 self-driving Volvo cars will be tested, by normal drivers and in daily traffic conditions.</p> <p>Nevertheless, the Swedish Transport Agency has found that legal support and clarifications seem to be pending regarding specific conditions under which the testing for "Drive Me" can be carried out. Current vehicle legislation will need amendments to set up procedures to grant the testing of vehicles with information systems.</p> <p>In addition, the Lindholmen Science Park is managing the development of the national "Automated Transport System" in Sweden to establish, through Vinnova (Swedish Innovation Agency), a Strategic Innovation Programme called Drive Sweden. It is an initiative that goes beyond driverless vehicles and targets new approaches for mobility. It ambitiously aims to optimize and automate the entire system of transportation, create smart solutions that will support the utilization of the driverless vehicles. Drive Sweden gathers all key players in the country from different sectors. This approach greatly facilitates the coordination among respective parties to better tackle larger challenges on road safety, infrastructure and legislation improvement. It has already contributed to several innovation projects including Drive Me.</p>
United Kingdom [27], [99], [100], [101], [102], [103]	<p>The UK government has been actively promoting automotive vehicles, related activities and the setup of a framework. Intelligent Mobility has been defined as one of the focus areas for the UK Automotive Council, aimed to link the government with the automotive sector. The Council is jointly chaired by the Secretary of State for Business, Innovation and Skills and leading industrialists. In parallel, the Transport System Catapult has also been set up by policy making bodies and the industry to accelerate and facilitate commercialisation in the field of intelligent mobility. These efforts have led to distinct results, such as the ULTRA driverless passenger transfer system at Heathrow airport.</p> <p>Under the theme of intelligent mobility, The UK's Department for Transport and the Department for Business, Innovation and Skills oversee the main activities and national strategies. They have also planned many other initiatives, including a connected corridor on the Strategic Road Network and calls for trials. This connected corridor links London and</p>

Country	Analysis findings
	<p>Dover to enable vehicles to communicate with infrastructure and other vehicles. The connected corridor is valued at approximately €17.5 million. In July 2014, the government announced an autonomous vehicles competition, inviting UK cities to bring private and public organisations to perform local vehicle trials. Four cities were awarded approximately €15.6 million in funding from Innovate UK for testing driverless cars in the real world. Compared to, for example, the USDOT Smart City Challenge from the USA, the UK challenge had a lower budget, but a greater focus on C&AD. An additional €14 million were added to the budget to ensure smooth implementation of the activities. Under strong market demand, the UK built in 2015 the Centre for Connected and Autonomous Vehicles (CCAV) to ensure innovation and breakthroughs in this area.</p> <p>In October 2015, the UK Transport Research Laboratory (TRL) announced it is part a new £11m research programme to develop fully autonomous cars. The programme, jointly funded by Jaguar Land Rover and the Engineering and Physical Sciences Research Council (EPSRC), will look at some key technologies and questions that need to be addressed before driverless cars can be allowed on roads without jeopardising the safety of other road users, including cyclists and pedestrians. The announcement follows a joint call for research proposals from Jaguar Land Rover and EPSRC entitled "Towards Autonomy - Smart and Connected Control" (TASCC). A total of five projects were selected from a pool of submissions. The UK Department of Transport and Department for Business, Innovation and Skills has also launched an opportunity for collaborative R&D projects to research how driverless cars can be integrated into everyday life in the UK. In terms of specific projects, the GATEway project, supported by the Transport Research Laboratory, aims to understand and overcome the technical, legal and societal challenges of implementing automated vehicles in an urban environment.</p>
EUROPE	<p>Europe has implemented a specific funding strategy for C&AD. The H2020 programme is Europe's biggest source of funding for the sector, with various calls related to C&AD. These can be grouped into five key calls, with three of them be directly related to C&AD, and two with some touching points. Regarding the most related calls, there is the Automated Road Transport²⁰ (ART), Mobility for Growth (MG) and Internet of Things (IOT) calls.</p> <p>Regarding ART, the recent 2016-2017 call targeted projects to support the short-term introduction of passenger cars at automated driving level 3, including safe stops, and of truck platooning in real traffic conditions from 2020 onwards. The call consisted of seven topics covering various aspects of C&AD with a budget of €114 million. This is the EU's biggest funding channel for C&AD in the single call. The specific topics were:</p> <ul style="list-style-type: none"> • ART-01-2017: ICT infrastructure to enable the transition towards road transport automation • ART-02-2016: Automation pilots for passenger cars • ART-03-2017: Multi-Brand platooning in real traffic conditions • ART-04-2016: Safety and end-user acceptance aspects of road automation in the transition period • ART-05-2016: Road infrastructure to support the transition to automation and the coexistence of conventional and automated vehicles on the same network • ART-06-2016: Coordination of activities in support of road automation • ART-07-2017: Full-scale demonstration of urban road transport automation <p>The call for Mobility for Growth 2016-2017 included three topics with a total budget of €27 million. This topic also addressed innovation in transportation. The specific topics were:</p> <ul style="list-style-type: none"> • MG-8-2-2017 (Big data in Transport) • MG-6.1-2016 (Mobility as a service) • MG-6.2-2016 (Large-scale demonstration(s) of cooperative ITS) <p>Lastly, within the Internet of Things topic, IoT-01-2016, Pilot 5 (Autonomous vehicles in a connected environment) is of relevance. Projects were requested to test scenarios of deployment of safe and highly and fully autonomous vehicles (up to level 5, full automation) in various representative use case scenarios, exploiting local and distributed information and intelligence.</p> <p>In addition to these calls, the European Commission is and has funded various projects related to C&AD. Within the FP6/FP7 programmes, which preceded H2020, more than 35</p>

²⁰ Automated Road Transport (H2020). <https://ec.europa.eu/inea/en/horizon-2020/automated-road-transport>

Country	Analysis findings
	<p>projects were funded related to highly automated urban road transport systems, driver assistance systems, connectivity and communication and networking/other challenges. Already within H2020, six projects have been approved focusing on safe and connected automation in road transport and networking.</p> <p>In H2020, namely the 2016-2017 Work Programme, the EU has also put its focus on smart and green vehicles²¹, with the emphasis on creating better mobility, less congestion, more safety and security with a substantial reduction of accident rates.</p>

2.2.2 Comparative analysis of major research and industrial projects/programmes for C&AD

As discussed in Section 2.1, there is some dispersion at Member State level regarding the focus of strategies for C&AD. While Member States, at public or private level, have moved forward with various programmes and/or projects for C&AD, there is a considerable gap in the programmes and projects between the Member States and third-countries. This is mostly visible in the degree of government support. The USA, Japanese, South Korean and Chinese governments have been paying attention to the development of C&AD since before 2010. In Europe, attention at Government level commenced in 2013, with UK's increased focus on R&D and Germany's Automated Driving Round Table launched by the Federal Ministry of Transport and Digital Infrastructure. This contrasts with the South Korean Government, who established their national ITS programme (a basis for C&AD) as early as 1997.

Moreover, there is also an increasing presence of public support in the development of C&AD in the USA, Chinese, Japanese, and South Korean governments when compared to those in Europe. The development of C&AD has become a priority in transportation technology of these third-countries compared to Member States. This is possible with the advance in research that has been done by the private and public sectors in the development of autonomous vehicles. Therefore, while Europe has been a pioneer in automotive manufacturing, employing more than 12 million people, the development of C&AD is not supported with an adequate number of programmes coming from the public sector.

Main differences in the priority for the development of C&AD

One of the biggest differences between Member States and the USA, Japan, South Korea and China is the priority given by governments towards the development of C&AD.

For example, the Japanese government and business leaders have declared their intention to use self-driving vehicles as the main means of transportation in the 2020 Summer Olympic Games. With C&AD as a key priority, in August 2016, work had already been done to develop high-precision three-dimensional maps (including other essential characteristics) to support autonomous driving technologies [104]. This is evidence of the support given by the Japanese government, which will lead to a more advance development of C&AD technologies. Similarly, the South Korean government has also prioritised C&AD, which led to the development of the K-City testbed. [82]

Allocation of funds for C&AD

All countries addressed in the study have invested a significant amount of funds in the development of C&AD (or ITS services, as discussed in Section 2.1). At Member State level, Germany, France and the UK, for example, have allocated a substantial amount of funds in the development of C&AD. On the one hand, Germany and France have focused on the R&D sector; on the other, the UK has jumped a step ahead and has also invested in infrastructure, testing and general implementation of C&AD. Moreover, these countries have also engaged the private sector to also contribute to financing C&AD.

At the EU level, one of the main programmes with funds allocated to C&AD and similar areas is H2020. Available funding under H2020 for C&AD has not only targeted R&D, but also supported projects focusing on safety issues, infrastructure development, demonstration of C&AD, as well as increasing end-user awareness and acceptance. Outside of the EU, namely in the USA and Japan, funding is still largely focused on C&AD R&D.

²¹ Green Vehicles (H2020). <http://ec.europa.eu/inea/horizon-2020/green-vehicles>

A sector built on public-private partnerships and collaboration

The joining of public and private interests is considered to be an important approach to build a stronger C&AD sector.

In Europe, many of the studied Member States have encouraged the involvement of multiple stakeholders – including private – in their C&AD efforts. France has established a strong collaboration with industrial partners, namely the Renault-Nissan Alliance, which has already launched various R&D projects (starting in 2015). It has also established the VEDECOM institute for research and training, with public and private funding. Germany has involved the private sector in various C&AD initiatives, including a working group on 'research', which led to a common research agenda for future research programmes. One of Germany's bigger projects – the 'Digital Motorway Test Bed' – is a Federal-project in cooperation with private partners (i.e. manufacturers and ICT companies). In Spain, the Government has supported various research groups that focus on C&AD projects. In Sweden, 'Drive Me – Self driving cars for sustainable mobility' is considered one of the biggest large-scale demonstration projects, sponsored by the government and involving Volvo Cars. In parallel, Sweden has launched the Drive Sweden programme, a public-private partnership that focuses on mobility beyond C&AD. Lastly, the UK Government has announced a research programme dedicated to developing fully autonomous cars involving the Jaguar Land Rover group. This group has also launched their own call for projects, thus encouraging additional projects for the C&AD sector.

Still within the EU, one of the four contractual PPPs supported by DG Research and Innovation is the European Green Vehicle Initiatives (EGVI)²². The initiative aims to increase the energy efficiency of vehicles including passenger cars, trucks and busses. Through this initiative, the EU has contributed €439.2 million distributed to 113 projects addressing Information and Communication Technologies (ICT), energy, environment (including climate change), transport, and nanotechnologies, materials and production technologies (NMP). This illustrates how C&AD could also benefit as a contractual PPP initiative.

Outside of Europe, third-countries are also investing in programmes and projects involving public and private cooperation. In the USA, the Connected Vehicle Pilot Deployment Programme encourages partnerships involving multiple stakeholders, including private companies. In China, public and private cooperation in the field of C&AD has been frequent, and private sector companies have also invested in their own research on automated vehicles. In Japan and South Korea, there are fewer references to existing public-private partnerships. Yet, in these countries, the private sector has been very active (e.g. in South Korea, the Hyundai-Kia Motors group launched a series of projects (competitions) on automated vehicles).

Similar to many previously discussed points, the Declaration of Amsterdam will be an important instrument to facilitate the emergence of new programmes and projects focused on C&AD. The Declaration has proposed a series of actions for Member States, the European Commission and the Industry. Notably, it proposes that the European Commission develop a coordinated approach towards research and innovation activities (i.e. new programmes and projects are expected). It is also proposes that the Industry participate in the development of the European strategy and agenda on C&AD; and that they participate in large-scale pilot deployment projects to explore the societal benefits of C&AD.

Programmes and projects for establishing infrastructure and testing vehicles

As presented in Section 2.1, one of the few common points on C&AD has been Member States' focus on the revision of legislation and regulation, namely to facilitate the testing of vehicles.

In line with this approach, most Member States have launched one or more projects that have built the necessary infrastructure or created the framework conditions for testing vehicles. In Europe, the large-scale New Industrial France programme includes, among other items, support to testing and deployment of C&A vehicles, also with the support of the Renault-Nissan Alliance. In Germany, the national 'Digital Motorway Test Bed' project aimed to build a test-field for C&AD. Spain has been investing in outdoor testing, with the national Government having supported a project that enables open road testing. Other national testing corridors have also been established. Likewise, the UK government has also established several projects that facilitate testing, including a connected corridor.

²² European Green Vehicles Initiative. <http://www.egvi.eu/>

Outside Europe, the four studied countries have also deployed programmes and/or projects which address infrastructure and/or testing. The USA's Dynamic Mobility Applications (DMA) programme aims to advance the development and testing of vehicles (among other priorities). Japan's Automated Driving Systems (ADS) programme aims to develop next-generation urban transportation infrastructure. Similarly, South Korea's ITS Master Plan aims to boost the technology and infrastructure behind C&AD. South Korea also has the K-City, which will be used for testing vehicles.

Thus, there are no significant differences between Europe and non-European countries regarding programmes for testing. However, and as discussed in Section 2.1.2, Europe does fall slightly behind regarding strategies for testing infrastructure. Furthermore, and while the EU and many Member States may currently be prepared in terms of infrastructure (for the current state of vehicle automation and connectivity), as C&AV become more advanced and reach higher levels of automation, the development and adaptation of infrastructure will be required. New programmes and large scale projects will be required to support this process, especially to implement cross-border infrastructure.

Programmes and projects for research, technology and innovation

The focus on research and technology development is also transversal to European Member States and third-countries. Within France and Germany's national initiatives, there is reference to the development of research and development of C&AD technology. In France, the Autonomous Vehicles Plan addresses the entire C&AD innovation value chain and TRL levels 2 to 9. In Germany, in addition to PPP, the Federal Government also funds specific privately-coordinated research projects such as the 'Cooperative and Highly Automated Driving' project, which focuses on safety, traffic efficiency and comfort. In Italy, Spain and the UK, important research and technology development is done within research groups and institutes. Italy has the VisLab, which has made progress on vision technologies for vehicles. Spain has various centres (e.g. Computer Vision Centre, Centro Tecnológico de Automoción de Galicia, CV-ADAS and AI2) that address various research topics of the C&AD sector. The UK also has a Centre for Connected and Vehicles (CCAV), which focuses on the development of innovation and breakthroughs for the sector. Lastly, the Swedish 'Drive Sweden' programme was launched by the national government and includes various projects that address the various challenges of C&AD and related areas.

Outside of Europe, research and technology development is also strong. The USA's USDOT Connected Vehicle Deployment Programme is a multimodal initiative that has a robust focus on research and technology (e.g. interoperability, communication among vehicles, etc.). It also focuses on the implementation of the technology (through testing) in a real-world context. Japan's ADS programme is a large-scale research and technology initiative, with a clear focus on developing automated driving systems and infrastructure. South Korea is also keen on research and technology, with the K-City testbed being used for the deployment of new technologies. Lastly, research and technology development is well rooted within China's recurring 'Five Year Plans'. It is expected that these national plans continue to reserve investment for C&AD.

At a European level, it is expected that research and technology programmes and projects will continue to be highly prioritised. Specifically, within the Declaration of Amsterdam, a common objective has been laid down to support innovation in C&A vehicle technologies, while the European Commission is expected to develop a coordinated approach towards research and innovation activities in the field of C&AD.

Programmes and projects on sustainability and social impact

In line with previous discussions, there are limited references to programmes and projects with a focus on sustainability and social impact.

In France, the VEDECOM institute (involving public and private funding), has a focus on the social component, and aims to ensure that autonomous cars are made available to everyone. In Germany, of the various working groups created as part of the 'Automated Driving Round Table', one focuses specifically on societal issues. In Sweden, the Drive Me project also aims to understand the social benefits of autonomous driving.

Within the EU, H2020 also focuses on creating smart, green and intelligent transport. As part of this programme, the European Green Vehicle Initiative was launched with the emphasis on creating more energy efficient vehicles using alternative powertrains, strengthening the future competitiveness of the automotive industry as well as helping reach targets set by the EU transport, energy and climate protection policies.

This goal is directly related with the C&AD development that enables the reduction of traffic congestion. By reducing traffic congestion, driving will be more efficient and use less fuel, therefore reducing carbon emissions. C&AD vehicles are also designed with image-capturing technologies, allowing the vehicle to scan the surrounding environment to make better driving decision on the best route. These factors help C&AV achieve a greater fuel economy and in eliminating extra emissions from inefficiency that would otherwise be caused from human drivers.

In addition, C&AV make it possible to shift away from individual car ownership and move to shared transport, reducing the number of wheels on the road. Driving in a tight formation could reduce energy consumption by up to 25%. Therefore, from the possibilities that come from C&AD vehicles, it can be seen that C&AV also have a significant impact on environmental sustainability.

Among the third-countries, Japan is particularly focused of the social impact of C&AD. The national ADS programme aims to create the safest road traffic environment and to significantly reduce the number of deaths caused by driving. Thus, there is an inherent social component in this vision.

2.2.3 SWOT analysis of major research and industrial projects/ programmes

Table 4: SWOT Analysis for EU on Major Research and Industrial Projects/ Programmes

Strengths		Weaknesses	
Main Point	Explanation	Main Point	Explanation
Variety of national programmes and projects with private participation	<ul style="list-style-type: none">At the national level, there have been many programmes and projects to encourage and develop C&AD	Lack of synergies between programmes	<ul style="list-style-type: none">Absence of a stronger coordinated approach and priority setting that enable synergies and avoid duplication and fragmentation, particularly considering the national and European levels
Availability of different funding sources and private investment	<ul style="list-style-type: none">There is a wide variety of programmes and funding sources, public and private, European and national, with a focus on various themes.Reasonable level of involvement of private companies in R&D.		
Established vehicle manufacturers	<ul style="list-style-type: none">Europe is the home to some of the world’s biggest and trusted automotive manufacturers (e.g. Mercedes-Benz, BMW, Volvo, etc.), which can help boost C&AD research and development with dedicated projects.		
Opportunities		Threats	
Main Point	Explanation	Main Point	Explanation
Possibility of an integrated approach	<ul style="list-style-type: none">A truly integrated approach can be deployed to the C&AD value chain, where all areas are addressed. This can support the channelling of funds in a more balanced way.	Over reliance on public funding	<ul style="list-style-type: none">Over dependence on public financial support to implement the priorities of C&AD programmes, particularly at the later stages of TRL.
Positive momentum	<ul style="list-style-type: none">The adoption of Declaration of Amsterdam created a momentum and illustrates the political will of EU leaders in realizing C&AV. This allows the automotive industry to put pressure on and influence the decision-making authorities to invest more dedicatedly in C&AD programmes/projects.	Emerging key players as competitors	<ul style="list-style-type: none">The emergence of other key players coming from China, Japan and South Korea is a reality, many which have substantial funding capacity to accelerate the R&D process.
Develop a coherent C&AD funding strategy	<ul style="list-style-type: none">With the reorganisation of funding programmes in 2020, there is an opportunity to develop a more coherent funding framework for C&AD at the EU level.		

STRENGTHS

Variety of national programmes and projects with private participation

At the European and Member State level, there have been a wide variety of programmes and projects with private participation, specifically created to encourage the development of C&AD. This is a *strength* considering the lack of harmonisation in terms of C&AD strategies at the EU level, and a sign that there is in fact effective national interest in promoting C&AD.

With exception to Italy, where references suggest C&AD research is still mainly within the private sector (e.g. VisLab), the remaining five studied Member States have promoted projects and programmes in close collaboration. France has established a strong collaboration with industrial partners, namely the Renault-Nissan Alliance, and has already launched various R&D projects. Through PPPs, it has also established the VEDECOM institute for research and training. Germany has established both public and private projects (e.g. the 'Digital Motorway Test Bed' project, a Federal-project in cooperation with private partners; and the 'Cooperative and Highly Automated Driving' project, run by private organisations with National funding). The Spanish Government has supported projects aimed at open road testing, and supports various research groups that focus on various C&AD projects. Sweden has launched 'Drive me – Self driving cars for sustainable mobility', considered one of the biggest large-scale demonstration projects, sponsored by the government and involving Volvo Cars. In parallel, Sweden has launched the Drive Sweden programme, a public-private partnership, which focuses on mobility beyond C&AD. In the UK, the Government has announced a research programme dedicated to developing fully autonomous cars involving the Jaguar Land Rover group. This group has also launched their own call for projects, thus encouraging additional projects for the C&AD sector.

However, non-EU countries have also invested in their own programmes and projects, equally involving public and private cooperation (with exception to Japan). In the USA, there are National and State level programmes for C&AD (e.g. the 'Connected Vehicle Pilot Deployment Programme' (2015) at Federal level, and the 'Florida Automated Vehicles Programme' at State level). Japan has a high-level programme called 'Automated Driving Systems', part of the SIP. In South Korea, as part of its various ITS initiatives, a project focused on developing the 'K-city' testbed for testing automated vehicles was launched (2016). In China, public and private cooperation in the field of C&AD has been frequent, and private sector companies have also invested in their own research on automated vehicles.

Experts believe that these programmes/ projects (specifically those they identified in Question 1B.3) contribute *largely* (40% of experts) to a faster development and diffusion of C&AD. Other experts have the opinion that they will only contribute *moderately* (more than 45% of experts). Most of the experts recognize the value of these projects to foster new business activity, develop new technologies, bring in an increase in public investment and also involve private actors. These general ideas are closely aligned with several the strengths identified in Table 4, namely the existence of 'different sources' and 'involvement of private investment'.

Availability of different funding sources and private investment

Aligned with the examples presented in the previous *strength*, there is evidence of the availability of different funding sources in Member States.

Among other funding, Germany will have €80 million for R&D up to 2020; France has invested €60 million in the VEDECOM institute; Sweden has invested more than €75 million in the Drive Me initiative (mixing public and private funds), and the UK has also invested more than €30 million in various programmes and competitions for C&AD. In the third-countries, there is evidence from three of the four countries of public funds also being allocated to C&AD, namely the USA (up to €40 million in the Connected Vehicle Pilot Deployment Programme) and Japan (approximately €17 million in the Automated Driving Systems Programme). South Korea and China also have funding for C&AD within their larger National programmes, but specific values are unknown.

Still within the EU, there is a considerable level of private investment in C&AD. The German automotive industry will likely invest up to €18 billion in R&D up to 2020; the French VEDECOM institute has equal private and public funding, at €60 million from each; and one of UK's R&D programmes, with more than €10 million in funding, is jointly funded by the Jaguar Land Rover Group. Outside of Europe, while there is evidence of private collaboration, the level of private investment in the sector is unclear.

At a European level, public funding has also been made available most recently through the H2020 programme, specifically in topics such as Automated Road Transport (ART), Mobility for Growth (MG)

and Internet of Things (IOT). Other instruments also provide funding for C&AD. Thus, this is a strength for Europe considering that public and private entities continue to invest in the sector.

Established vehicle manufacturers

It can be considered that one of the key factors for the long-term success and sustainability of C&AD is the extent to which private actors are willing to invest in the sector. All the countries addressed in this study, European and non-European, are home to one or more car manufacturers.

Europe is particularly well established regarding its vehicle manufacturers, being home to some of the world's biggest and most trusted manufactures: Mercedes-Benz, BMW, Volvo, among others. These are simultaneously some of the most successful manufacturers and thus have the capacity to continue to invest in vehicle R&D, namely C&AD.

Mercedes-Benz and BMW, for example, have their own strategies for the sector, and aim to make connected, automated and mobility key focus areas. Volvo is already highly involved in the sector (e.g. Drive Me project), and will likely continue to invest in similar efforts. This is not to say that manufacturers outside of Europe are neglecting the sector. In fact, Toyota and Honda (both based out of Japan), are also leading manufactures in the field of C&AD. In contrast, two major manufacturers in the USA (General Motors and Ford) are somewhat behind.

Thus, while European manufacturers do not solely lead in R&D for sector, they do rank high and are an important contribution to the success and sustainability of the sector.

WEAKNESSES

Lack of synergies between programmes

While there are various programmes at the Member State level – public, private or public-private in nature – there is a lack of synergies with other Member States' programmes. Member States tend to follow their own C&AD agendas and projects follow accordingly. Even when private involvement is prominent, these tend to be limited to private organisations originating from the same country. Thus, there is an absence of a stronger coordinated approach between Member States and the setting of common priorities that enable fruitful synergies and avoid duplication and fragmentation.

Yet, even with third-countries, there is limited evidence of synergies taking place (except South Korea and USA, which have signed a Memorandum of Understanding).

Within Europe, the Declaration of Amsterdam is likely to help revert this scenario. Not only does it aim for Member States to work towards a coherent European framework for the deployment of interoperable connected and automated driving, it also aims to foster international cooperation. In doing so, work should be done on defining a common agenda, where each country's strengths are maximised to ensure fruitful synergies and avoid unnecessary duplication of efforts.

Consulted experts also identified the lack of synergies as a problem. Thus, it is important that projects increasingly foster synergies. In cases where projects originate from public initiative, private involvement should be encouraged in order to contribute to the financial requirements of the project. In cases of projects originating from a private initiative, new ways of involving public entities and support should also be analysed.

OPPORTUNITIES

Possibility of an integrated approach

Despite each Member State operating within its boundaries and according to its own agenda, there is an opportunity to transform the current lack of synergies into a truly integrated approach for the C&AD value chain.

For example, and starting with each country's programmes (as outlined in 2.2.2), one approach is to assign the objectives of each programme to different nodes of the C&AD value chain in order to ensure continuous financial support during the full innovation process. Another important item is the current readiness level for testing. The majority of Member States have or will revise their legislation to allow for testing, open or off-road. Facilitating cross-border testing (i.e. testing of vehicles and each country's specific road landscape) also contributes to a more integrated approach.

By establishing an integrated approach, public funds at the EU level can also be funnelled in a more balanced way, ensuring that different research activities along the C&AD value chain receive the necessary funding rather than be neglected in detriment of others which are recurrently funded.

Positive momentum

Europe's C&AD sector is living a positive momentum, which will likely last for some time. Much of this momentum is based on the framework that the Declaration of Amsterdam sets for the sector and its development.

The Declaration of Amsterdam outlines the political will of European leaders in achieving autonomous vehicles on EU roads. As previously discussed, the Declaration defines several shared objectives for C&AD, including the development of a coherent framework for the deployment of interoperable C&AD; the adoption of cross-border cooperation; and the support for additional innovation in technologies. This is coupled with the objective to agree on coherent rules, the establishment of communication technologies, ensuring public awareness and acceptance and cooperation with other international regions. Lastly, it defines actions for Member States, the European Commission and the Industry. Many of these actions are interrelated and call to responsibility these stakeholders to ensure the success of the sector.

Thus, there is a political motivation to take advantage of the good results being achieved at the individual Member State level to ensure these also become the success of Europe. The Declaration, while likely arriving later than desirable, arrives at a time when Europe is making positive advances in the sector, and contributes to providing relevant boundaries and additional guiding points for C&AD. Furthermore, it allows the automotive industry to put more pressure and influences those with power to invest more dedicatedly in C&AD programmes/projects.

Develop a coherent C&AD funding strategy

With the reorganisation of funding programmes in 2020, there is an opportunity to develop a more coherent funding framework for C&AD at the EU level, but to also align efforts with Member States. A strategy could be put in place that focuses on three or four key programmes and increases the funding available for C&AD. The strategy should also encourage the involvement of national authorities to ensure an alignment of priorities and avoid duplication among Member States. Relevant programmes to consider include H2020 (and exploring the potential of public private partnerships) and IPCEI.

THREATS

Over reliance on public funding

As discussed, public funding of C&AD programmes and projects has been frequent for many Member States. As national strategies and respective programmes have a strong governmental and public framing, stakeholders may consider that public funding will continue to be steady. However, for reasons similar to those discussed in the SWOT from Section 2.1.3, budgetary limitations may restrict the funds a Member State can invest in the sector.

Furthermore, many smaller private organisations may continue to excessively rely on public financial support to implement the guidelines of the programmes, especially those focused on later TRL stages, and when there is a lack of capacity to overcome the 'valley of death' of the C&AD sector.

Thus, it is important for bigger private companies to balance this effort. It is important for EU and national governments to show there is interest in C&AD and to provide some level of funding to facilitate the growth of the sector, but private investment must also be guaranteed to support the long-term sustainability of the sector.

Emerging key players as competitors

In addition to the USA (e.g. Google in ICT; General Motors and Ford in manufacturing), other key players are emerging in China (e.g. Baidu in ICT), Japan (e.g. Toyota and Honda in manufacturing) and South Korea (e.g. Hyundai and Kia in manufacturing). In these three countries, ITS has been on the map longer than in Europe (almost 20 years in the case of South Korea). Thus, these third-countries are key EU competitors in the C&AD sector.

China in particular, being one of the world's largest economies, is not only a threat to Europe, but to other third-countries as well. With a large amount of funds to invest, a high capacity to implement at a fast pace and with Government support, China is in fact a key C&AD competitor.

Yet, before Europe worries about external competition and its global position in the market, it must first reorganise its own strategies and ensure it is itself competitive and with the right capacity. Furthermore, and following the ideals of the Declaration of Amsterdam, Europe must also favour international cooperation with other regions (namely the USA and Japan), working with them work towards a global framework and international standards for C&A vehicles.

2.3 Subtask 3 – New regulations or standards

Subtask 3 includes an analysis of European, Member States and third-countries' regulations and standards linked to C&AD. The analysis is based on official documents and other relevant resources.

The reviewed information is used as a basis for the development of a comparative analysis, which is complemented by a detailed SWOT that analyses Europe compared to the third-countries. Information collected from experts is also used to justify the performed analysis.

2.3.1 Review of the legislative framework and differences between standards and status of the regulatory environment of EU compared to third-countries

Standards have been collected into those covering similar topics, followed by a cross comparison to identify and discuss key differences between them. The analysis focuses on the potential consequences of such differences for traditional European automotive manufacturers as well as others in the value chain. From the information gathered, it is possible to identify differences in the:

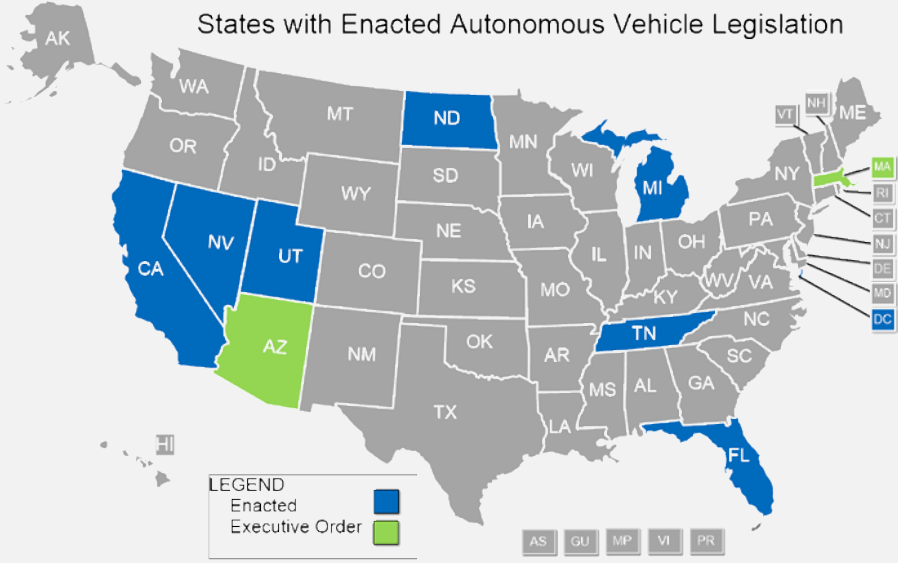
- Technologies approved.
- Possibilities and requirements for manufacturers to test or deploy C&A vehicles.

The potential consequences of these conditions are considered for different actors in the value chain. This task aims to look at the previously collected new regulations and standards and analyse the differences between EU standards and those in place in third-countries. Regarding standards, the following constitute the main sources of detailed information on the content of standards relevant to C&AD:

1. CEN/ETSI – Intelligent Transport Systems standards Cooperative Intelligent Transport Systems (C-ITS) Standards Assessment, 1st January 2015 – Review of more than 160 standards from the ETSI release 1, CEN/ISO release 1 and from SAE and IEEE for the USA.
2. Association of Radio Industries and Businesses (ARIB) for Japanese standards.
3. Telecommunication Technology Association (TTA) for Korean standards.
4. National ITS Standardisation Committee for China.
5. International Organization for Standardization – Technical Committee (ISO/TC) 204 – Intelligent transport systems standards.
6. Institute of Electrical and Electronics Engineers (IEEE).
7. Society of Automotive Engineers (SAE).

Table 5 presents the main standards/ standard making bodies and regulations/ regulatory authorities regarding authorized technologies, testing and deployment of autonomous vehicles.

Table 5: Examples of standards/standard making bodies and regulation/regulatory bodies

Country	Descriptive status
USA [105]	<p>In the USA, individual States are responsible for vehicle licensing and registration, traffic laws and enforcement, and motor vehicle insurance and liability regimes. As the relevance of autonomous vehicles for the automotive industry increases, State and municipal governments are starting to address the potential impacts of these vehicles on the road. In early 2016, sixteen states introduced legislation related to autonomous vehicles, up from 12 states in 2014, nine states and D.C. in 2013, and six states in 2012.</p>  <p>States with Enacted Autonomous Vehicle Legislation</p> <p>LEGEND Enacted Executive Order</p> <p>Figure 6: States with Enacted Autonomous Vehicle Legislation (Status as of Oct 13, 2016) Source: National Conference of State Legislatures</p> <p>No single entity within the Executive Branch of the Federal Government has jurisdiction to regulate all aspects of driverless vehicles, although the USDOT has the major responsibilities. If connected vehicle communications are aspects of driverless vehicles, the Federal Communications Commission will have a major role regarding driverless vehicles that are also connected vehicles.</p> <p>The Federal Trade Commission is concerned with consumer issues. The Environmental Protection Agency will have jurisdiction over issues such as fuel efficiency testing and environmental matters related to driverless vehicles. The National Highway and Transportation Safety Administration (NHTSA) is responsible for achieving the highest standards of excellence in motor vehicle and highway safety, having issued guidance for the safe development of highly autonomous vehicles (HAVs). The American National Standards Institute (ANSI) is a non-profit organization that facilitates standard development in the United States. The Institute of Electrical and Electronics Engineers (IEEE) is a leading consensus-building organization that enables the creation and expansion of international markets, and helps protect health and public safety, being responsible for the development of international standards related to electrical systems, electronics, and information technology. The U.S. National Transportation Communication for ITS Protocol (NTCIP) is a joint standardization project of AASHTO, ITE, NEMA, and the Office of the Assistant Secretary for Research and Technology of USDOT. The Protocol is a set of standards that provide both the rules for communicating (called protocols) and the vocabulary (called objects) necessary to allow electronic traffic control equipment from different manufacturers to operate with each other as a system.</p> <p>Japan [106]</p> <p>The objective of the Association of Radio Industries and Businesses (ARIB) is to carry out, among others, studies, research and development, and consultation work, relating to radio wave use. These activities are conducted to promote the practical application and dissemination of radio systems in the telecommunications and broadcasting fields, as well as to achieve robust advancement and development of radio industries, thereby</p>

Country	Descriptive status
	<p>contributing to public welfare.</p> <p>Japan's National Police Agency (JNA) is expected to establish a panel of experts, who will have to analyse possible legislative reforms for the new technology on C&AD. Topics that stand out refer to who would be legally responsible in the case of an accident, anti-hacking measures and how the driver's license system for C&AV would be modified. Additionally, the Japanese Industrial Standards committee (JISC) serves as a lead organization based on the approval of the cabinet. An international standardization committee and several technical committees carry out the activities for ISO/TC 204 on behalf of the JISC. These activities are led by the Society of Automotive Engineers of Japan (JSAE).</p>
South Korea [107]	<p>The Telecommunications Technology Association (TTA) is a non-government and non-profit organization for ICT standardization, testing and certification services that seeks and establishes new standards for the ICT industry and provides world-class one-stop testing and certification services for ICT products.</p> <p>The Korean Agency for Technology and Standards is a government agency in charge of national and international standards in South Korea. It aims to harmonize South Korean industrial standards with international standards, conducting research for standardization, and endorsing international agreements related to standardization. The Ministry of Land, Infrastructure and Transport of the Republic of South Korea (MOLIT) is responsible for revising its regulations on test-driving of autonomous vehicles to allow test-driving of autonomous vehicles in the entire country.</p>
China [108]	<p>The China National Institute of Standardization (known as the Institute of Standardization of the State Science and Technology Commission when set up in 1963) is under the responsibility of the General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ). As a national social service institution dedicated to standardization research, it mainly addresses the global, strategic and comprehensive standardization issues in the national economy and social development of China.</p> <p>Also, the China Automotive Technology & Research Centre (CATARC) and the China National Centre of ITS Engineering and Technology are two major research organizations responsible for ITS and C&AV related standards.</p> <p>Additionally, the Chinese Electronics Standardization Institute – a research and policy group set up under the guidance of SAC, the Ministry of Industry and Information Technology (MIIT), the Ministry of Science and Technology, and the State Council Information Office – oversee TCs in the electronics sector and play a large role in setting the industry's standards policy and direction.</p>
France [109]	<p>The Ministry of Environment, Energy and Sea, responsible for international relations on climate change, and the Ministry of the Interior, issued in 2016 a decree to allow road testing in France through specific authorizations.</p>
Germany [46]	<p>The German Federal Ministry of Transport and Digital Infrastructure, announced in 2015 the launch of an "Automated Driving" Round Table, responsible for delivering a roadmap on the development of the legal framework. Germany's Federal Government presented in September 2015 its Strategy on Automated and Connected Driving at the International Automobile Exhibition in Frankfurt (IAA). The German Ministry of Transportation and Digital Infrastructure (BMVI) is the main responsible for the country's policy on C&AD.</p>
Italy [27]	<p>In Italy, automated activities are not allowed on public roads for safety reasons. However, some very special tests may be performed on short road sections after the area has been secured for testing purposes. In principle, automated transport systems in Italy may be considered legal if they are certified according to a technical standard that has been developed for rail systems. The only regulatory acts on this matter are the Decree of 1 February 2013 on the diffusion of Intelligent Transport Systems (ITS) and the National Action Plan for ITS approved on 12 February 2014. The problem is that both documents deal exclusively with cooperative driving (connected car, vehicular applications), whereas no mention is made to automated driving (driverless cars on public roads).</p>
Spain	<p>The Spanish DGT (Traffic General Department) was the regulatory body responsible for</p>

Country	Descriptive status
	publishing, in 2015, the legal framework to allow testing of automated vehicles on public roads in Spain. This legal framework details the requirements needed to conduct the tests, and a classification of vehicles depending on their level of automation.
Sweden [110]	A report called "The Road to self-driving vehicles – Experimentation" was submitted to the Swedish Minister for Infrastructure in March 2016, and included a number of proposals for the regulations of trials using self-driving vehicles. It is expected that the proposals be passed into a law in May 2017.
United Kingdom [54]	<p>The UK Government published a review of regulations on 11 February 2015, examining the regulatory framework for the safe testing of driverless cars. The main conclusions were:</p> <ul style="list-style-type: none"> • Driverless vehicles can be legally tested on public roads in the UK today, providing a test driver is present and takes responsibility for the safe operation of the vehicle. • The Department for Transport (DfT) has published a non-statutory Code of Practice that organisations testing autonomous vehicles in the UK are expected to follow. • Domestic regulations should be reviewed and amended by the summer of 2017 to accommodate driverless vehicle technology. • Communication at an international level should be done to amend international regulations by the end of 2018.
Europe	<p>The EC created the GEAR 2030 Working Group on "highly automated and connected vehicles" with two project teams, one focused on policy and regulatory issues aiming to review the existing legal and policy framework for highly C&AD and another on financing instruments for the development and implementation of C&A vehicles.</p> <p>The European Committee for Standardization (CEN) supports standardization activities in relation to a wide range of fields and sectors including IT, transport and smart living.</p> <p>The European Committee for Electrotechnical Standardization (CENELEC) is responsible for standardization in the electro-technical engineering field. It adopts international standards wherever possible, notably through collaboration with the International Electro-technical Commission (IEC).</p> <p>The European Telecommunications Institute (ETSI) produces standards for information and communications technologies. For instance, ETSI and CEN issued in 2014 "Release 1" specifications, with the basic set of standards for Cooperative Intelligence Transport Systems (C-ITS). Both organisations work together at the European level to build a legal framework that will facilitate the application and use of C&AD. While ETSI is focused on developing vehicle-to-vehicle (V2V) communications standards on the 5.9 GHz spectrum, CEN is focused on the overall framework architecture (platform using multiple communications technologies) and on vehicle-to-infrastructure (V2I) applications related to roadside and traffic management applications.</p> <p>ERTICO – ITS Europe²³ is a cooperation platform for all relevant stakeholders to develop and deploy ITS in Europe. It is a PPP consisting of over a hundred partners across eight different sectors working towards bringing intelligence into mobility of people and goods in Europe. The platforms within the group ensure successful development, deployment and maintenance of core ITS services/issues through competence centres for policy advice.</p>

The analysis of the legislative framework for C&AV considers large scale testing authorizations related to traffic rules and safety, and considers the insertion into market of C&AV relating to the provisions on road safety, vehicle legislation, driver behaviour, liability and other.

The United Nations Economic Commission for Europe (UNECE) is one of five UN regional commissions administered by the UN Economic and Social Council. The UNECE Inland Transport Committee (ITC) is a platform for international cooperation to facilitate the international movement of persons and goods by inland transport modes.

²³ ERTICO – ITS Europe. <http://ertico.com/vision-and-mission/>

The ITC has two permanent subsidiary bodies whose work is relevant for the introduction of C&AD:

1. The **Working Party on Road Traffic Safety (WP.1)**, which is a permanent intergovernmental body responsible for administering the international road-traffic related conventions including the 1968 Convention on Road Traffic and the 1968 Convention on Road Signs and Signals.
2. The **World Forum for Harmonization of Vehicle Regulations (WP.29)** is a permanent intergovernmental body responsible for the harmonisation of technical vehicle requirements. WP.29 prepares the work of the ITC to develop and adopt harmonised vehicle regulations. It works as a global forum allowing open discussions on motor vehicle regulations.

Any member country of the United Nations and any regional economic integration organization set up by country members of the United Nations may participate in the activities of the World Forum and may become a contracting party to the Agreements on vehicles administered by the World Forum. Governmental and non-governmental organizations (NGOs) may also participate in a consultative capacity in WP29 or in its subsidiary working groups [111]. Furthermore, at the international level there are two framework agreements with implications for automated driving currently in force:

- The **1949 Geneva Convention**, accepted by 95 states, which established uniform rules to promote road safety at the international level. One of the issues that impacts C&AD is related to the need that every vehicle shall have a driver and that they shall always be able to control their vehicles.
- The **1968 Vienna Convention of Road Traffic** (referred above) established standard traffic rules, having been ratified in 73 countries. One of the fundamental principles of this treaty requires that every vehicle have a driver, who must, always, be able to control the vehicle, be in a fit physical and mental condition to drive and (in case of power-driven vehicles), possess the necessary driving knowledge and skills. In 2006, a paragraph was added requiring the driver to minimize activities other than driving such as use of hand-held phones on motor vehicles.

All EU Member States are signatories of the Vienna Convention except for the UK and Spain. Outside Europe, the United States, Japan and China are not signatories. [112]

Considering this introduction, Table 6 presents descriptive information on the following aspects:

- Signature of International Conventions;
- Efforts to build a legal framework;
- Authorizations for C&AD testing;
- Road Traffic Regulations;
- Liability;
- IT Security and Privacy.

Table 6: Descriptive status of countries of Standards and Legislations

Country	Descriptive status
USA [105], [113], [114], [115], [116]	<p>In the USA, individual States have responsibilities for vehicle licensing and registration, traffic laws and enforcement, and motor vehicle insurance and liability regimes. As the relevance of autonomous vehicles for the automotive industry increases, state and municipal governments are starting to address the potential impacts of these vehicles on the road. In early 2016, sixteen States introduced legislation related to autonomous vehicles, up from 12 states in 2014, nine states and D.C. in 2013, and six states in 2012.</p> <p>At present, a regulatory proposal specific to driverless vehicle (aside from the above-mentioned licensing measures in a few States) does not exist. A national driverless vehicle law has not yet been proposed.</p> <p>On September 20, 2016, the National Highway and Transportation Safety Administration (NHTSA) issued updated guidance for the safe development of highly autonomous vehicles (HAVs). The policy update is broken down into four parts: (1) vehicle performance guidelines, (2) model state policy, (3) current regulatory tools, and (4) possible new regulatory actions. NHTSA is clear in its guidance that States retain their traditional responsibilities for vehicle licensing and registration, traffic laws and</p>

Country	Descriptive status
	<p>enforcement, and motor vehicle insurance and liability regimes, and that the model state policy included in NHTSA's policy release is in no way binding on States wishing to take action regarding use of HAVs in their own State.</p> <p>For potential HAV manufacturers, the policy includes a set of 15 best practices regarding the safe pre-deployment design as well as development and testing of HAV's prior to commercial sale or operation on public roads. Separately, the NHTSA issued an enforcement bulletin regarding its authority to issue recalls on automated technology. The notice has a particular focus on semi-autonomous technologies where the driver can allow the car to take over certain driving aspects, which the NHTSA believes could result in increased distracted driving.</p> <p>In July 2016, the NHTSA committed to develop a model state policy on automated vehicles. This policy materialized in September 2016 with the publication of Federal Automated Vehicles Policy. This model policy is intended to create a path to a consistent national policy. It was developed in cooperation with State partners, the American Association of Motor Vehicle Administrators, and other stakeholders. The USA National entity is encouraging manufacturers to submit rule interpretation requests, where appropriate, to help enable innovation in the area of automated technologies and autonomous vehicles. This document also provides recommendations on interpretation of current laws and to help with the formulation of new regulations, as well as a 15-point checklist ensuring the safety development of C&AD.</p> <p>In January 2016, the Secretary of US Transportation Secretary unveiled a new policy that updated the National Highway Traffic Safety Administration's (NHTSA) preliminary policy statement on autonomous vehicles from 2013.</p> <p>Also in 2016, the Technology Innovation and Policy Division from the USA Department of Transports presented a document with a review of the Federal Motor Vehicle Safety Standards (FMVSS) for Automated Vehicles. The report describes how Federal Motor Vehicles Safety standards may pose challenges to the introduction of automated vehicles. The agency will have to consider what regulatory changes may be needed to continue to ensure safety while not unduly affecting innovation.</p> <p>Recognizing that vehicles are cyber-physical systems and that cybersecurity vulnerabilities could impact the safety of the driver, passengers and pedestrians, the NHTSA has also focused on outlining guidance to the automotive industry for improving motor vehicle cybersecurity. The guidance focuses on solutions to ensure vehicle systems are designed to take appropriate and safe actions when being attacked. The guidance emphasizes the importance of making cybersecurity a top leadership priority for the automotive industry. It suggests that companies should allocate dedicated resources and enable seamless communication in organisations related to vehicle cybersecurity matters. The report also proposes best practices for researching, investigating, testing and validating cybersecurity measures.</p>
Japan [117], [118], [119]	<p>Although Japan signed the Geneva Convention (but not the Vienna Convention), there are a number of legal restrictions for testing automated vehicles in the country. Private companies are pushing the government to modify the current international legislation.</p> <p>Media reports suggest that the Government considers autonomous driving as a key item for the ITS growth strategy, aiming to put self-driving cars into practical use before the 2020 Tokyo Olympics. Currently, test permissions are granted by authorities on a case by case basis and the presence of a driver is legally required at all times.</p> <p>The first official permission to test autonomous cars in Japan was obtained in 2013 by the automaker Nissan, which was allowed to test its vehicles in the Kanagawa prefecture. The Kanagawa prefecture, due to its status as a National Strategic Special Zone and thus allowing higher regulatory flexibility compared to rest of the country, was granted a special permission to start testing Robot Taxi from March 2016.</p> <p>A draft guideline released in the first week of April 2016 by the National Police Agency (NPA), stated that all tests should be made with a driver behind the wheel, ready to take control of the vehicle in case of possible malfunctions. The driver would also have to ensure safety and comply with traffic laws. However, companies/ stakeholders willing to experiment C&AV will be allowed to do so without obtaining permission to use public roads as long as they comply with a number of rules:</p> <ol style="list-style-type: none"> 1. Public road tests should be conducted in stages, starting with places that have few pedestrians.

Country	Descriptive status
	<ol style="list-style-type: none"> 2. A passenger is required inside the car along with the driver, while partner vehicles should accompany the car with a sign attached to the car informing other motorists of the tests. 3. Drivers are responsible for any accident. 4. Experimental cars must also sound warnings when they shift to autonomous driving. 5. Cybersecurity measures are required to protect the test vehicles and full recording and storage of the test-driving data. 6. Fully autonomous cars will have to be equipped with black boxes, similar to those used in aviation, which will record data that will be analysed in case of an accident to determine what went wrong and to take the necessary measures before tests are resumed. <p>Japan's Road Traffic Act (RTA) will likely need to be revised if fully autonomous cars eliminate the need for a driver. The RTA allows autonomous driving if it can be controlled.</p> <p>Japan's National Police Agency is expected to establish a panel of experts, who will have to analyse possible legislative reforms for the new technology. Topics that stand out refer to liability aspects, such as who would be legally responsible in case of an accident and how the driver's license system for self-driving cars will be modified. Issues regarding IT Security and Privacy, especially related to anti-hacking measurements, will also be addressed by the NPA panel of experts to be modified in the early future.</p> <p>Related to the aforementioned point on cybersecurity, Japan's Internal Affairs and Communications Ministry has also focused on developing guidelines to prevent possible cyber-attacks against next-generation C&AV.</p>
South Korea [82], [120], [121]	<p>The Ministry of Trade, Industry & Energy (MOTIE), the Ministry of Science, ICT and Future Planning (MSIP), and the Ministry of Land, Infrastructure and Transport (MOLIT) initiated a private led "Smart Car Council", with each Ministry having its own role to execute the plan. The entity responsible for the legal framework is the Ministry of Land, Infrastructure and Transport (MOLIT). The Smart Car Council will provide:</p> <ul style="list-style-type: none"> • The improvement of the legal system for autonomous driving (short term); • The revision of the legal system for developing and applying autonomous vehicles in the market (long term) • The improvement of legislation according to various levels, such as testing level (test, license, etc.), evaluation/certification level (performance and safety criteria), distributing level (accident, responsibility, personal information protection, education/training, etc.) • The preparation of standard certification and performance safety evaluation methods for securing the safety of the autonomous vehicle. <p>Recently, MOTIE officially announced that they will legislate the detailed criteria of autonomous vehicles so that road testing operations are possible.</p> <p>The government expected to have test operations of autonomous vehicles by February 2016, with actual commercialization by 2018. The current development status has reached the 2nd stage, where it is possible to control the direction and speed at the same time.</p> <p>MOLIT has issued a Public Notice of the revised version of 'The Enforcement Rule of the Motor Vehicle Management Act', which allows test-driving of autonomous vehicles in the entire country including urban areas, under certain conditions.</p> <p>Under the previous regulations, road-testing of autonomous vehicles is allowed only on routes designated by MOLIT. So far, a total of 375 km have been designated as routes for test-driving, which includes one expressway, five national highways and two urban areas. Eight autonomous vehicles from five entities have acquired a temporary permit from MOLIT for test driving and now operate on these routes.</p> <p>There have been increasing demands from the private sector for wider and more diverse testing environments for autonomous vehicle technologies. To satisfy these demands and to secure safety at the same time, MOLIT has conducted a study to identify specific areas or conditions with higher risks during tests. After several consultations with experts, the Ministry decided to open up the entire public road systems except enhanced safety zones for the vulnerable (children, elderly, disabled).</p>

Country	Descriptive status
	<p>Additionally, there are media reports in early August 2016 which indicate that the government of South Korea has launched a project to develop a new test bed for self-driving cars that will include the development of new technologies to test autonomous cars. The new test bed, called the K-city, will be built around the Korea Transportation Safety Authority's existing proving ground in Hwaseong, Gyeonggi Province, according to the Ministry of Land, Infrastructure and Transport. This is another effort to commercialize level 3 self-driving cars by 2020. The ministry has already designated sections of existing roads for testing self-driving cars, totalling 320 km.</p>
China [82], [122], [123], [124]	<p>In June 2016, China inaugurated its National Intelligent and Connected Vehicle Testing Demonstration Base, located in the Jiading district of Shanghai, which concentrates many actors, activities, R&D centres and production plants related to the automotive sector.</p> <p>The Ministry of Industry and Information Technology (MIIT) plans to release Intelligent Connected Vehicle Technology Development Guidelines in 2016. The Ministry is also drafting a production standards framework and a committee of experts to establish the standards for the technology.</p> <p>Ministries are also drafting regulations on the testing of intelligent connected vehicles on public roads, allowing only those products in line with regulations to conduct highway tests. MIIT has progressively participated in the global regulations and standards discussion established through the United Nations Forum for Harmonization of Vehicle Regulations, and the Automotive Branch of the China Standardization Association.</p> <p>There is uncertainty regarding the wireless technology for cars. China may adopt cellular data technology, which is already used in many cars to access internet, rather than the dedicated short-range communications (DSRC) standard used in the USA and Europe. This possibility could make it harder for Chinese companies to adapt the latest C&AD technology developed by EU or USA manufacturers.</p>
France [40], [54], [109], [112]	<p>France published its roadmap for automated vehicles in July 2014, which identifies pilot zones for testing, changes to driver training, R&D projects running up to 2018, and authorisation of experimental on-road testing of highly automated vehicles in 2016.</p> <p>France is a signatory of the Vienna Convention. However, in October 2014, the French National Assembly authorised automated vehicles for testing purposes. France is focused on enhancing self-driving car deployment. The government has defined five zones where tests are currently allowed and further testing zones will soon be introduced in order to help the development of vehicle automation in the country.</p> <p>In August 2016, the French Ministry of Environment Energy and Sea, and the Ministry of interior launched a decree regarding the testing of C&AV on public roads. Testing requires an authorization guaranteeing the security of the testing process. Authorization is granted by the Ministry for Transport after consultation with the Ministry of the Interior and other relevant traffic and transport authorities.</p> <p>Official standards to regulate tests are expected to be operative by 2020. Peugeot Citroën was the first automotive company to obtain the authorisation for testing on French roads. Permissions were granted for four vehicles in 2015 and another 15 vehicles in 2016.</p> <p>France is considering what legislative changes may be needed at the national level. For instance, the Data Protection Authority's most recent annual report highlighted that C&AV will be an emerging issue that they will need to address. The French approach is to focus on setting professional standards where the parties involved agree the principles which govern data management and that these standards then become binding. This collaborative industry approach is seen as a first step, but if an agreement cannot be reached then the government is likely to step in.</p> <p>Regarding data protection, the case of France is particularly special. Legislation is being developed in response to recent terrorist attacks giving government agencies increased access to personal data. In the new scenario, law enforcement agencies could demand access to a vehicle's data to help them track a terrorist's location. Connected cars mean everyone's location and journey history is potentially available to a third party. This places the vehicle manufacturer at the centre of far reaching questions about civil liberties and the role of the state.</p>

Country	Descriptive status
Germany [27], [125]	<p>The Federal Highway Research Institute published a report concluding that, although existing levels of automation comply with German law, highly and fully automated vehicles do not. Currently, each Federal state can grant exemptions from the German Road Traffic Licensing Regulations, allowing the testing of automated vehicles, provided there is a driver who has full legal responsibility for the safe operation of the vehicle. In Germany, there is no specific legal framework on the testing of automated vehicles, but testing in traffic is allowed on the basis of a special permission.</p> <p>German legislation contains legal obligations for drivers regarding vehicle control and road and traffic monitoring. The legal concept of vehicle control is part of the Vienna Convention and was also included in paragraph 3 of the German Road Traffic Code (StVO), while paragraph 1 of StVO requires the road user to act considerately and with caution.</p> <p>The "Automated Driving" Round Table, launched by the German Federal Ministry of Transport and Digital Infrastructure, announced in 2015 a roadmap on the development of the legal framework to be published in the near future. Germany's Federal Government presented in September 2015 its Strategy on C&AD at the International Automobile Exhibition in Frankfurt (IAA). The strategy is a far-reaching reform of the existing regulations, in order to facilitate autonomous driving in the near future. The key aspects regarding the legal framework are summarized as follows:</p> <p>Road traffic regulation</p> <ul style="list-style-type: none"> • Adjusting the term "driver" to include "systems with full control over a vehicle" (Art. 1 of the Vienna Convention on Road Traffic). • Allowing automated cars to go as fast as 130 km/h and change lanes automatically (changing in particular regulation no. 79 on steering equipment of the UN-Regulations on Road Traffic). • Enabling C&AD systems to participate in road traffic (adjustments to the German Road Traffic Ordinance (StVG)). <p>Liability</p> <ul style="list-style-type: none"> • Proper usage of C&AV per se does not constitute driver negligence or results in increased liability risks for the driver. • Road traffic laws shall be reviewed, defining whether in certain situations the controlling systems are functionally equivalent to a "driver". <p>Product safety</p> <ul style="list-style-type: none"> • International standards on highly automated driving shall be developed. • The scope of the "European Code of Practice for Safe Development of Advanced Driver Assistance Systems" shall be extended to cover safety standards for automated vehicles. • Suitable system structures and tests shall be developed, in cooperation with the Automobile industry. New standards for the periodic technical surveillance (PTI) of cars shall be defined and included in the directives 2014/45/EU and 2007/46/EG. <p>IT-Security and Privacy</p> <ul style="list-style-type: none"> • The Automobile industry must guarantee the safe encryption of data and communication. The BMVI will review possibilities of controlling these processes, such as an external department inspecting such systems and/or the certification of these processes. • Security standards against unauthorised data access shall be developed and presented to the UNECE (United Nations Economic Commission for Europe). • Functional safety standards (ISO 26262), IT and encryption standards shall include C&AD. • The principles of data minimization and specific purpose of usage shall continue to apply. • Technological solutions for anonymizing data shall be further developed. • User consent for collecting and processing data must be free and informed, as well as revocable. Users must have the option to select and turn off data enabled services, other than those directly related to vehicle functions and safety. • Privacy friendly systems in the components and the initial settings must follow the principles of "privacy by design" and "privacy by default".

Country	Descriptive status
Italy [27]	<p>In Italy, automated activities are not allowed on public roads for safety reasons. However, some very special tests may be performed on short road sections after the area has been secured for that purpose. In principle, automated transport systems in Italy may be considered legal if they are certified according to a technical standard that has been developed for rail systems.</p> <p>The only regulatory acts on this matter are the Decree of 1 February 2013 on the diffusion of Intelligent Transport Systems (ITS) and the National Action Plan for ITS approved on 12 February 2014. The problem is that both documents deal exclusively with cooperative driving (connected car, vehicular applications), whereas no mention is made to automated driving (driverless cars on public roads).</p> <p>In 2013, the University of Parma ran a test specifically aimed at demonstrating their technology on public urban roads – the PROUD (Public Road Urban Driverless car test). The test used an open road route with a mix of rural, freeway, and urban traffic. The test was carried out with a police escort at all times and a passenger ready to use the brake pedal in case of any emergency situations.</p>
Spain [126]	<p>The Spanish DGT (Traffic General Department) published in November 2015 the legal framework to allow testing of automated vehicles on public roads in Spain. This framework details the requirements needed to conduct the tests, and a classification of vehicles depending on their level of automation.</p> <p>Until now, the Spanish traffic regulation included the possibility of testing and performing research studies on public roads with non-automated vehicles. With the new framework, automated vehicles can also be tested. Spain allows testing of vehicles on roads including from SAE level 1 up to SAE level 5.</p> <p>With this measure, DGT aims to encourage universities, companies and research centres to test autonomous vehicles in Spain, and to support autonomous driving research as a means to improve traffic safety and efficiency. Authorization for testing and trials can be requested by manufacturers of autonomous vehicles, official laboratories, suppliers of autonomous driving technologies, universities and consortia involved in research projects.</p> <p>The framework also specifies the requirements that need to be satisfied to obtain the corresponding authorization, including the requirements of the applicant, the driver, the vehicle, and the owner of the vehicle. The scope of the authorization is national, and establishes the sections of urban and interurban roads on which the automated vehicle is authorized to perform the tests. Authorizations will be granted for a period of maximum of 2 years, but these can be renewed.</p> <p>The legal instrument also regulates the requirements for the application and granting of authorisation for autonomous vehicle tests and trials on public roads. This is a nationwide authorisation that defines the sections of urban and interurban road on which the vehicle can be tested and trialled.</p> <p>As for the requirements, the autonomous vehicle must hold valid insurance covering the compulsory insurance limits for motor vehicles in Spain, as well as civil liability for any damage caused. It requires the autonomous vehicle to have passed with a technical service provider accredited by the National Accreditation Body the procedures set out in the above-mentioned Instrument:</p> <ol style="list-style-type: none"> 1. Review of documentation (registration certificate, log book, software version and emergency shutdown and override information); 2. Inspection (safety elements check); and 3. Dynamic checks (manual driving check, override systems check and basic functions affecting safety check). <p>Otherwise, evidence must be provided that the competent authority of another Member State of the European Union has already issued authorisation to conduct tests on public roads. Such evidence must include a Risk Assessment document based on HARA ('Hazard Risk Analysis'), which forms the basis of the entire functional safety activity according to ISO 26262 and FMEA ('Failure Mode Effects Analysis'). The Instrument provides that the National Administration must respond to such applications for authorisation within a maximum time limit of one month. The first driverless experiment was conducted following these steps in November 2015, on the 600 km Vigo – Madrid route.</p> <p>Platooning trials have already been undertaken, with more planned for the end of 2016,</p>

Country	Descriptive status
	<p>as well as a trial test of an automated vehicle on 100 km of highway. The Government has invested in an outdoor test track for testing the most advanced technologies. The government has invested in building offices and an outdoor test track for testing the most advanced driving technologies. Scania is working with a Spanish test laboratory (IDIADA) to test their entire platooning system on Spanish roads in autumn 2016.</p>
Sweden [127]	<p>Findings from the Swedish Transport Agency in May 2014 stated that current vehicle legislation, driver's license rules and liability rules may need amendments to allow the testing of vehicles. Existing vehicle regulations and roadworthiness testing would have to be amended to cover the hardware and software used for automated vehicles. The study highlighted a required improvement to Sweden's registry of all national and local traffic regulations.</p> <p>A recent report called "The Road to self-driving vehicles – Experimentation" was submitted to the Swedish Minister for Infrastructure in March 2016, and included a number of proposals for the regulations of trials using self-driving vehicles. It is expected that the proposals be passed into a law in May 2017.</p> <p>The Vienna Convention and the Swedish Road Traffic Ordinance coexist. Swedish authorities have incorporated several regulations from the Convention into the national legislation. At the moment, the Ordinance makes it mandatory for a driver to always be inside the vehicle, capable of intervening at all times, as someone has to be legally responsible at all times.</p> <p>Nevertheless, Swedish legislation does not categorically forbid the utilisation of advanced driving systems to support the driver, but points out some limitations. Due to the latter, automotive manufacturers will have to demonstrate that their automated systems will not affect basic driving tasks and allow the driver to always maintain control over the vehicle.</p> <p>According to the Ordinance, local authorities and municipalities are authorised to issue special traffic laws and define regulations independently from national directives. In any case, special authorisation is only granted for situations that guarantee road safety at all times.</p>
United Kingdom	<p>The UK has not ratified the Vienna Convention and their legislative framework does not require major changes to test automated vehicles on public roads. Nevertheless, the government sought to clarify the legislative and regulatory environment for connected and autonomous vehicles in the UK.</p> <p>Its first action was to conduct a review of the regulations and legislation to examine their compatibility with automated vehicle technologies, which is documented in a report titled the "Pathway to Driverless Cars". The government has emphasised that the regulatory framework that will be introduced will be sufficient to ensure that manufacturers and suppliers can easily test and develop autonomous vehicles. The aim is to introduce the new legal regulatory framework by the summer of 2017.</p> <p>The Department for Transport (DfT) has published a non-statutory Code of Practice that organisations testing autonomous vehicles in the UK are expected to follow. This provides guidelines and recommendations for measures that should be considered to ensure safety during testing. Moreover, in July 2015, the UK government launched a £20 million competitive fund for collaborative research and development into driverless vehicles.</p> <p>The UK Government published a review of regulations on 11 February 2015, examining the regulatory framework for the safe testing of driverless cars. The main conclusions were:</p> <ul style="list-style-type: none"> • Driverless vehicles can be legally tested on public roads in the UK today, providing a test driver is present and takes responsibility for the safe operation of the vehicle. • A Code of Practice would be published (Spring 2015) for those wishing to test driverless vehicles on UK roads. • Domestic regulations should be reviewed and amended by the summer of 2017 to accommodate driverless vehicle technology. • Liaise at an international level with an aim to amend international regulations by the end of 2018.
EUROPE	<p>In September 2015, the Transport Ministers of the G7 States and the European</p>

Country	Descriptive status
[58], [128], [129], [130], [131], [132], [133], [134], [135]	<p>Commissioner for Transport approved a declaration on C&AD which emphasised the need to take steps to put in place a harmonised regulatory framework. Sustained cooperation between the G7 States and the European Commissioner for Transport is required in following areas:</p> <ul style="list-style-type: none"> • Coordinating research and promoting international standardisation within an international regulatory framework; • Evolving technical regulations; • Ensuring data protection and cyber security. <p>The EC is also promoting connectivity and interoperability by working on the international harmonisation of technical standards, in particular together with the European Standardisation Organisations and in cooperation within the US/EU Standardisation Harmonisation Working Group. With initiatives such as the iMobility Forum and the C-ITS Platform, the EC brings together private and public stakeholders to coordinate the technical developments at the European level and to ensure interoperability and coherent deployment of the systems.</p> <p>Of the three aforementioned areas, cybersecurity is of particular importance. There has been some negligence towards IT security, including in the EU. However, the European Union Agency for Network and Information Security (ENISA)²⁴ has made efforts to meet with car manufacturers, suppliers of software for cars and national agencies responsible for cybersecurity to address this issue in C&AV. Also, ENSIA has made plans to draft security recommendations directed to manufacturers and possible suggestions for legislation on C&AV for 2017. Within the framework of cybersecurity, ENSIA has published a study aiming to identify good practices that safeguard the security of smart cars (or C&AV) against cyber threats. The study presents relevant assets present in smart cars, as well as the corresponding threats, risks, mitigation factors and possible security measures that should be implemented to ensure security. Regarding the proposed good practices, these focus on policy and standards, organisational measures and technical aspects. At a broader scale, the EC has already developed a document that proposes a contractual public private partnership on cybersecurity and accompanying measures. Furthermore, the EU has other strategies in place for cybersecurity, including the cybersecurity strategy for the EU and the European Agenda on security. These references outline the overall strategic framework for the EU initiatives on cybersecurity and cybercrime, which are also applicable to C&AD.</p> <p>Related to cybersecurity is also the area of big data. As C&AV become increasingly connected (to vehicles and infrastructure) and automated, they also generate more information. C&AV and their drivers will generate more information which is broadcast to and managed by different infrastructure and actors. This raises the question of the security of the data but also how it is handled and who authorises its use. Currently, C&AD must comply with the General Data Protection Regulation²⁵, meaning that information must be used with consent from users. The EC, through its strategy for C-ITS, defends that the protection of personal data and privacy is essential for the successful deployment of CA&V. Thus, the EC has proposed that C-ITS service providers offer transparent terms and conditions to end-users, enabling them to give their consent for the processing and management of their personal data. The EC expects to propose initial guidance in this regard during 2018.</p> <p>Related to standards, the EC has adopted Regulation (EU) 2015/758 43, which establishes the rules of the eCall initiative. Section 6 of the Regulation lays down specific provisions related to the privacy of users' personal data (i.e. owners of the car) of the eCall system. Essentially, the provisions follow the data protection principles laid down in EU Data Protection Directive 95/46/EC. For example, under the Regulation, the data must only be used to handle emergencies. In terms of data retention, the Regulation requires that data must be deleted as soon as it is no longer necessary for such purposes. In other words, if no accident occurs, the data must be cancelled right away. Manufacturers must ensure that the 112-based eCall system is not traceable and not subject to constant tracking. The data in the system (i.e. in the memory installed in the cars) must be automatically removed, with one exception: the last three locations recorded can be kept, only as long as it is necessary to understand the exact location</p>

²⁴ European Union Agency for Network and Information Security (ENISA). <https://www.enisa.europa.eu>

²⁵ Reform of EU data protection rules. http://ec.europa.eu/justice/data-protection/reform/index_en.htm

Country	Descriptive status
	<p>and the direction the car was traveling at the time of the accident. In addition, no individual outside the eCall system may have access to the data, and privacy enhancing technologies must be used to minimize risks of privacy violations and misuse. EU Privacy Law 45 requires that due notice of data processing must be given to the data subject (i.e. the person whose data is being processed). In the case of eCall, the manufacturers have this obligation. This information is to be provided in the owner manual.</p> <p>From the perspective of mobility, and as discussed in Section 1.2, C&AD will likely lead to the emergence of new business models linked to transport and/or mobility services, which can also be connected to specific C&AD infrastructure. Current EU regulation covers all modes of transport, which have been mainly regulated through a sector-specific approach. However, the novelty and challenges of these mobility services requires specific regulation so that this complex system can work properly. However, it is considered that this comprehensive regulation is yet to be fully developed. Nevertheless, the EC recognises that a renewed regulatory framework is necessary and should focus on five key aspects:</p> <ol style="list-style-type: none"> 1. Regulating customer protection. With (big) data becoming increasingly important, privacy and data security will become a major issue for the entire transport sector. Therefore, EU standards are needed at the technical level and the level of general cross sectoral principles and rules for data protection. 2. Regulating mobility solution providers. Travellers will increasingly become customers of mobility solution providers rather than transport operators. Mobility platforms will become mainstream as will companies that facilitate the exchange of services. The regulation of these actors, definition of fair competition and clear liability guidelines is essential. 3. Regulating the newly emerging data layer. Integrated mobility solutions and services require an open and accessible transport data. For this data layer to become openly accessible and usable, regulations on data standardisation and data accessibility are required. This is considered one of the key challenge for EU regulators. 4. Regulating intermodality and intermodal competition. As mobility services are intermodal, intermodality and intermodal competition needs to be regulated. On the one hand, intermodal transport hubs (ports, airports, railway stations) must be regulated as such. On the other hand, attention needs to be paid to removing distortions among the different transport modes. 5. Regulating the infrastructure layer and guaranteeing a stable legal framework to favour investments. With the emergence of new mobility services, transport service providers and transport infrastructure operators will face additional financial pressure. Thus, regulation will have to ensure a stable and EU-wide regulatory framework.

2.3.2 Comparative analysis of European and third-country standards and legislations

EU Member States have created several bodies and government agencies to specifically study and create standards and regulations related to C&AD development. These bodies have also been created at the EU level, therefore increasing the involvement of the EU in C&AD development. Despite these bodies, and the existence of country-specific regulations which to some extent have supported C&AD development and testing, there are still some obstacles, mainly related to obtaining specific permits for testing. This analysis is further detailed in the discussion points below.

Bodies tasked with standard making and regulations

With the exception of Italy, the Member States considered in this study have created or tasked specific government agencies with the responsibility of creating standards and regulations in their respective country. For example, the German Federal Ministry of Transport and Digital Infrastructure announced the launch of an "Automated Driving" Round Table that is tasked to deliver a roadmap for the development of the legal framework to be published in the near future. Meanwhile, several legal frameworks that allow for road testing of C&AD vehicles have also been published by the Spanish

Traffic General Department and Swedish Ministry for infrastructure. This highlights the importance of these government bodies in supporting the development of C&AD.

This is also the case at the European level. The EC has created the GEAR 2030 Working Group on "highly automated and connected vehicles", a group that allows the competitive deployment of C&AD in Europe. One of its two project teams is responsible for investigating policy and regulatory issues aiming to review the existing legal and policy framework for C&AD across Member States.

Another European initiative related with standard making and regulation is ITS Europe (ERTICO), a platform for the cooperation of all relevant stakeholders to develop and deploy ITS in Europe. ERTICO is a PPP consisting of over a hundred partners across eight different sectors working to bringing intelligence into mobility of people and goods in Europe. The platforms within the group ensure successful development, deployment and maintenance of core ITS services/issues through competence centres for policy advice.

Within the USA, and considering the State role in regulating traffic and transportation, there is no single entity within the Executive Branch of the federal government that has jurisdiction to regulate all aspects of driverless vehicles, although the US Department of Transport (DOT) has major responsibilities. Similarly, in Japan and South Korea, there has been very few government initiatives in creating agencies tasked with regulating C&AD technology. Therefore it can be concluded that EU Member States have a broader approach in terms of government agencies responsible for standards and regulations of C&AD technology.

National and European legislations for the development of the C&AD

One of the main challenges for C&AD in the EU are the regulations and legal framework that enable companies involved in C&AD to conduct tests and additional research. A clear regulation that allows the conducting of tests both on testbeds and on public roads is needed since the data obtained from these tests will contribute to solving problems related to C&AD. This regulation needs to address liability issues as one of the most problematic aspects both in testing as well as in the future deployment of C&AD on public roads.

Therefore, legislation concerning safety requirements and traffic rules related to autonomous vehicles are needed, especially for the more distant future. Moreover, the future development of technologies in C&AD also demand the adaptation of driving education and licensing that also needs to be formulated in order to increase the practicality of C&AD in Europe. With the potential that autonomous vehicles may have for ride-sharing service providers such as Uber, Lyft, or Didi Chuxing, a rigorous regulation is needed.

The lack of regulations and respective implementation contrasts to what occurs in the USA, where at least 34 States and Washington D.C have proposed legislation related to C&AD development [105]. While the regulation in each State is varied, the existence of regulations helped stakeholders further develop C&AD in the USA. However, there is still some disparity in terms of regulation across the different states, which may in the future present new challenges.

The Japanese government, through its National Police Agency (NPA), published in May 2016 a guideline on autonomous vehicles. This guideline regulates that self-driving cars can be tested on public roads as long as a human driver is present [136]. This guideline also regulates the need of a "black box" that automatically records driver and system data during the operation of autonomous cars.

General condition of regulations and standards

Most European Member States considered in this study have made some progress in creating regulations and standards related to C&AD. For instance, in 2016 France launched a decree regarding the testing of C&AV on public roads and defined that by 2020, official standards to regulate tests would be operative. In Germany, there is no specific legal framework for the testing of automated vehicles, but testing in traffic is allowed on the basis of a special permission. In Spain, national authorities have published a legal framework for public road testing that entails specific requirements for the application and granting of authorisation for autonomous vehicle tests and trials on public roads.

At the EU level, in 2015 the Transport Ministers of the G7 States and the European Commissioner for Transport approved a declaration on C&AD that emphasised the need to take additional steps to create a harmonised and cross-border regulatory framework. This declaration particularly addressed the

coordination of research and international standardisation, evolving technical regulations and ensuring data protection and cyber security.

Outside of Europe, particularly the USA, regulatory proposals specific to driverless vehicles and a nationwide driverless vehicle law have not yet been proposed. In 2016, the NHTSA published updated guidance for the safe development of highly autonomous vehicles, but there are no federal level guidelines for testing C&AD vehicles on public road.

In Japan, the regulation for testing C&AD vehicles appear to be more flexible. Permission to test automated vehicles has been given as early as 2013. Draft guidelines regulating C&AD tests were published in April 2016 and included a more detailed procedure to adhere to in C&AD tests. However, these guidelines are not binding and test-drivers are encouraged to consult with police in cases where experiments do not meet the guidelines.

The situation is similar in South Korea, where intentions to legislate requirements for C&AV road testing were announced in September 2015. Similar guidelines were published by the Chinese Ministry of Industry and Information Technology in 2016. The Ministry is also drafting a production standards framework and a committee of experts to establish the standards for the technology, intelligent assistant, and information security for intelligent connected vehicles.

From this explanation, it can be seen that apart from the USA, competing countries have more comprehensive standards and regulation regime compared to EU Member States. These regulations and guidelines for road testing were also published earlier, putting them in a more advantageous position in the development of C&AD. Moreover, these guidelines are also seen as more flexible and less bureaucratic, particularly in Japan, which allows for experiments that do not meet the terms stipulated in the guidelines.

Another important advantage of the third countries is that none are a signatory of the Vienna Convention, which imposes some restrictions related to C&AV. This has led The USA, Japan, China, and South Korea to have an advantage in terms of regulations and standards for C&AD development.

However, one confluent area of C&AD where the EU is comparable to other countries is cybersecurity. Cybersecurity is in fact of particular importance. Some sources [137] consider that cybersecurity is one of the biggest threats for C&AV, boosted by the Jeep Cherokee hacking incident of 2015 [138]. The complexity of C&AV, assembled with extensive and interconnected electrical components, make them vulnerable to attacks. Furthermore, the fact that different manufacturers assemble vehicles with parts from multiple suppliers means that no single player is in full control.

Recognizing the importance of cybersecurity and how it can eventually impact the deployment and usage of C&AV, various key players have been taking action, in Europe and abroad. In the EU, the European Union Agency for Network and Information Security (ENISA) has worked with various players to ensure cyber security in C&AV. They have also proposed various good practices to be considered. In the USA, the NHTSA has also provided guidance to the automotive industry for improving vehicle cybersecurity. The guidance emphasizes the importance of making cybersecurity a top leadership priority for the automotive industry. Furthermore, several manufacturers (e.g. Tesla, GM) have also moved forward with special programmes that reward individuals in identifying security flaws in vehicle systems [137].

Regarding mobility services, a comprehensive regulation is still missing in the EU. In the USA, for example, the Federal Transit Administration under the USDOT has made some progress in this area [139]. Furthermore, other studies have also outlined key recommendations to address policy issues [140]. The EU recognises the importance of defining regulations for mobility services, and has already outlined five key areas on which regulation should focus: (1) customer protection, (2) mobility solution providers, (3) the newly emerging data layer, (4) intermodality and intermodal competition, and (5) the infrastructure layer and guaranteeing a stable legal framework to favour investments.

2.3.3 SWOT – Analysis for Europe on standards and legislations

Table 7: SWOT Analysis for Europe on standards and legislations

Strengths		Weaknesses	
Main Point	Explanation	Main Point	Explanation
Implementation of regulatory changes to enable testing	<ul style="list-style-type: none">Several Member States have developed initial strategies that enable testing of C&AV on public roads and tackle regulatory issues.	The need for permission to conduct tests	<ul style="list-style-type: none">Existing regulations require manufacturers to obtain authorisation or permission to conduct tests. This could be bureaucratic and delay tests and advancements in technology development.
Implementation of guides for C&AD tests facilitates procedures, increase testing safety and harmonises legal framework	<ul style="list-style-type: none">Several countries have developed a Code of Practice for technology companies to test their automated vehicles on public roads.This guideline for the automotive industry is important to promote legal harmonisation and can help other local entities to adopt the guidelines through new regulations and standards.	Lack of an integrated legal framework approach for C&AD at the national level	<ul style="list-style-type: none">EU Member States have developed regulations and standards independently, which lack uniformity with other countries.As C&AD development would imply crossing national/ regional borders, the lack of harmonised and integrated regulations can hinder the future harmonisation of legislations for C&AD, compromising the introduction of products into the market.
		Need to amend the Vienna Convention	<ul style="list-style-type: none">Systems with high or full automation are mostly still incompatible with the Vienna Convention that requires the presence of driver in a vehicle.
Opportunities		Threats	
Main Point	Explanation	Main Point	Explanation
Studies on the legal challenges to promote discussions and enable C&A vehicles	<ul style="list-style-type: none">EU Member States are conducting studies of the legal frameworks and the impact of C&AD regulations that can provide clarity, demonstrate different perspectives, stimulate discussion between stakeholders and provide recommendations for policy and legislations.	Existing regulations and standards could jeopardise the insertion of C&AD products into market	<ul style="list-style-type: none">The majority of regulation changes with regard to the development of C&AD have been focused on testing and still lack aspects related to market introduction.Within the testing regulation, there is still a lack of insurance and liability policies for C&AV.Regulation related to cybersecurity is also not seen as a key issue for C&AD.
Creation of workgroups to discuss regulations in C&AD	<ul style="list-style-type: none">The creation of specific workgroups with various stakeholders to discuss regulatory challenges and present recommendations to policy makers.	Cybersecurity and privacy issues require additional focus and involvement of all C&AD actors	<ul style="list-style-type: none">C&AD will require that vehicles’ locations and journey history be recorded and preserved on a server. The current IT security conditions do not yet negate the possibility of this data being externally accessed and putting user’s safety at risk.With the user’s data stored in servers, government agencies may also use this data to track criminals, including terrorists’ location. On the other hand, this raises the far-reaching questions about civil liberties and the role of the state.
Integrated approach for European legal framework	<ul style="list-style-type: none">The EC has been instructed to adopt the necessary regulatory provisions, coupled with initiatives (including funding) aimed at developing the required legal standards.		

STRENGTHS

Implementation of regulatory changes to enable testing on national public roads

The process of creating a comprehensive regulation for C&AD has already started with several EU Member States implementing regulatory changes that enable C&AV to be tested on public roads. This is a strength considering this effort has supported the European automotive industry in the development of their products and helped increase Europe's competitiveness.

With the exception of Italy, where references suggest that very special tests of automated vehicles may be performed on secured short road sections; France, Spain, and the UK have explicitly allowed for automated vehicles to be tested on public roads, although limited to particular requirements. In France, the Ministry of Environment, Energy and Sea, together with the Ministry of the Interior issued a decree to allow road testing in France through specific authorizations in 2016. The Spanish General Traffic Department (DGT) has also published a legal framework to allow testing of automated vehicles on public roads in Spain. In the UK, the legal framework is considered to support the testing of driverless vehicles, as long as a test driver is present and takes responsibility for the safe operation of the vehicle.

In the USA, the each State has responsibilities for vehicle licensing and registration, traffic laws and enforcement, as well as motor vehicle insurance and liability regimes. At the end of 2016, various States had provisions to allow automated vehicles to be tested on public roads. China, Japan, and South Korea have not come up with specific regulations for C&AD testing on public roads.

It is relevant to note that experts' feedback shows that progress has been made towards the introduction of new or revised regulations related to C&AD. More than 75% of experts indicated being aware of regulatory frameworks for testing autonomous vehicles in their country/elsewhere (Question 1C.1). It should be noted that the majority of experts who replied positively were from Europe, suggesting that advances in regulation are in fact a priority across Europe and Member States (at least those considered in this study). This validates the point on the 'implementation of regulatory changes to enable testing on national roads' as being one of the strengths of EU Member States.

When asked about the existence of differences between regulations/standards from the expert's country compared to other countries (EU and third countries) (Question 1C.2), less than 50% of the experts were in agreement. Among those that were in agreement, several did not justify the extent of the existing differences. Considering that more than 25% of experts did not provide an answer, it is possible to say that experts' knowledge of regulations/ standards beyond their own country is limited. These results suggest that in fact regulation and standardisation is a priority across Europe, mainly within the Member States.

Implementation of guides for C&AD tests facilitates procedures, increase testing safety and harmonises legal framework

Several Member States, including the UK (and Belgium and the Netherlands outside of the scope of the study) have developed a Code of Practice for technology companies wishing to test their automated vehicles on public roads. The UK Department of Transport conducted a detailed review of its existing legislation to establish the regulatory framework with respect to the testing of automated vehicles and their longer-term introduction to the market.

In France, the implementation of C&AD testing on public roads has led government agencies to consider what legislative changes may be needed in their jurisdictions. For instance, the Data Protection Authority's 2016 annual report highlighted that connected vehicles will be an emerging issue that will need to be addressed. In Germany, the fact C&AV are allowed to be tested in traffic has facilitated the creation of an autonomous vehicle testing corridor on the A9 motorway between Berlin and Munich. In Spain, the Spanish DGT is encouraging universities, companies and research centres to test autonomous vehicles and to support autonomous driving research as a means to improve traffic safety and efficiency.

In the same direction, Japan has also presented a set of guidelines that need to be followed by testers. In the USA, the National Highway and Transportation Safety Administration (NHTSA) issued updated guidance for the safe development of highly autonomous vehicles (HAVs) considering safety testing legal framework.

Therefore, allowing C&AD tests on public roads facilitates procedures, increases testing safety and can contribute to harmonising the legal framework in the EU Member States considered in this study. This is a strength that Europe has when compared to its competitors. These guidelines and codes of

practice facilitate the understanding of stakeholders and can make it easier for the automotive industry to implement different tests. It also improves safety for testing and gives more assurance to the automotive industry. The presentation of guidelines to the automotive industry is important to promote legal harmonisation and can help other local entities to adopt the guidelines through new regulations and standards.

WEAKNESSES

The need for permission to conduct tests

While regulations to conduct tests on public roads have been enacted in several European Member States, authorisations or permissions are still often needed to conduct these tests. This process can be bureaucratic and delay tests and progress in technology development, putting the European industry behind competitors that do not have these requirements. Therefore this could be considered as a weakness in the development of C&AD in Europe.

France has issued an amendment to the Vienna Convention and has authorised testing of C&AV through a permission from the Ministry of Transport and Ministry of the Interior. Germany does not have a specific legal framework for testing, but special permissions have already permitted the implementation of tests. In Sweden, special authorisation is only granted for situations that guarantee road safety at all times. However, Swedish transport regulations allow authorities to make rapid decisions for specific and innovative purposes, such as self-driving tests.

In the UK, the regulation for conducting C&AD tests requires the presence of a test driver to take responsibility for the safe operation of the vehicle. This may delay the development of more advanced automated vehicles that reduce the role of driver. Domestic regulations in the UK will likely be reviewed and amended by the summer of 2017 to accommodate driverless vehicle technology. In the case of Italy, automated car tests are only allowed on short road sections after the area has been secured for testing purposes.

Outside Europe, the USA (although varying within each State), Japan, South Korea and China have more flexible authorizations for testing. In Japan, the government has issued guidelines that enable the industry to go ahead with tests if they comply with them. In South Korea, the government has authorised testing in the entire country. China has also issued guidelines that facilitate the testing of C&A vehicles.

Lack of an integrated legal framework approach for C&AD at the national level

Member States involved in C&AD deployment have independently started to issue regulations, passing legal changes and issuing amendments to current legislations.

China, Japan and South Korea do not need trans-border regulations on C&AD. However, the scenario is different with the USA, as the States are able to pass specific laws which might not be harmonised between them. Thus, cross-State testing is currently not fully possible since many States do not have a harmonised legal framework for C&AD.

Considering that C&AV would work cross border (national and regional borders), the lack of a European integrated approach on regulations can hinder the future harmonisation of legislations for C&AD and can compromise the implementation of products into the market. This lack of an integrated approach is considered a weakness for the EU in fostering C&AD.

The need to amend the Vienna Convention

All Member States are signatories of the Vienna Convention – only the UK and Spain have not ratified it. While interpretation of this Convention may still be debateable, there are several Articles that certainly need to be addressed before C&AD can be fully deployed. Therefore, an amendment process is necessary to permit driverless vehicles.

In Sweden, for example, the Vienna Convention and the Swedish Road Traffic Ordinance coexist. Swedish authorities have incorporated several regulations from the Convention into the national legislation. At the moment, the Ordinance requires the presence of a driver inside the vehicle, capable of intervening at all times, as someone has to be legally responsible at all times. The German legislation also contains legal obligations for drivers regarding vehicle control and road and traffic monitoring. The legal concept of vehicle control is part of the Vienna Convention and was also included in the German Road Traffic Code (StVO).

As the USA, China, Japan and South Korea are not signatories of this Convention, they do not face the same limitations as other EU Member States.

OPPORTUNITIES

Studies on the legal challenges to promote discussions and enable C&A vehicles

EU Member States have or are conducting an analysis of the legal frameworks and the impact of C&AD regulations. The aim is to adapt regulations and have a better idea of the future needs to enable C&AD vehicles. This is an opportunity that Member States have in comparison to their competitors.

France published its roadmap for automated vehicles in July 2014. The roadmap indicates pilot zones for testing, changes to driver training and research and development projects up to 2018, with authorisation of experimental on-road testing of highly automated vehicles in 2016. In Sweden, a report titled "The Road to self-driving vehicles – Experimentation" was submitted to the Swedish Minister for Infrastructure in March 2016, and included a number of proposals for the regulations of trials using self-driving vehicles. It is expected that the proposals be passed into law in May 2017.

The UK has also conducted a review of the regulations and legislation to examine their compatibility with automated vehicle technologies, which is documented in a summary report titled the "Pathway to Driverless Cars". The UK government has emphasised that the regulatory framework that will be introduced will be sufficiently light-touch to ensure that manufacturers and suppliers can easily test and develop autonomous vehicles. The aim is to introduce the new legal regulatory framework by the summer of 2017.

Creation of Workgroups to discuss regulations in C&AD

China, Germany, Japan, and South Korea have created specific groups that bring together private and public stakeholders to discuss regulatory challenges and present recommendations to policy makers. There is an opportunity to carry out a similar action within Europe, complementing for example of the already existing GEAR 2030.

In 2015, the German Federal Ministry of Transport and Digital Infrastructure announced the launch of an "Automated Driving" Round Table, responsible for delivering a roadmap on the development of the legal framework to be published in the near future. Germany's Federal Government presented in September 2015 its Strategy on Automated and Connected Driving at the International Automobile Exhibition in Frankfurt (IAA). The strategy is a far-reaching reform of the existing regulations, in order to facilitate autonomous driving in near future.

This idea is also corroborated by the majority of experts' opinions that 'sustainability and regulation' are either a 'very important' or 'important' item for deploying C&AD. However, this verified importance is not fully aligned with the current trend at Member State level, where one of the most common processes verified only allows C&AD testing when specific authorisations and permissions are granted. This, in fact, is not an efficient approach to facilitate C&AD development or deployment, as the entire process is time-consuming.

Integrated approach for European legal framework

The EC has committed millions of euros to funding research projects aimed at assessing the relevant legal issues (such as product liability, road traffic laws, regulatory laws, data privacy and data security) resulting from automation of traffic systems and vehicles, and determining guidelines for implementing a uniform regulatory framework for all EU member states.

The EC also promotes connectivity and interoperability by working on the international harmonisation of technical standards, in particular together with the European Standardisation Organisations and in cooperation within the US/EU Standardisation Harmonisation Working Group. With initiatives such as the iMobility Forum and the C-ITS Platform, the EC brings together private and public stakeholders to coordinate the technical developments on European level and to ensure interoperability and a coherent deployment of the systems.

The EU has implemented various directives to give the EC the power to adopt the necessary regulatory provisions for automated traffic systems and vehicles, as well as initiatives aimed at developing legal standards for ensuring public safety. However, the fact that experts' knowledge of regulations is mainly limited to the sphere of their own country suggests that additional efforts are required in the development of a cross-European framework. Considering the values of Europe and the fact that traditional driving is cross-border (national and regional), a Europe-wide regulatory and

standardisation framework for C&AD should be developed with each Member State adapting it as necessary to their national rules.

THREATS

Existing regulations and standards could jeopardise the insertion of C&AD products into market

C&AD imposes a series of challenges to the current legal framework, with particular impact on road traffic safety, liability, insurance, product safety as well as IT-security and privacy. Most of the regulation changes implemented in Europe have focused on testing permissions, with limited consideration of the regulatory changes needed for the introduction of C&AV in the market. Therefore, the lack of regulations addressing this area could be considered a threat for the development of C&AD technology.

There is a strong need for revision of codes of practice on road safety in order to further develop C&AD. Even within regulations related to testing, there is a lack of insurance and liability policies for C&AV. From the EU Member States considered in this study, only Spain regulates the insurance covering connected vehicles as well as civil liability for any damage caused. Furthermore, information collected for this study suggests that cybersecurity is not yet considered a key issue for C&AD. Only Germany has considered it in respective strategies and reports for a C&AD legal framework.

Cybersecurity and privacy issues require additional focus and involvement of all C&AD actors

Cybersecurity is one of the biggest issues in C&AD development. Connected cars require that every vehicles' location and journey history be recorded and saved. The advancement of IT security has not yet eliminated the possibility of this sensitive data being accessed by an unwanted third party, thus putting every users' safety at risk. This is a particular threat that could jeopardise the development of C&AD if IT security is developed at a slower pace than other C&AD technologies.

The EU, through the European Union Agency for Network and Information Security (ENISA), has already started this process, having proposed good practices that should be considered. In the USA, the NHTSA has done similar work. However, additional efforts are required at the EU-level to guarantee the integrity of C&AV functions, the safety of the passengers (and pedestrians), and the multiple streams of data associated to the vehicle. As cybersecurity measures in C&AD are a global effort, international collaboration in this area is recommendable.

Moreover, privacy is also a major issue, taking into account France's recent legislation that has granted government agencies significantly more access to personal data. With connected vehicles, this will allow law enforcers to track lawbreakers' location. However, this also raises questions about civil liberties and the role of the state.

2.4 Subtask 4 – Legislative and infrastructure barriers to the deployment of C&AD

This subtask includes an analysis of European, Member States and third-countries' legislative and infrastructure barriers to the deployment of C&AD.

The reviewed information is used as a basis for the development of a comparative analysis, which is complemented by a detailed SWOT that analyses Europe compared to the third-countries. Information collected from experts (when relevant) is also used to justify the performed analysis.

2.4.1 Review of legislative and infrastructure barriers to the deployment of C&AD

This section provides an overview of the barriers and challenges for the successful deployment of C&AD on the basis of desk research.

Two different groups of barriers for the deployment of C&AD

While technology for C&AD is developing, barriers and challenges remain. The conducted desk research shows that barriers can be categorized into two different groups:

- **Barriers related to a country's legislation (legal barriers):** including a(n) (absent) legal framework or strict regulation ('restricted flexibility') with regards to testing C&AV.
- **Barriers due to restrictions in the existing (technical) infrastructure,** or lack thereof. Automated driving requires a suitable road infrastructure, sufficient bandwidth of the internet infrastructure, and a common communication technique across stakeholders.

An important difference between these categories is that the barriers can be solved in a different way. While barriers from the infrastructure category could be solved with (private) investments, legal barriers can only be tackled by the country's legislators.

Legal barriers

An adequate legal framework is imperative for the future deployment of C&AV. Since these vehicles are likely to cross borders, a European framework is favourable. A European Parliament report of March 2016 states that a legal framework should include ways to deal with [112]:

- **Liability:** if an automated car causes an accident, who is responsible (manufacturer or "driver")? Currently, liability rests on manufacturers for test drives.
- **Insurance policy:** if the liability shifts from driver to manufacturer, to what degree do manufacturers need insurance? Do drivers still need insurance? Thus, conditions of insurance need to be defined.
- **Registration:** since EU registered vehicles can travel freely across European roads, EU-registration of automated cars is needed. The legal framework should contain safety criteria for EU-registration to prevent automated cars from being banned in countries with stricter safety requirements.
- **Data protection:** C&AV collect and send a large amount of personal information. Clear boundaries have to be set to prevent inappropriate use of data. Cybersecurity is also a key issue. Responsibilities related to the prevention of hacking have to be defined in the legal framework.

One situation in which European coordination is important is flexibility in terms of existing regulation, as well as possibilities to adapt to future developments. Strict, nationally determined regulation will delay the testing and deployment of C&AV. Currently, the degree of flexibility in regulation differs between countries. This is especially relevant for Europe, due to the sheer number of cross-border movements between Member States. A strict regulation can "lock" a manufacturer or slow the development process completely. [97]

Related to legal barriers, there are two International legal frameworks that must be considered for an international comparison of how to deal with barriers. From an (automated) driving perspective the relevant conventions are: the **Geneva Convention on Road Traffic** (1949) and the **Vienna Convention on Road Traffic** (1968).

Countries that have not ratified these conventions are not limited in their rules on driver requirements while testing C&AV. At the moment, it is not fully clear which technologies are in accordance with the Vienna convention and which are not [141]. Therefore, it remains unclear whether action at the international level in terms of legal frameworks is required.

Infrastructure barriers

Automated driving puts requirements on infrastructure. This barrier has several dimensions.

Road infrastructure needs to be improved and changed before the deployment of automated cars is possible. For instance, automated driving may require visible road markings. Although these infrastructure requirements are not fully clear yet (depending on the technology used), most countries' infrastructure do not yet fully support automated cars. Only highways and major roads are considered to be (in early stages of) compatibility. Infrastructure that allows automated vehicles in city roads still needs to be adapted.

Another barrier, which is especially relevant for governing bodies to address in the early stages of development, is the diversity in **communication techniques**. Manufacturers and suppliers have the freedom to choose their own form of communication, creating incompatibilities in the industry. Without standardization across markets regarding communication, it is likely that some equipment will not function in different region [142].

Another barrier to consider is a temporary one, and will disappear once communication network standards move to 5G, even if ITS G5 also has a role in exchanging safety critical messages. However, insufficient bandwidth of the current internet infrastructure remains a barrier, especially when considering long range cellular networks. The emergence of driving and safety functions in addition to existing entertainment functions will place a heavy burden on mobile networks.

Based on this introduction, Table 8 provides an overview of the challenges and barriers for C&AD deployment at the level of the Member States and third-countries.

Table 8: Summary of legislative (legal) and infrastructure barriers for C&AD deployment in third-countries and Member States

Country	Analysis findings
USA	<p>Legislative: Many initiatives exist to stimulate the development of C&AD. In the USA, individual States have the possibility of drafting and enacting their own laws on automated driving. Some States have created their own legal frameworks. At this moment, this seems to stimulate the development of C&AD. However, this puts the USA in a similar position as the EU, where different legal frameworks for each constituency may pose problems in the long run. State-by-state laws vary significantly and according to one source, no State has fully determined how existing traffic laws should apply to automated vehicles. Without a uniformed approach, car manufacturers are put in a disadvantage versus countries with a coherent legal framework.</p> <p>Infrastructure: Infrastructure deficiencies are another barrier for the USA. While road infrastructure is often in a technical poor condition with regard to maintenance, in terms of connectivity, the USA is a step ahead. 5G networks are also currently being developed.</p>
Japan	<p>Legislative: C&AD is high on the agenda. A national legal framework is in place and automated cars can be tested on public roads. However, permissions are on a case-by-case basis, which constitute a challenge for large scale testing. However, the current four-phase timetable development plan allows for gradually more aspects of automated driving to be tested. By 2025, fully automatic driving would be allowed.</p> <p>Infrastructure: Infrastructure challenges tend to be less of an issue for Japan, compared to the USA and other countries, The government has already invested in V2I communication networks with the aim of helping vehicles learn about the environment. 1,600 transmitters have been installed with some 100,000 vehicles already constantly connected to the V2I communication network. Also, Japan is likely to meet the internet requirements of automated driving at the national level.</p>
South Korea	<p>Legislative: C&AD is promoted by South Korean companies and an agenda towards the development of safety technologies in the transport sector has been created. However, the current legislation hampers exhaustive testing. South Korean manufacturers tend to test their technologies in the USA, mostly due to the strict nature of South Korean legislation. For instance, the South Korean law requires two drivers be present in the car.</p> <p>Infrastructure: Road infrastructure may not be a barrier for the deployment of automated driving, with plans to expand the 5G capabilities in the coming years and a test site to be developed in addition to designated road sections for testing purposes. South Korea is committed to invest \$ 230 million USD (€217.7 million) in a smart infrastructure system.</p>
China [124]	<p>Legislative: The Chinese legislation does not adhere to the Vienna Convention. However, until new regulations are released, the Chinese government has advised not to test automated cars. This poses the major challenge for the deployment of automated vehicles, such that stakeholders urge for the rapid development of a full framework. China has the advantage that most of its regulatory processes related to automotive industries operate at a top-down national level. However, there is still fragmentation over who will oversee the regulation and development of C&AD technology. In all, nearly 10 ministries and agencies have formal jurisdiction in some part relating to the C&AD development. Moreover, with regard to the legal liability, it is less clear how to evaluate liability when there is no driver or the driver is relying upon automated controls. In China, policymakers are considering rules that shift legal liability away from drivers.</p> <p>Infrastructure: One of the major infrastructure barriers in China is to improve its highway infrastructure and traffic management. Both semi-autonomous and fully autonomous vehicles need roads that allow their cameras and sensors to operate effectively. Moreover, the current Chinese network does not lend itself for the development of a proper and sufficient internet infrastructure.</p>
France	<p>Legislative: Amendments to the Vienna Convention have facilitated the testing of automated cars in France and the testing of automated cars is allowed. Test cars were able to drive from Paris to Bordeaux in 2015. The government is currently reviewing regulatory issues that may pose problems for automated driving.</p> <p>Infrastructure: Some 2,000 km of roads will be equipped with transmitters.</p>

Country	Analysis findings
Germany	<p>Legislative: Like France, Germany has approved an amendment to the Vienna Convention that allows automated cars on German roads. A special corridor between Berlin and Munich will be established to test automated driving. State-to-state differences in the requirements (or exemptions thereof) may encourage cutting edge development and deployment. However, these differences could also hamper the development of C&AD in Germany.</p> <p>Infrastructure: In terms of infrastructure, the situation is unclear. The current road network is hampered by a lag in maintenance.</p>
Italy	<p>Legislative: Safety reasons have led to the ban of automated testing on public roads at this moment. Most legislation does not consider automated driving as defined for this study, but rather focuses on cooperative driving. A new legal framework has to be developed before fully automated cars enter Italian roads.</p> <p>Infrastructure: A main infrastructural barriers is the condition of roads considering that investments in road maintenance have been decreasing since 2006.</p>
Spain	<p>Legislative: Spain has not ratified the Vienna Convention. Therefore, legislative barriers are minimal. Automated tests are allowed once a permit is approved by the government. Testing can only be done on highways.</p> <p>Infrastructure: In terms of infrastructure, barriers are related to road signs and markings that need to be improved, as well as a communication system that will have to be installed.</p>
Sweden	<p>Legislative: Close cooperation between Volvo and the Swedish government exists. In and around Gothenburg, the Swedish government has allowed testing for automated Volvo cars in 2017. While the conditions under which these tests have to be carried out are not yet defined, the focus of this programme is to identify infrastructure requirements.</p> <p>Infrastructure: Due to intensive maintenance, road infrastructure is in very good condition.</p>
United Kingdom	<p>Legislative: A legal framework is in place. A report with rules and standards was published in 2015, indicating that tests can be conducted on public roads without special certificates and permits. A driver being able to take control over the car on public roads is the sole requirement.</p> <p>Infrastructure: 4/5G-communication infrastructure lags behind the rest of countries studied in this report, potentially becoming a barrier over time.</p>
EUROPE [143], [144]	<p>Legislative: As discussed, Member States are already acting within their own jurisdictions. However, initiatives to support a harmonised approach across all EU Member States to adapt regulations is also necessary (which is foreseen in the Declaration of Amsterdam). It is evident that a common strategy at EU level is needed.</p> <p>Yet, according to the European Commission, and the outputs of a GEAR 2030 Discussion Paper, there are no significant barriers in the EU legislation for C&AV up to level 3. However, it is recognized that for higher levels of automation and car connectivity, changes may be needed related to, for example, traffic rules, connectivity, driving licence, liability framework, insurance, cybersecurity, privacy and data protection. As highlighted in Table 6, cybersecurity and data protection are of particular importance. Regarding cybersecurity, there has been work from ENSIA in defining good practices. The EC itself has presented a cPPP as well as other strategies for cybersecurity at a broader scale. In regard to big data and data privacy, the EC requires compliance with the General Data Protection Regulation and will propose initial guidance in this regard during 2018.</p> <p>Infrastructure: ERTRAC suggests that infrastructure performance (e.g. visibility, state of repair, etc.) regarding traffic signs, signals and road markings to support higher levels of safe and reliable automated driving must be taken into consideration. In the aforementioned GEAR 2030 Discussion Paper, and reflecting on Directive 2008/96/EC on infrastructure safety management National law, it is suggested that a revision of the minimum requirements for road infrastructure could be required for the deployment of partially and fully automated vehicles. These requirements are related to minimum standards for road signs and markings, digital mapping of speed limits, digital infrastructure for connectivity, common agreement for readability of temporary structures (e.g. around road works, among others). In fact, ERTRAC, suggests that infrastructure</p>

Country	Analysis findings
	performance (e.g. visibility, state of repair, etc.) regarding traffic signs, signals and road markings to support higher levels of safe and reliable automated driving have to be recognised. To note that the Declaration of Amsterdam proposes several guidelines for both legislation (e.g. coherent national, European and international rules; privacy of data; EU regulatory framework) and infrastructure (e.g. vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication).

2.4.2 Comparative analysis of legislative and infrastructure barriers

As discussed in Section 2.3, there are two international frameworks that influence C&AD: the 1949 Geneva Convention and the 1968 Vienna Convention of Road Traffic. The ratification of these agreements by Member States and third-countries is of relevance, as these create specific limitations that must be taken into account in the country's own legislation and regulations.

In Europe, all Member States are signatories, with exception to the UK and Spain. None of the studied third countries are signatories of the Vienna Convention of Road Traffic. As highlighted in previous sections, this factor may have enabled a revision of laws which facilitated an earlier move towards testing of autonomous vehicles.

Comparison and analysis on legislation

Among all studied countries, the USA is of particular interest. Because of its administrative division into States, which have the authority to enact their own laws, various States have in fact developed their own legal frameworks. While this can stimulate the development of C&AD in the country, it also leads to a disparity in legislation across the country. In fact, it is still not clear what impact this can have in the future for driving in States with different legislations.

Still regarding the third-countries, C&AD is on the agenda of Japan, South Korea and China. In Japan, there is still some barriers in legislation, where testing is done on a case-by-case basis, thus limiting large-scale testing. This is also the case for South Korea, where massive testing is still limited. Likewise, legislation is still a barrier in China, with a revision still to take place. This has been a challenge for manufacturers, where only selected companies can test autonomous vehicles. Furthermore, China faces the bureaucratic complexity of having 10 ministries and agencies with some sort of jurisdiction on C&AD development.

In Europe, and as signatories of the Vienna Convention of Road Traffic, France and Germany were required to approve amendments to facilitate testing. Additional revisions to legislation are underway. Spain and the UK, not being signatories of the Convention, face limited legislative barriers. Tests have been conducted in both Member States with minimal limitations. Sweden has faced some barriers, but has recognized the need to revise their legislation to allow for more complex testing, which is currently allowed on a smaller scale (e.g. as verified through the Drive Me project). Lastly, Italy still faces significant barriers for testing due to a lack of favourable legislation.

Based on this information, it is not evident that Europe is behind compared to the compared third-countries. In fact, for some Member States (e.g. the Spain and UK), it appears that they have more favourable legislation than South Korea or China.

Comparison and analysis on infrastructure

Regarding infrastructure, the current status of infrastructure is to some extent a barrier for both European and non-European countries, with some countries facing more limitations than others.

Among the Member States, Germany and Italy face a similar barrier: a lag in adequate road maintenance. In fact, Italy has seen its road maintenance budget decrease since 2006. In Spain, the current road infrastructure is also a barrier, where road signs and markings have to be improved. In the UK, the main barrier is related to the 4/5G network infrastructure, an area in which it falls behind compared to other countries. In contrast, information suggests there are no particular barriers in Sweden and France regarding infrastructure. In fact, Sweden is subject to intensive maintenance and thus has good road infrastructure. France, on the other hand, is already looking to invest in the instalment of transmitters on up to 2000 km of road.

Outside of Europe, there are apparently less barriers in infrastructure than in Europe. In the USA, and while roads are not in optimal condition, there are minor connectivity-related infrastructure barriers. Japan and South Korea also face minimal barriers in infrastructure, both road and technology related. Japan has already invested in technological infrastructure to facilitate vehicle communication, which has also taken place in South Korea. Moreover, South Korea is also investing in the redesign of specific road sections suitable for C&AD.

Linked to road and communication is the respective high cost of C&AD infrastructure. C&AV need special features in infrastructure. While the full requirements for infrastructure have yet to be clarified, an important prerequisite for intelligent transport systems will be an agreement on what communication is needed between vehicles (V2V), between vehicles and infrastructure (V2I) and vehicles to anyone else. There has been some developments in Sweden, for example, but these are still lacking at the EU level. Meanwhile, technical standardisation is necessary for international compatibility and interoperability. This is important in the scope of European roads and highways that are interconnected between Member States.

The Recommendations of the Strategic Policy Forum on Digital Entrepreneurship has claimed that one of the major challenges in C&AD is the investment to upgrade Europe's physical, digital, and security infrastructures in order to meet the demands of different industries [145].

One of the most urgent technologies is fifth generation mobile networks and telecommunications standards (5G), which are vital for autonomous vehicles to function well. However, 5G technology has not been publicly deployed yet. C&AD also requires a major development in Global Positioning System (GPS), cybersecurity, as well as big data aspects. Regarding GPS, the European Galileo system provides a global navigation satellite system, highly accurate, and guaranteed global positioning service under civilian control. [146] This satellite system is also important for the development of C&AD as it allows autonomous vehicles to interact with their surroundings. Thus, supporting the Galileo system is an important infrastructure development that could further support C&AD technology.

Another important aspect relating to C&AD infrastructure is cybersecurity. However, and based on previous analysis, manufactures in Europe are more focused on car manufacturing. There is a lack of companies that develop the cybersecurity aspect of C&AD, especially compared to the USA. Therefore, the safety and security of the vehicle connection needs to be guaranteed. The limited number of European programmes focused on the development of cybersecurity may be an obstacle to developing C&AD in Europe.

2.4.3 SWOT analysis for EU on legislative and infrastructure barriers/ challenges for C&AD deployment

Table 9: SWOT Analysis for EU on challenges for C&AD deployment

Strengths		Weaknesses	
Main Point	Explanation	Main Point	Explanation
Visible changes in legislation	<ul style="list-style-type: none"> Many EU Member States have revised or are in the process of revising legislation on C&AD. 	Variable infrastructure quality	<ul style="list-style-type: none"> In general, the quality and appropriateness of the European infrastructure (road and technological) is variable among Member States.
Legislation that favours testing	<ul style="list-style-type: none"> Member States' revision of legislation has prominently addressed the possibility of testing C&AV. In countries with strong automobile manufacturers, there is further lobbying for testing to be allowed through the revision of legislation. 	Diverging legal framework	<ul style="list-style-type: none"> Rules for the testing of C&AV differ between European countries and between states or provinces within countries. Harmonisation of the legal framework is desired.
Opportunities		Threats	
Main Point	Explanation	Main Point	Explanation
Uniform communication standards	<ul style="list-style-type: none"> If Europe succeeds in agreeing on a uniform communications standard, it may set a global standard enabling the prerequisites for a cost-effective roll-out of C&AD. 	Reluctance to a European wide legal system	<ul style="list-style-type: none"> It may prove difficult to implement a European legal system due to the high number of countries involved and that may have differing views on regulation.
Manufacturers pushing for change and a global market	<ul style="list-style-type: none"> The big European car manufacturers are active on a global market. This is in contrast to many other car manufacturers that are often active on a more regional market. This could offer opportunities for a 'European system' of C&AD. 	Limited availability to invest in infrastructure	<ul style="list-style-type: none"> Many Member States currently face budgetary limitations that may continue to be long-term. These limitations may limit their capacity to invest in infrastructure, both road and technological.

STRENGTHS

Visible changes in legislation

As discussed in Section 2.4.2, and with exception to Italy whose legislative situation on C&AD is somewhat unclear, the other five studied Member States have made visible changes regarding their legislation. UK and Spain, unlimited by the restrictions of the Vienna Convention of Road Traffic; France and Germany, with amendments to the Convention; and Sweden having recognised the need for revisions; have all moved forward with a legislative revision, thus working to overcome this specific barrier.

While non-European countries have also made changes to their national legislation, it appears that they are still limited by some barriers since much of the testing that these revisions have allowed is still on a case-by-case basis. Moreover, and while none of the third-countries are limited by the Vienna Convention of Road Traffic, they apparently hold no specific advantage compared to the studied Member States.

In Europe, the Declaration of Amsterdam will be an important driver to support changes in legislation. Specifically, it proposes that work be done towards the removal of barriers and to promote legal consistency. Moreover, this revised legal framework should offer flexibility to accommodate innovation, facilitate the market introduction of C&AV and enable their cross-border use.

Still concerning changes in legislation, and considering the most relevant user concerns (i.e. vehicle owners/drivers) for C&AD (Question 1D.5A), experts agreed on the ideas of 'safety', 'reliability', 'liability', 'cybersecurity', and 'privacy'. These are closely aligned with the challenges identified in the literature review related to legislation/legal barriers. When questioned about the most relevant societal concerns for C&AD (Question 1D.5B), a more diversified repertoire of answers was received, including 'equity issues' (i.e. the possibility of C&A vehicles being available to all), concerns regarding job reductions in traditional public transport, as well as a number of concerns also mentioned in Question 1D.5A.

As some experts suggested, people themselves are a barrier. A maturity period will be needed for people to ultimately get used to and trust the technology behind C&AV. However, various experts agree that communication is also necessary. Thus, as suggested by stakeholders, "a communication strategy is needed" and "it should be clearly communicated that user and society will win safety, comfort and resource saving." Also, open discussions and public exposition of developments in testing can contribute to overcome concerns. Thus, and as the Declaration of Amsterdam proposes, large-scale projects (which can be facilitated through legislation) should be used to increase public awareness and acceptance.

Legislation that favours testing

As discussed in Section 2.1, ongoing changes in Member States' legislation and regulations tend to address changes related to testing C&AV. Within Europe, this has taken place in France, Germany, Spain, Sweden and the UK. The UK, for example, likely influenced by the fact that it is not restricted by the Vienna Convention of Road Traffic, allowed vehicle testing in 2013. This is transversal to the majority of the other studied countries. This has been an important step not only for the competitiveness of the sector in Europe, but also because it aims to ensure road safety. Outside of Europe, the current legislative framework in the USA, Japan, South Korea and China also allows testing, although it occurs under different conditions.

Still within Europe, it should be noted that many European manufactures have prioritised C&AD and testing. This is particularly visible in Member States with many and strong manufacturers (e.g. Germany, France and the UK) also lobbying in favour of reducing barriers to testing. In some cases, 'test' facilities have been established to allow for more systematic testing.

WEAKNESSES

Variable infrastructure quality

The quality and appropriateness of European infrastructure is variable among Member States. Considering that the safety of the car and driver not only depend on the technology but also the road on which the car runs, this is an important limitation that must be addressed. Regarding technological infrastructure, it is also unclear the extent to which the studied Member States are well equipped.

This contrasts to the non-EU countries. While there may exist some variability in road quality, these countries appear to be better suited in terms of technological infrastructure, and thus more prepared for the 'connected' aspects of C&AD.

Diverging legal framework

While the majority of the Member States are moving forward with revisions in legislation to overcome existing national barriers, there is still a diverging legal framework in Europe. Rules for the testing of C&AV differ between European countries and between states or provinces within countries. Thus, it may be possible to test a vehicle within France, but it is unclear if a specific vehicle can be tested within the same conditions in the neighbouring Germany or Italy.

Thus, harmonisation of the legal framework is required. Once again, the Declaration of Amsterdam is an important instrument for this harmonisation, proposing that stakeholders agree on coherent European and national rules (as well as international). Moreover, it proposes that Member States adapt their national regulations, removing legal barriers to testing; and that the European Commission adapt the EU regulatory framework to support the development and use of C&AD.

OPPORTUNITIES

Uniform communication standards

The global interest in C&AD presents an interesting opportunity to move forward with a uniformity of communication standards that are necessary to guarantee the 'connected' element of C&A vehicles. If Europe succeeds in agreeing on a uniform communications standard in 5G, it may set a global standard that enables the prerequisites for a cost-effective roll-out of C&AD. The combination of 5G and ITS-G5 may be the optimal way forward. Therefore, there are many expectations regarding the development of hybrid communication.

More than an opportunity, this is a particularly relevant item at the European level. As part of the joint agenda of the Declaration of Amsterdam, there is interest in fostering international cooperation (particularly with the USA and Japan), in areas that include establishing a global framework and international standards for C&AV. Moreover, there is a call to the industry to continue work related to standardisation to ensure that new services and systems are interoperable at the EU level.

Manufacturers pushing for change and a global market

C&AD is an opportunity for various stakeholders. The European industry and car manufacturers are particularly active on a global scale within the market, in contrast with other manufacturers that focus on a more regional market.

To continue with a global presence and not be limited by particular markets, the industry and car manufacturers are key players in the push for change. This change is relevant in terms of legislation, so that specific vehicles can be tested in various markets. It is also relevant for road and technological infrastructures, as C&AD require specific infrastructure.

Building on this interest, there is an opportunity for the industry to be involved at various levels and to push for change in the C&AD sector. The Declaration of Amsterdam calls the industry to actively participate in the development of the European strategy and agenda for C&AD. This is extremely important because the industry is an interested party in the success of the sector. As discussed, the industry is also called to help identify areas where policy and regulation must be changed to lower existing barriers to the development of vehicle technologies. This is relevant because vehicle innovation should not have to be fully limited by legislation. Within reason, policy should be able to adapt to innovation, as long as driver, passenger(s) and pedestrian safety is guaranteed. Lastly, to achieve the required change and continue to have access to the global market, the industry is called to participate in large-scale deployment projects, particularly those involving cooperation at various levels and with different stakeholders.

To complement this analysis, experts were questioned on challenges for C&AD at the level of OEMs. Of the received answers, 90% of experts indicated that they 'strongly agree' or 'agree' that European OEMs are developing clear medium/ long-term strategies for C&AD (Question 1D.1). Moreover, 80% of experts are affirmative in thinking that the development of C&AD will reshape the traditional supply chains of automotive companies (Question 1D.2). When asked to justify, a number of experts mentioned that new suppliers/actors and technology will be important in reshaping the traditional supply chains. With regard to key challenges faced by European OEMs for the deployment of C&AD

(Question 1D.3), a number of different answers were received, including: the role of suppliers, reliability of vehicles, end-user acceptance, regulatory certification, liability, finding qualified staff and skills, among others.

When asked about the support actions that can help OEMs meet these challenges (Question 1D.4), many experts emphasized the need to implement projects at the EU level, with one expert highlighting the need for funding. Another of the common actions relates to regulation, which was mentioned by a number of the experts, with one mentioning that regulation should be done at a worldwide level.

THREATS

Reluctance to a European wide legal system

Despite the large ambitions included within the Declaration of Amsterdam, it may continue to be difficult to implement a European wide legal system.

The Europe Union, with 28 Member States as of the beginning of 2017, is culturally diverse. Many Member States have their own visions and thus have differing views on the best legislation for C&A vehicles (or driving for that matter). Thus, and while Member States are called to adapt their national regulations, there is no indication of this being mandatory in the short-term (or at all). Thus, negotiations may take time before a European wide legal system on C&AD is in play.

Limited availability to invest in infrastructure

As discussed in Section 2.1.3, many Member States face budgetary limitations. For this reason, selected Member States' capacity to invest in infrastructure, both road and technological, may be limited. If Member States are not able to prepare road/technological infrastructure to receive C&A vehicles, cross-border driving may become impossible in the long term. For example, if Austria and Croatia prepare themselves with the necessary infrastructure to enable this type of driving, but neighbouring Member States are unable to do so, then cross-border driving between these countries becomes impossible. Thus, and as full deployment of C&A vehicles becomes a reality, it is important that all Member States be equipped with the financial resources (including, if necessary, support from Europe) to adapt and install the required infrastructure.

03. Operational Approach – Task 2

3 Operational Approach – Task 2: Comparative assessment of technological and commercialisation readiness level of automated and connected driving in US, Japan, South Korea, China and the EU

Task 2 focuses on reviewing the readiness level of current C&AD functions, including the views of the automotive industry and infrastructure opportunities. The selected C-ITS, environment perception, and ADAS++ technologies (e.g. HMI, sensing systems, communication, road monitoring, etc.) are evaluated in the selected countries of the study. The assessment is not only technology driven, but also focuses on non-technical challenges, such as user acceptance, mixed traffic scenarios, among others.

This task is mainly based on a literature review, using outputs from the iMobility forum related to cooperative and automated driving standards and development trends in the EU. Moreover, in addition to the connections in the EU, existing connections to the USA, Japan, South Korea, and China are also used for a better understanding of the current situation.

Task 2 includes 3 subtasks:

Subtask 1 – Review of the existing technologies in the market analyses the existing knowledge related to EU projects (e.g. interacIVe, AdaptIVe, RobustSENSE, MiniFaros, Drive-C2X, AutoNet2030). Membership in organisations such as ERTICO, ERTRAC, ECTRI, etc. is used to select the proper technologies to be assessed. These organisations are supported by the automotive industry, and have the responsibility for bringing autonomous cars/road vehicles to the market. Technologies are assessed according to their maturity level and how time-to-market is expected in the near future. The key results of this subtask are:

- Assessment of the selected key automated driving technologies in different clusters (environment perception, driver support, infrastructure components, etc.).
- Review of the existing technologies in the selected target countries (USA, Japan, South Korea, China and the relevant EU Member States).

Subtask 2 – Automated and connected cars/ road vehicles technology analysis analyses the technologies at SAE level 3 and 4 cars [SAE standard J3016] and vehicles. As technology readiness is a broad spectrum, the study will address how to distinguish between different levels of automation and the different maturity levels of the technology. The analysis allows an understanding of the potential influence to safety and investments expected from infrastructure providers to support autonomous driving functionalities. In addition, new up-coming trends in automation and connectivity research, such as the use of big data, cyber-security concerns, and Internet-of-Things development trends are considered.

Subtask 3 – Technical and non-technical barriers in the development of C&AD focuses on the challenges to bring new automation and connectivity technologies to vehicles. This subtask reviews the technical solution timeline needed to protect valuable vehicle data from being stolen or from having its path manipulated. The key results of this subtask are:

- Major technical challenges in introducing new in-car technology.
- Mixed traffic scenarios (manual driven cars/ road vehicles, pedestrians, animals, etc.) in semi-autonomous driving phase.

Introduction to topic

In the context of road transport automation, both automated and autonomous vehicles are often mentioned [147]. An automated vehicle is one that can at least partly perform a driving task without a driver. The word autonomous, on the other hand, refers to the ability of an automated vehicle to operate independently and without a driver in a dynamic traffic environment, relying on the vehicle's systems and without communicating with other vehicles or the infrastructure. Remotely controlled vehicles are another category. These vehicles are controlled by an operator who is in contact with the vehicle through wireless remote control and operates the vehicle through a real-time drive simulator or another similar user interface. The automation level in road transport has progressed gradually (Figure 7) and the annual business potential (Figure 8) is expected to be \$60-90 billion USD (€56.8-85.2 billion) by 2030 [11] [148].

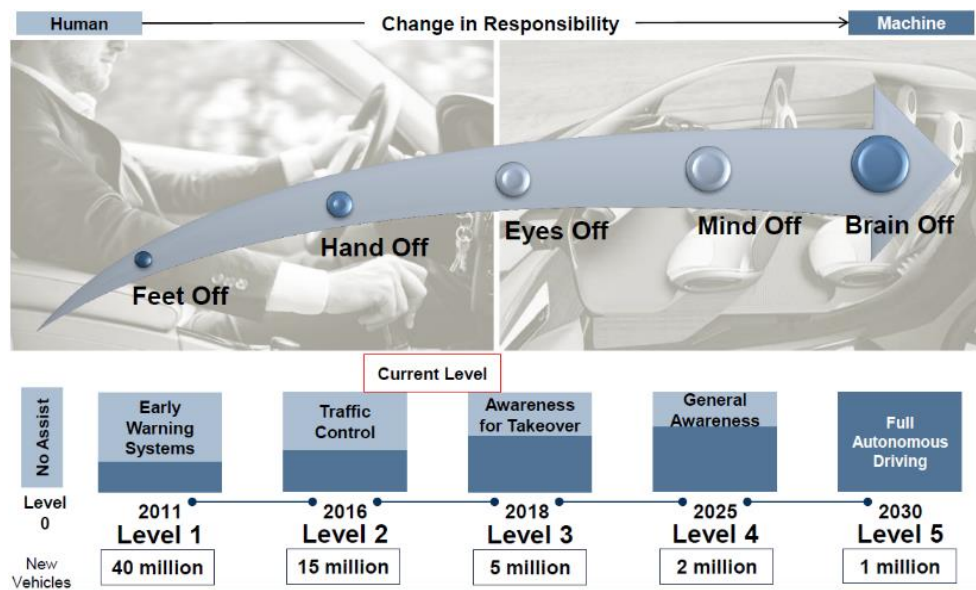


Figure 7: Emergence of semi- and full autonomous vehicles [149]

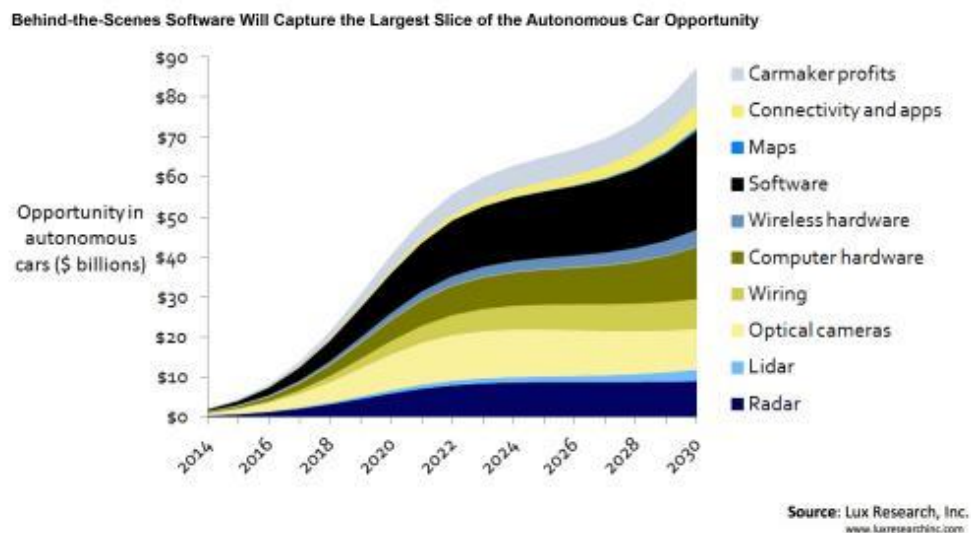


Figure 8: Business potential and share in autonomous driving [11]

Levels of automation

The six-step classification of SAE International is currently used in most cases to describe different automation levels (Table 10). In Task 2, the analysis focuses on the technologies and their readiness level at level 3 and 4. At these levels, automated systems take control of the vehicle and driving modes in most situations and thus, the role of the human driver is reduced. At level 3 the driver may undertake other tasks while driving, but if necessary, must take control of the vehicle. At level 4, the driver may even be asleep as the system gives a signal (e.g. warning, announcement) if the driver needs to take control of the vehicle. [147]

Table 10: Different levels of automation with characteristics [147] [150] [151]

Level	Name	Definition	Execution of steering and acceleration; deceleration	Monitoring of driving environment	Fallback performance of dynamic driving task	System capability
Human driver monitors the driving environment						
0	No automation	Full intervention of driver in all tasks, even when enhanced by warning or intervention systems.	Human driver	Human driver	Human driver	-
1	Driver assistance	Driving mode with specific execution by a driver assistance system of either steering or acceleration/ deceleration of using information about the driving environment with the expectation that the human driver performs all remaining aspects of the driving task.	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial automation	Driving mode with the support of one or more driver assistance systems (steering and acceleration/ deceleration) using information about the environment and with the expectation that the human	System	Human driver	Human driver	Some driving modes

Level	Name	Definition	Execution of steering and acceleration; deceleration	Monitoring of driving environment	Fallback performance of dynamic driving task	System capability
		driver performs all remaining driving tasks.				
Automated driving systems monitor the driving environment						
3	Conditional automation	Driving mode where the system controls all aspects of the driving task (including latitudinal and longitudinal control) with the expectation that the human driver will respond to a request to intervene.	System	System	Human driver	Some driving modes
4	High automation	Driving mode where the system controls all aspects of the driving task, even if a human driver does not respond to a request to intervene. If the human driver fails to take control of the vehicle, the system steers the vehicle to the side of the road in a controlled manner and stops it.	System	System	System	Most driving modes
5	Full automation	Full-time performance of an automated driving system in all driving tasks in all roadway and environmental conditions.	System	System	System	Most driving modes

3.1 Subtask 1 – Review of the existing technologies in the market

Subtask 1 includes an analysis of the existing technologies in the market and how they are present in the EU, Member States and third-countries.

The reviewed information is used as a basis for the development of a comparative analysis, which is complemented by a detailed SWOT that analyses the EU compared to the third-countries. Additional information collected from experts is also used to justify the performed analysis.

3.1.1 Review of existing technologies

Automated vehicles strongly rely on Advanced Driver Assistance Systems (ADAS), the integration of ADAS systems, communication between vehicles and the infrastructure, Connected Intelligent Transport Systems (C-ITS), the sharing of data produced by system sensors, and an analysis of collected (real-time) data.

All major vehicle manufacturers and original equipment manufacturers (OEMs) are already providing additional and optional factory installed ADAS. These include, for example, adaptive cruise control, low-speed collision avoidance, lane departure warning systems, blind spot information systems, parking assist systems, and speed limit sign recognition systems [152]. According to the SAE classification, level 2 (partial automation) has already been reached, but level 3 vehicles (conditional automation) will probably be achieved by 2020.

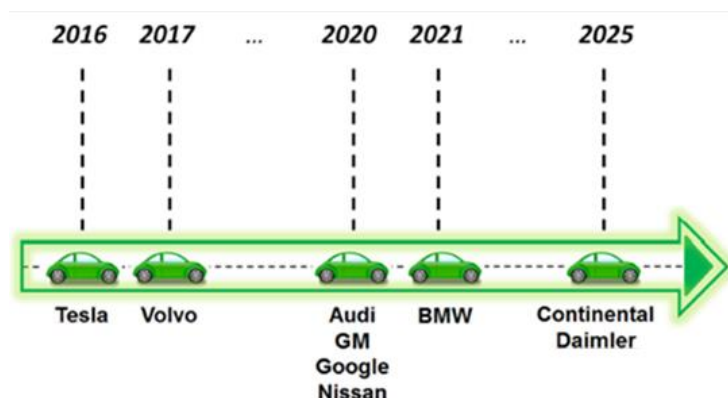


Figure 9: Estimated release years by vehicle manufacturers [153]

Technology related to the automation of road transport is evolving extremely fast. For this reason, estimates of when automated vehicles will circulate on roads diverge [152]. It is expected that the first vehicles with full or advanced automation, which will only operate within limited areas, will be released in the 2020s. According to some estimates, optional equipment packages for “autonomous driving” as factory installations in new vehicles may be available as early as 2019. The same estimates suggest that by 2025, there may be a sufficient range of standard equipment and options available to support automated operation and vehicles of levels 3 and 4. Fully automated vehicles that operate on public roads are unlikely to emerge before 2030 [154]. Most authorities believe that fully automated vehicles will only become mainstream around 2040 [155].

Various sensor technologies, including short and medium range radar systems, cameras, ultrasound sensors, and lidar or light detection and sensing equipment, play a vital role in the progress of automation in road transport. In an automated vehicle, an electronic horizon is created based of data input from the sensors, representing the vehicle’s situational picture and perception of the world around it. The development and use of sensor technology is especially vital for enabling automated driving in challenging conditions, including fog, rain, or snow fall.

In addition to sensors, highly accurate digital maps and reliable and correct positioning data are essential to automated driving. These allow vehicles to detect their position in regard to their surroundings, which sensors are unable to do. Through satellite positioning, vehicles may be placed accurately on the map. In a shadow zone, relative positioning based on 3D maps and sensors may be used. [152]

It is likely that more advanced automation (level 3 and above) will first be introduced on motorway sections between exits and, on the other hand, in service concepts offered in urban areas where low speeds are used (20–40 km/h). The development of automation and the idea of travel as a service are also strongly interlinked. New types of travel services could be the most natural area for the wider introduction of vehicles which are capable of higher levels or fully automated driving.

Existing technologies

C&AV received a considerable level of attention. In recent years, significant development efforts and dramatic progress has been made. While general use of C&AV for widespread use on public roads will take years, these vehicles are already being tested in closed test sites and even in real-life traffic. Several key enabling technologies are responsible for enabling C&AD. These technologies are:

- Radars
- Cameras
- Lidars
- Sensor data fusion units
- V2X communication technologies (5G and ITS-G5)
- In-vehicle embedded computer units
- Actuation devices
- Infrastructure components
- ITS services

These technologies are the main development trends of automotive OEMs today [149], and are categorised in this study according to their maturity level and level of automation. Radars and traditional monochrome cameras have been used in vehicles for more than 10 years and therefore, already belong at TRL level 7-8. Laser scanners and lidars are used for moving in the machine industry. However, due to challenges of real traffic, lidars are not deployed by the automotive industry in C&AD systems. The reality is that lidars have potential in long range object detection, but developments are still needed to tackle existing challenges.

Technology categorization

Among the many technologies which make autonomous vehicles possible is a combination of sensors and actuators, sophisticated algorithms, and powerful processors to execute software. Technologies (including the selected key technologies) in C&AV fall into four broad categories [156] [157] [158] [159]:

1. **Navigation and localization** (position, destination, and route).
2. **Driving and safety** (controlling and steering of vehicle, sophisticated decision-making and following the rules).
3. **Performance** (managing the vehicle's basic internal systems).
4. **Communication** (V2V and V2I).

Navigation and localization

The objective of navigation, localization, and guidance is a fundamental issue in autonomous driving. The issue addresses two major questions: what is the current position of the vehicle and what are the available routes to a destination. For the autonomous vehicle, the navigation and guidance subsystem must always be active and must continually assess how the vehicle is doing compared to the defined destination. For example, if there are unexpected events on the primary route, the vehicle must be rerouted in real time to avoid a potential loss of time. Because the vehicle is obviously constrained to the roadways, this requires additional computational effort compared to simply drawing a straight line between point A and B.

The primary subsystem used for navigation and guidance is based on a GPS (Global Positioning System) receiver, which computes the present position based on complex analysis of signals received from the (low-orbit) satellites (positioning commonly requires a connection of a minimum of four satellites). In optimal circumstances, GPS systems can provide location accuracy up to one meter. This is a good starting point for the vehicle, but not enough for the autonomous vehicle which may require accuracy of a few centimetres. Furthermore, GPS receivers often take 30 to 60 seconds to establish

the initial position, so the autonomous vehicle may have to continue immobile until it knows its position.

GPS is not sufficient by itself because the signal can be hindered or blocked by several obstacles (e.g. canyons, tunnels, or radio interference). Depending on the obstacle, this data blackout can last for several minutes. To complement the GPS signal, autonomous vehicles use inertial guidance which does not require any external signal. The inertial measurement unit (IMU) includes an in-vehicle platform which is based on three gyroscopes and three accelerometers, one for each axle (X, Y and Z). The initial location must be determined by GPS or entered manually because an IMU can only identify motion and direction.

Driving and safety

C&AV must be able to recognize and interpret what is in front, behind, and next to them, and therefore require a 360° view. Cameras are the most obvious choice because they can be used for several purposes, such as identifying lanes, sensing objects, markers or obstacles on the road and roadside. However, merely using cameras can cause problems, such as:

- Installing multiple cameras correctly and keeping them clean is challenging (i.e. a mechanical problem)
- Heavy graphic in-vehicle processing would be needed for image recognition (i.e. computing power)
- Different lighting, shadow and weather conditions set challenges to accurately decide what the camera is seeing and what remains hidden (i.e. need for a depth perception in addition to basic imaging)

In addition to traditional cameras, autonomous vehicles are equipped with a Light Detection and Ranging system (Lidar). A lidar is a remote sensing technology that measures and maps the distance to targets, as well as other property characteristics of objects in its path. Lidar maps its surroundings by illuminating its targets with laser light and then analysing the light to create a high-resolution digital image. The lidar system provides accurate, real-time 3D information on the surrounding environment and enables quick decision-making required for self-driving vehicles. The lidar unit is well-suited to “big picture” imaging and provides the needed 360° view by using a rotating, scanning mirror assembly on top of the vehicle. Low-spinning (i.e. low-resolution) lidar sensors are already used today in vehicles with adaptive cruise control systems (ACC). Nevertheless, more sophisticated, fast-spinning (i.e. high-resolution) lidars are needed to guarantee higher resolution imagery at a closer range.

Different types of radars are used for close vehicle control, such as parking, lane-changing, or in traffic congestions. In these situations, the LIDAR system is not as efficient and must be complemented by radars in the front, rear, and sides of the vehicle. Millimetre-wave radar systems are the most common and consist of various infrared and optical sensors. High-frequency radar is ideal for detecting objects (vehicles, pedestrians, and large animals) in a vehicle’s immediate area. Radar technology is relatively mature and has been used for years in parking backup systems. Current developments in radars aim for more advanced day and night-time system for driver assistance functions while integrating these functions with other ADAS technologies. These would provide rich, natural, and intuitive images, even during harsh weather, with real-time sophisticated computer-vision features, such as Lane Departure Warning, Forward Collision Warning, Pedestrian Detection, and other automatic capabilities.

Performance

Although component and subsystem development used for navigation and sensing receive significant attention, a key aspect of the design of an autonomous vehicle involves everyday issues such as power management. Monitoring the current power of the batteries is required, because keeping in-vehicle systems and operations reliable requires measuring and managing the requirements to control power, overall consumption, and thermal dissipation.

In-vehicle computers are heavily related to the performance of vehicles as these have to know their exact location, identify the objects around them, and continuously calculate the optimal route. These measures require a powerful visual computing system that can compute data – all in real-time – from cameras, other sensors and vehicles, and navigation sources, while also calculating the safest and best route. [160]

Communication

To operate a sophisticated vehicle requires millions of lines of code. An efficient vehicle operation requires the different systems and technologies described above. Communication with other vehicles and road users (i.e. V2V) and infrastructure (V2I or I2V) is needed to ensure safe, sustainable, and smooth traffic. The U.S. Department of Transportation expects that V2X communication may prevent up to 80% of accidents by warning drivers about the hidden dangers that cannot be sensed by traditional on-board equipment. By sharing information between vehicles (for example within a half-mile radius), the driver or the vehicle will have sufficient time to take correct actions?

Table 11 lists use cases of V2X communication. It must be noted that the secure credential management system for ensuring the authenticity, security, and privacy of V2X communications has yet to be implemented, with OEMs and other stakeholder presently working on it.

Table 11: V2X communication with use cases

V2I	V2V	Convenience
Red light (violation) warning	Emergency brake light warning	Eco-driving
Curve speed warning	Forward collision warning	Smart cities
Spot-specific weather	Red light (violation) warning	Parking information
Work zone safety	Slow traffic ahead	Truck Platooning
Bridge height	Aggressive driver warning	Speed harmonization
Pedestrian crossing the road	Emergency vehicle notification	Queue warning
Stop sign gap assist	Road hazard detection	Insurance pricing (pay-as-you-drive)

The increasing use of smart devices is not the only reason for prompting the telecommunication industry to invest resources in developing faster wireless technology and connections. Thus, 5G is believed to support the development of machine-to-machine (M2M) (e.g. V2X) and IoT applications. Amongst these are services and applications that will enable truly connected vehicles and driverless vehicles. Although LTE (i.e. 4G) has already been tested by OEMs for emulating non-safety critical V2V applications and for transferring data and information (e.g. exchanging non-critical information including weather, road conditions, and traffic data) directly between vehicles, it is believed that only 5G – providing low latency (1ms) – will offer the industry the possibility of dedicated short-range DRSC V2V technologies. [161]

Another existing communication standard is the ITS-G5 (also known as Wireless Access in Vehicular Environments – WAVE), which at the moment is the most popular basis for V2X communication (IEEE, 2012). The standard is a refinement of the IEEE802.11a/h standard, but due to the different target application areas, significant effort has been put into three critical requirements while defining IEEE802.11p: (1) real-time characteristics, (2) density and scalability, and (3) localization. [162] ITS-G5 will have a significant role in the future because it is mobile network independent. The other benefit is low latency times because of direct connections and not requiring base stations. There will most likely be a hybrid solution where 5G and G5 technologies work in parallel. In short range communications (e.g. platooning), ITS G5 will have the major role whereas entertainment will be provided via the 5G channels.

Key Enabling Technologies

The selected technologies represent the different aspects and sectors of transport and mobility. Therefore, the review and assessment of technologies will be clustered into the following sections: (1) environment perception, (2) autonomous assistance functions, (3) infrastructure support technologies, (4) situation awareness, and (5) concept vehicles. Table 12 presents the assessment of the selected technologies. The table also provides an overview of the technology readiness level of the key enabling technologies.

Table 12: Clustering of key enabling technologies

Technology	Environment perception	Autonomous assistance functions	Infrastructure support technologies	Situation awareness	Concept vehicles	Example manufacturers
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Technology	Environment perception	Autonomous assistance functions	Infrastructure support technologies	Situation awareness	Concept vehicles	Example manufacturers
Radar	x	x		x		Bosch, Continental, Autliv, TRW
Cameras	x	x	x	x	x	Bosch, Continental, Autoliv, VALEO, MobilEye, FLIR
LIDAR	x	x		x	x	Velodyne, Ibeo, Hitachi
V2X coms		x	x	x		NXP, Commsignia, DENSO
In-vehicle computers		x		x	x	NVIDIA, ADASWorks
Actuator devices		x				Bosch, TRW, Magnetti Marelli

List of Day1 services

The C-ITS Platform [158] has identified ITS services which are technologically mature and hence should be available in the short term, and will likely bring several societal benefits. These services are referred to as “Day 1 services” and have information purposes only:

Hazardous location notifications:

- Slow or stationary vehicle(s) and traffic ahead warning
- Road works warning
- Weather conditions
- Emergency brake light
- Emergency vehicle approaching
- Other hazardous notifications

Signage applications:

- In-vehicle signage
- In-vehicle speed limits
- Signal violation / intersection safety
- Traffic signal priority request by designated vehicles
- Green Light Optimal Speed Advisory (GLOSA)
- Probe vehicle data
- Shockwave Damping (falls under ETSI Category “local hazard warning”)

The C-ITS platform also lists “Day 1.5 services” that are also mature and desired by the market. The services are the following:

- Information on fuelling and charging stations for alternative fuel vehicles
- Vulnerable road user protection
- On street parking management & information
- Off street parking information
- Park & ride information
- Connected & Cooperative navigation into and out of the city (1st and last mile,
- Parking, route advice, coordinated traffic lights)
- Traffic information and smart routing

However, “Day 1.5” services are not expected soon since the specifications or standardization is still in progress. Issues related to security and certification, as well as communication and liability, are causing problems even for Day 1 services. Thus, it is recommended that:

- There should be one common standardised C-ITS trust model and certificate policy across the EU (“no security, no C-ITS”).

- A hybrid communication (i.e. combined short- and long-range communication) be developed to ensure the full range of necessary services anytime.
- Drivers be made aware that limitations of available information may exist and that the driver always remain responsible for the vehicle.
- Full control of personal data should be guaranteed.

Deploying C-ITS services must bring benefits to different parties. It is relevant to note that these services may not necessarily appear in the short-term. Table 13 presents the list of Day 1 and Day 1.5 bundles.

Table 13: Bundle of services [158]

#	DAY 1 Services	Com	Context	Bundle
1	Emergency electronic brake light	V2V	Safety	1
2	Emergency vehicle approaching	V2V	Safety	1
3	Slow or stationary vehicle(s)	V2V	Safety	1
4	Traffic jam ahead warning	V2V	Safety	1
5	Hazardous location notification	V2V	Highway	2
6	Road works warning	V2I	Highway	2
7	Weather conditions	V2I	Highway	2
8	In-vehicle signage	V2I	Highway	2
9	In-vehicle speed limits	V2I	Highway	2
10	Probe vehicle data	V2I	Highway	2
11	Shockwave damping	V2I	Highway	2
12	GLOSA / Time To Green (TTG)	V2I	Urban	3
13	Signal violation/Intersection safety	V2I	Urban	3
14	Traffic signal priority request by designated vehicles	V2I	Urban	3
#	DAY 1.5 Services	Com	Context	Bundle
1	Off street parking information	V2I	Parking	4
2	On street parking information and management	V2I	Parking	4
3	Park & Ride information	V2I	Parking	4
4	Information on AFV fuelling & charging stations	V2I	Smart routing	5
5	Traffic information and smart routing	V2I	Smart routing	5
6	Zone access control for urban areas	V2I	Smart routing	5
7	Loading zone management	V2I	Freight	6
8	Vulnerable road user protection (pedestrians and cyclists)	V2V	Vulnerable Road User	7
9	Cooperative collision risk warning	V2V	Collision	8
10	Motorcycle approaching indication	V2V	Collision	8
11	Wrong way driving	V2V	Wrong way	9

C-ITS and ICT as a tool for efficient and consistent traffic management

The Day 1 services are mostly related to traffic management. These services can be used to keep traffic flowing, reduce gas emission levels and warn vehicles of dangerous situations ahead. Day 1 services may have the following benefits:

- The early and accurate localization of problematic areas, obstacles and accidents, which is vital for sending and sharing warnings to other vehicles in the area. Therefore, dangerous situations can be avoided and an overall consistent traffic flow can be maintained even in dense traffic.

- In construction areas, speed funnels are crucial for reducing vehicle speed and to keep traffic moving smoothly to avoid accidents. Through the use of C-ITS, warnings are precisely defined and transmitted to vehicles.
- Weather warnings are usually linked to dangerous and often very dynamic situations. The warnings must be quickly transmitted to the relevant vehicles in order to influence driving behaviour.
- Services created by infrastructure operators are initially sent to motorways and expressways where busier traffic is common. Simultaneously, vehicles equipped with C-ITS also communicate directly between each other (e.g. exchange warnings if they abruptly slow down or are approaching the end of a traffic jam). These types of services will likely be the first to be included in vehicles equipped with C-ITS.
- Traffic lights are already an essential part of C-ITS. In the future, vehicles can be warned if another vehicle ignores traffic light signals ("red light violation"). Furthermore, based on the SPAT (i.e. traffic light standard) information from consecutive traffic lights, the optimal speed for a so-called "green wave" can be calculated ("Green Light Optimum Speed Advisory – GLOSA").

Application areas of and scenarios for technologies

Figure 10 represents the modern key technologies and their relevance to the different application areas. Traffic environment, driver interaction with the vehicle and vehicle control functions will create the triangle to develop the creation of a harmonised entity.

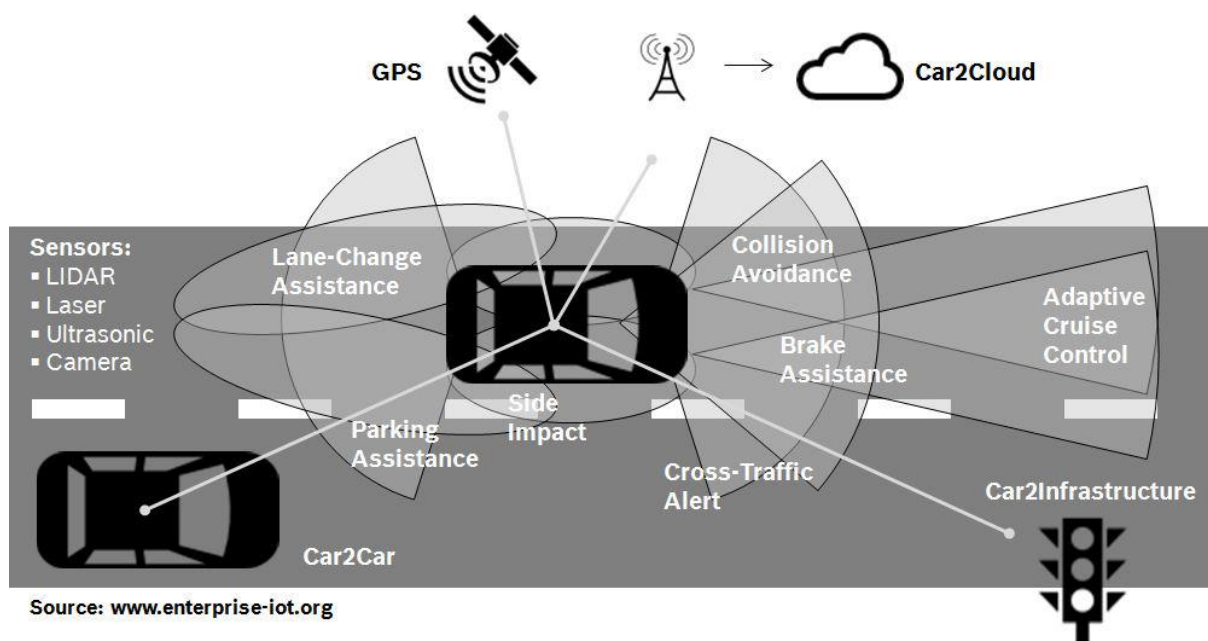


Figure 10: Set of technologies needed by the different application areas relevant for autonomous driving

The aforementioned bundles can be combined into five deployment scenarios that are additive and complementary, and mostly chronological:

- **Scenario A:**
 - Deployment of all safety based V2V services (Bundle 1) starts on all roads (as V2V is road independent, the determining factor is the uptake rate in vehicles).
 - Traffic information and smart routing (Bundle 5) is deployed on TEN-T corridors and core roads first and initially for passenger cars only.
- **Scenario B:**
 - The (mainly) motorway-focused V2I services from Bundle 2 (such as road works warning and shockwave damping) are deployed on TEN-T corridors and core roads.
 - Traffic information and smart routing extends to comprehensive networks and now includes freight vehicles.
- **Scenario C:**
 - Urban deployment of the applicable services from Bundle 2 and the very urban focused services from Bundles 3 (e.g. GLOSA, traffic signal priority) and 4 (Parking information).
 - Traffic information and smart routing extends to all other equipped roads.
 - Safety based V2V services (Bundle 1) extend to buses.
 - Motorway-focused V2I services (Bundle 2) are deployed to all equipped roads.
- **Scenario D:**
 - Loading zone management is deployed to freight vehicles and equipped roads.
- **Scenario E:**
 - All additional Day 1.5 V2X services (e.g. motorcycle approaching indication or VRU protection) are deployed across all vehicle types and equipped roads

Communication has been one of the major developments in recent years. The original idea was to extend the electronic horizon beyond the limits of the stand-alone sensors. Afterwards, the automotive industry identified an important channel to bring useful traffic and entertainment facilities to the car. Road operators and authorities are using V2I communication for delivering warning messages and traffic situation information to vehicle drivers. However, the cooperative traffic services still need development before they are ready for deployment phase. Currently, V2X services are in technology readiness level 4-7, whereas autonomous driving needs TRL 7-9 due to reliability demands.

On the other hand, common platforms for having autonomous vehicles in road infrastructures are required. Vehicles are part of the bigger ecosystem that need to be maintained and supervised in order to have both manually driven and autonomous vehicles simultaneously.

From a communication perspective, one of the major targets is to introduce Vehicle-to-Everything [163] (V2E, also known as V2X) technologies. V2E refers to an intelligent transport system where all vehicles and infrastructure systems are interconnected. Vehicle-to-vehicle cooperation has been developed in the past in several projects in the EU, USA and Japan. However, recent innovations include vehicle-to-traffic light and vehicle-to-pedestrian communication aspects.

One of the major challenges in the deployment of C&AV is to verify the technology and evaluate the potential impacts for mobility, environment, and traffic safety. About 30 different test site building activities exist at the moment around the globe, and about 1,000 minor test fields dedicated for specific functions have been initiated. Industry driven (OEM, Tier 1, suppliers) test sites are mostly dedicated for component durability and reliability tests, whereas the public sector looks for impact and evaluation aspects. One of the big questions from an economic perspective is to understand what type of infrastructure investments are needed in the future since the life-cycle of road systems is typically decades-long.

Patent/inventions to identify leadership in technologies

Patents are a frequently used indicator to monitor technology development. However, patents may be applied for in a different country from the one in which the intellectual property (IP) was developed. Thus, it is important to consider the ownership of the patent rather than the geographic region in which the patent is registered.

Patents have a long history as a sign of inventive activity [164]. The report "The 2016 State of Self-Driving Automotive Innovation" [166] indicates there were more than 22,000 unique self-driving

inventions from January 2010 through October 2015 (Figure 11). The trend continues to ascend, although not as aggressively as in previous years.

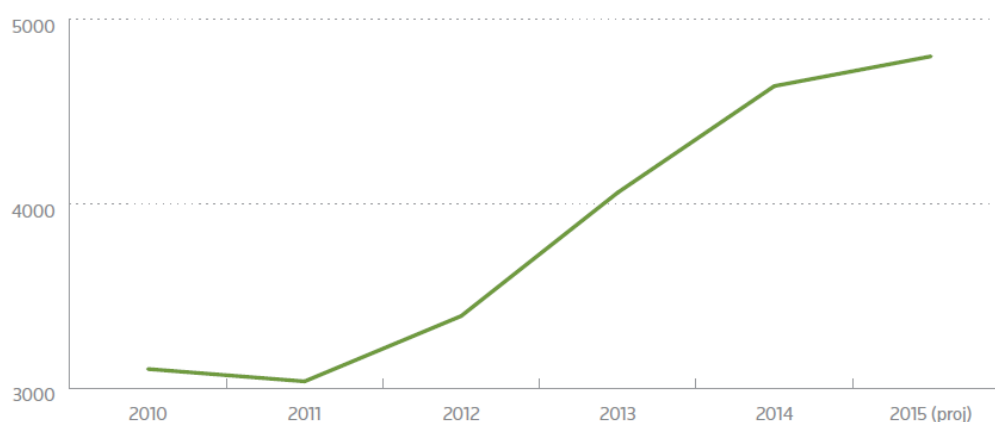


Figure 11: Self-Driving Inventions by Publication Year

Source: Thomson Reuters Derwent World Patents Index

Technology-based businesses acting in the automotive sector continue to attract attention. For example, Ford made a number of announcements during its press conference at the 2016 International Consumer Electronics Show (CES)²⁶. Although there were rumours that manufacturer would announce a joint venture with Google to build autonomous cars, this was not confirmed. Instead, Ford revealed a new partnership with Amazon and drone maker DJI, as well as additions to console software and “infotainment” systems. Although the carmaker plans to test its self-driving cars this year, Ford made it clear that its priorities are focused on advancing in-auto technologies [165].

Moreover, as iterated in previous sections, most of the patents and standards considering C&AD originate from the USA or Japan, especially patents owned by Google in terms of IT-related technology and Toyota in term of automotive manufacturing. According to the aforementioned report, Toyota owns more than 1,400 patents related to C&AD, which exceeded other automotive manufacturers by a factor of two. [166] The close competitors of Toyota are Japan’s Denso Corp, Korea’s Hyundai Motor Co, and General Motor. This shows the capability and influence of non-European stakeholders in developing C&AD related technology. The large number of patents owned by non-EU manufacturers is a threat that could lead to distortion of competition faced by European manufacturers, since patent ownership could be used to obstruct other stakeholders to develop new technology. In this case, their competitors could use patent-ownership to hinder European manufacturers who have the opportunity and capability of developing C&AD.

With all the media publicity, it is easy to summarise that tech companies are taking the lead in terms of automotive innovation. However, the truth is that these companies are not leading the industry. Automotive leaders are intensively getting involved in making this technology a reality (Table 14). Toyota (Japan) is the overall global leader in autonomous automotive innovation, followed by Bosch (Germany), Denso (Japan), Hyundai (South Korea) and GM (USA). The same report from Thomson Reuters classifies potential candidates into the three areas comprising self-driving car innovation: (1) autonomous driving, (2) driver assistance and (3) telematics.

Table 14: Top 26 Self-Driving Automotive Innovators (2010 – October 2015)

Company	Autonomous Driving	Driver Assistance	Telematics	Total
Toyota	1450	550	30	2030
Bosch	200	800	25	1025
Hyundai	225	525	150	900

²⁶ The International Consumer Electronics Show (International CES) showcases more than 3,800 exhibiting companies, including manufacturers, developers and suppliers of consumer technology hardware, content, technology delivery systems and more; a conference program with more than 300 conference sessions and more than 160K attendees from 150 countries.

Company	Autonomous Driving	Driver Assistance	Telematics	Total
Denso	675	150	50	875
GM	130	300	325	755
Nissan	450	200	25	675
Daimler	175	425	25	625
Honda	440	130	30	600
Continental	125	300	30	455
Mitsubishi	290	50	40	380
Volkswagen	61	250	10	321
Audi	75	240	5	320
BMW	75	220	10	305
Mando	80	215	2	297
Ford	80	190	20	290
Hitachi	175	75	20	270
Fuji	190	70	2	262
Fujitsu	202	20	2	224
Valeo	20	180	2	202
Panasonic	145	35	5	185
ETRI	109	37	38	184
LG	75	22	70	167
Samsung	105	20	40	165
Scania	63	99	2	164
Clarion	98	35	15	148
Google	84	50	4	138

Source: Thomson Reuters Derwent World Patents Index (*Approximate numbers)

Autonomous Driving

Autonomous driving involves the act of moving and navigating a vehicle without human input through the use of sensor, control and navigation equipment that responds to the environment when travelling from point A to point B [167]. Japan is the world leader in autonomous driving innovation with four of the top five innovator spots. Toyota (Japan) is the leader, followed by Denso (Japan), Bosch (Germany), Nissan (Japan) and Honda (Japan), as shown in Figure 12. Google ranks 19th in this area, followed by Ford at number 20. Overall, Asia has 11 of the world's top 20 autonomous-driving innovators.

There are a number of other organizations innovating in this area, including Amazon (with 14 unique inventions), Boeing (35), IBM (34), Microsoft (10), Qualcomm (24), Samsung (107) and Southeast University in China (24). Carnegie Mellon University and MIT are also on the list with four and seven unique inventions, respectively.

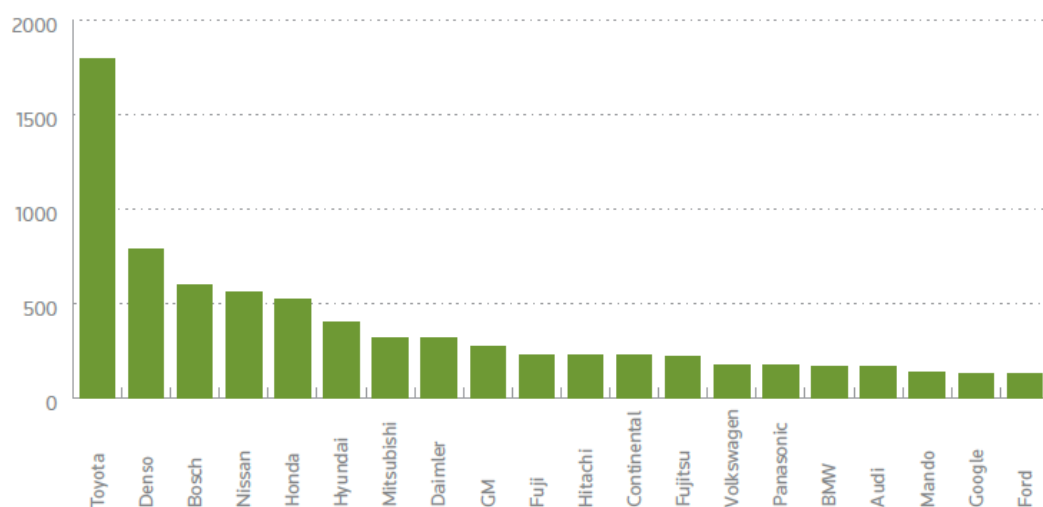


Figure 12: Top Autonomous Driving Innovators (2010 – October 2015)

Source: Thomson Reuters Derwent World Patents Index

Driver Assistance

Driver assistance automates and enhances vehicle systems for safety and improved driving when the driver is in control of the vehicle, helping avoid collisions and accidents by alerting the driver to potential problems or implementing safeguards to take control of the car. Technologies associated with driver assistance include, among others, rear-mounted radar, automatic high-beam control, blind-spot detection, pedestrian detection, lane-departure warnings, intelligent braking, traffic sign recognition and active cornering headlights.

In this area, Germany takes three of the top five innovator spots. Bosch leads the group while Daimler and Continental come in fourth and fifth, respectively. Toyota (Japan) and Hyundai (South Korea) come in second and third place, as shown in Figure 13. Hyundai, BMW and Ford have the largest recent ascends in their driver-assistance portfolios, despite their absence from the top five. BMW ranks 9th and Ford is 12th overall in this category. Google is 23rd overall. Jaguar, Peugeot Citroen Automobiles SA and Renault are also well ranked in driver-assistance innovation, with 85, 68 and 62 unique inventions, respectively. Chang'an University (or University of Xi'an) in China is the leading academic institution with intellectual property in this area.

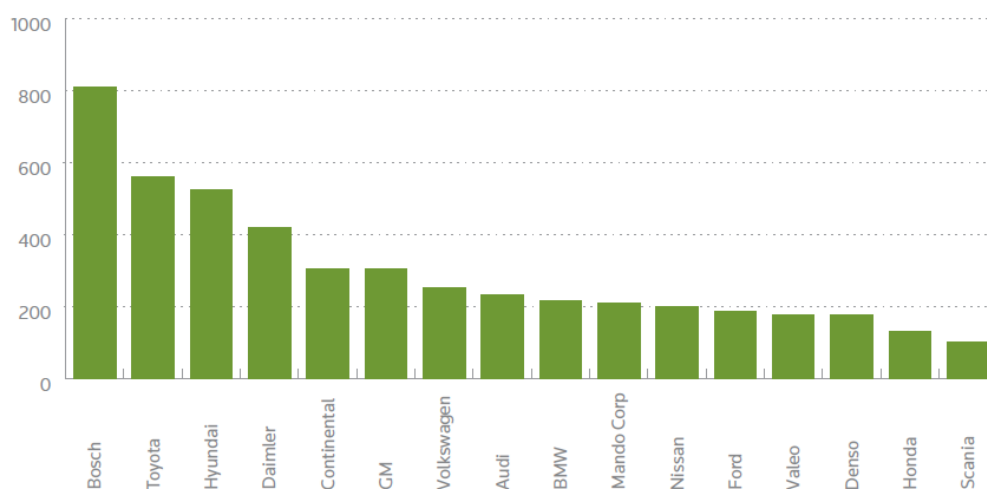


Figure 13: Top Driver Assistance Innovators (2010 – October 2015)

Source: Thomson Reuters Derwent World Patents Index

Telematics

Telematics is an interdisciplinary field encompassing telecommunications, vehicular technologies, road transportation, road safety, electrical engineering and computer science, which allow cars to communicate with each other while on the road [168]. Volume wise, this area has significantly less activity than autonomous driving and driver assistance innovation, totalling just over 2,500 unique inventions for the period of January 2010 to October 2015. Comparatively, autonomous driving had more than 15,000 unique inventions and driver assistance had nearly 8,000 inventions in that period. General Motors (USA) has the highest number of innovation in telematics, followed by Hyundai (South Korea), Marvell (USA), LG (South Korea) and Denso (Japan), as shown in Figure 14.

The largest increases in telematics are by SK Hynix and HTI IP. The former entered the field for the first time in 2014 with 15 unique inventions in the area. The latter went from zero activity in 2013 to 10 inventions in 2014.

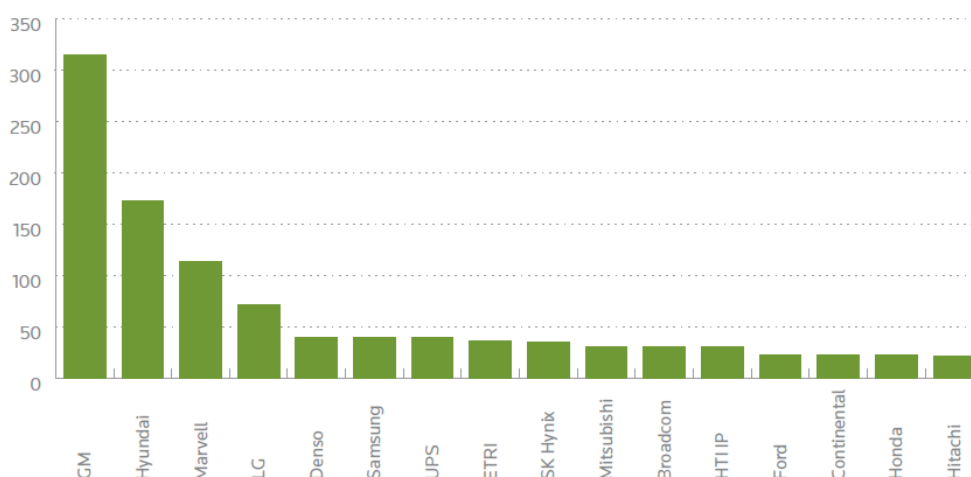


Figure 14: Top Telematics Innovators (2010 – October 2015)

Source: Thomson Reuters Derwent World Patents Index

Patenting and risks to leadership

Currently, most of the patents related to C&AD originate in the USA or Japan. This gives these two countries a competitive advantage and a dominant position. The USA is clearly the global leader in the field. Google and GM Global hold the largest patent portfolios, ranging from system sensors (e.g. LIDARs) and platforms for 3D environment mapping to cameras for lane detection and vehicle control. Japanese OEMs and technology developers (e.g. Toyota, Mitsubishi and Panasonic) have mostly patented technologies regarding vehicle controlling, artificial intelligence and passenger safety systems. From the EU perspective, falling behind in this domain implies that other competitors are in a direct advantage.

As for standards, many discussions on establishing international C&AD standards have been made. Since C&AD addresses multiple technical and social aspects (e.g. data security, privacy, safety, communication), there is also the involvement of various standard developing bodies (ISO, IEEE, ETSI, SAE International, etc.). Establishing a consensus between the national and international bodies and OEMs is challenging and time consuming. The ICT industry has historically used technical standards to make communication systems possible and to ensure the compatibility of different products. A similar approach to standardisation in the automotive industry would facilitate fast and extensive product development for C&AD.

Standardisation is crucial for a timely and cost efficient market development of C&AD. Because of this, the EU automotive and communication industries should agree to map all relevant standardisation activities and jointly determine priorities.

Country analysis

Table 15. Review of existing technologies in the market per country

Country	Analysis findings
USA [21], [112], [169], [170], [171], [172], [173]	<p>The transport system serves society best when the technologies with the greatest potential are used. This enables transportation system managers to connect effectively and share information from various factors that affect transportation operations (e.g. weather, planned special events, and response to unanticipated emergencies). Adoption and deployment of the connected system rely on V2X, especially V2V, communication. The development of systems is focusing on both short-range communications (DSRC) technology and long-range communication technology (such as cellular and satellite networks).</p> <p>Due to the large automotive and technology industry, multiple automotive manufacturers and vendors are USA based. For example Tesla, Ford, and General Motors are heavy investing in automated driving and cooperative systems. Google and Apple's attempts to build their own driverless car should not be forgotten. Also, many component manufacturers like Velodyne and Trilumina who are producing lidars or computer manufacturers Nvidia and Texas Instruments have origins in the USA. In addition, Fisker Inc. will develop an electric car that is able to travel approximately 650 km and the cars will be equipped with self-driving hardware. However, the fully autonomous driving capability would not be available until it meets regulatory approval. Ford also announced that they will develop an operating system for their automated vehicles with Blackberry. A plan is to offer a fully automated vehicle for commercial ride-sharing in 2021.</p>
Japan [90], [112], [153], [174]	<p>The Japanese government highlights the essence of V2X communication for the development of autonomous vehicles. Japan has introduced "ITS spot" technology that is based on high bandwidth communication. At the moment, roughly 1600 "ITS spot" locations have been established and over 100,000 vehicles can communicate with them. Currently "Spots" provide traffic information, announcements, and warnings. In the future, spots will give support for the lane keeping assist and adaptive cruise control to avoid traffic congestions. The roadmap by the Japanese "autopilot system council" announces that the highly automated vehicles will be seen on Japanese highways until 2020.</p> <p>Toyota is developing a modified Lexus GS called Highway Teammate, using on-board technology to evaluate traffic conditions and drive autonomously on motorways. Toyota said it aims to launch products based on Highway Teammate around 2020. Also, some models (e.g. Crown) are equipped with V2X technologies that allow vehicles to talk to ITS sensors at intersections, which warn of pedestrians and vehicles hidden by blind spots.</p> <p>In Japan, a company called Robot Taxi is planning to test a fully automated taxi service on 50 residents of the Kanagawa prefecture shortly.</p>
South Korea [31], [33], [90], [175]	<p>South Korean research institutes are conducting research on two types of self-driving vehicles: (1) the autonomous vehicle that collects information from in-vehicle sensors and (2) the use of "Automatic Vehicle Guidance System" (AVGS). In this case, the vehicle can receive information from in-vehicle sensors and a roadside infrastructure at the same time.</p> <p>South Korean car manufacturers such as Hyundai-KIA, Renault Samsung, and GM-Daewoo have been developing their own systems to provide drivers convenience and safety. In the coming years, various services will be applied to a wide range of models. For example, Hyundai-KIA's "Blue-link" – system provides real-time weather conditions, voice to text conversion and messages, and the connection between smartphone and navigation. Locking and unlocking a car, engine start and automatic emergency calls are possible too. Other manufacturers are providing similar services. Hyundai-KIA has also their development program for fully-automated vehicles.</p>
China [35], [176]	<p>China is becoming one of the earliest countries to develop fully autonomous cars. The public and private sector are investing in R&D and testing facilities and programmes on automated driving. At the moment, trial and development is focusing on short and long-range communication and exploiting GPS and satellite data. In the near future,</p>

Country	Analysis findings
	<p>more sophisticated in-vehicle systems and technologies will be developed more intensively. Currently, SAIC and Alibaba Group, BAI and Letv, BMW and Baidu are collaborating on developing semi and fully autonomous vehicle technology.</p> <p>China is also encouraging car manufacturers to install its own answer to Global Positioning System and advance autonomous driving technology developed by the USA as part of a broader push to upgrade the country's transportation sector. The government of China is promoting the state-developed Beidou Navigation Satellite System as the standard configuration for vehicle-navigation devices and smartphones.</p>
France [112], [153]	<p>Renault and Peugeot Citroën PSA are the French automotive companies most involved in self-driving development. The company is developing an automated system relying on Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication technology. Both Peugeot Citroën and Renault have announced that they will introduce their models in the market by 2020. Naturally, initiatives launched by the car manufacturers have an impact on the vendors as well. For example, Valeo is doing a close collaboration with PSA nor forgetting their internal projects.</p>
Germany [46], [112], [149], [177]	<p>The German Government has set the objective of ensuring basic coverage at a speed of at least 50Mbit/s by 2018. Regarding the road network, the government reserves the frequency of 700MHz (Second Digital Dividend) which obliges the purchasers to ensure that motorways are connected with a bit rate of at least 50 Mbit/s. It is supposed to support the deployment of new technologies and even higher bitrates. In the future, 5G is considered a potential communication standard.</p> <p>Regarding car manufacturers, at least Audi, Mercedes-Benz, and BMW have their own development initiatives. All of those manufacturers have already performed tests of new technologies and even fully autonomous vehicles. HERE, a German-owned company, is investing heavily in high-definition maps because sensors do not make for automated cars alone. For a driverless car to fully understand the environment around it, it needs to 'read' a richly detailed map. Generating HD-maps is one of the core technical components.</p> <p>As the European leader in the automotive industry and as one of the biggest automotive producers, Germany is a home country for various world class companies (e.g. Continental, Bosch, ZF-TRW), etc.), who have their own visions, objectives and strategies for autonomous driving and exploiting their technologies in autonomous vehicles.</p>
Italy [178], [179]	<p>The Italian based VisLab and its know-how is globally recognized for their monocular, stereo, trinocular, up to tetra-vision systems, using daylight and infrared cameras; analogue and digital cameras. Passive and active safety systems are also one of the focus areas. Some example technologies are: lane detection, vehicle detection, pedestrian detection, obstacle localization, sensor fusion with radar and laser scanner, night vision, start to inhibit²⁷. Fiat Research Centre (CRF) works as in multiple EC funded projects (e.g. AdaptIVE, inDrive) in which they are mainly focusing on in-vehicle geolocation for automation and automated functions for urban driving.</p>
Spain [112]	<p>Spanish activities are mostly connected to the V2X communications and assistance systems. These are mainly coordinated by the automotive provider Applus IDIADA. It launched the VRAIN project (Vehicular Risk Awareness Intelligence Network) in collaboration with the telecommunications company Cellnex Telecom. The project aims at investigating V2X communication and use of those to avoid road accidents.</p>
Sweden [51]	<p>Current and future activities in the development of automated driving will focus on different active safety systems, real-time information sharing between vehicles and between vehicles and infrastructure (C-ITS, cooperative intelligent transport systems). Radar and camera-based safety systems have traditionally been a strong expertise area for Swedish automotive industry. When it comes to communication, Volvo has a joint research program with Ericsson²⁸.</p>

²⁷ VisLab. <http://vislab.it/automotive>

²⁸ Ericsson Automotive. <https://www.ericsson.com/ourportfolio/transport/automotive>

Country	Analysis findings
United Kingdom	<p>There are many research efforts underway in the UK to develop autonomous vehicle technology, and fully autonomous vehicles are a long-term goal for policy makers and car manufacturers. As one of the biggest issues, communication, V2I and V2V, must be studied and reliable technology must be developed.</p> <p>There are currently many ongoing initiatives, such as real-time vehicle tracking, vehicle and infrastructure monitoring (e.g., sensors, computers) and traffic management systems. In the future, satellite-based communication and navigations will probably become even more important, just like more powerful on-board computers.</p>
EUROPE	<p>The EU automotive industry is a strong technology provider at the global level. Europe is strong in sensor technologies, C-ITS solutions and hardware products. However, embedded computing and system level artificial intelligence are two areas linked to C&AD in which the EU industry is not at the same level as competitors from the USA and China IT sectors.</p> <p>Testing and verification in the EU is strong due to a systematic approach and traditions in verifying automotive systems. Current systems meet the strict safety and ecology requirements. However, this also causes friction for the renewal of the industry. Thus, and due to strict EU safety requirements, the automotive industry is not able to follow the clock speed of USA and Asian competitors. Using C-ITS services (especially Day 1) is essential for traffic management, especially in (Central -) Europe where traffic volumes are high and many areas invariably suffer from congestion.</p>

3.1.2 Comparative analysis of technologies

Environment perception technology

Japan, South Korea and China are strong in the development of hardware and sensor products, not only for the automotive industry but also in many other industrial branches. However, EU countries have reached an equal level. Optical sensors (cameras and lidars) are available from EU markets and are increasingly designed for automotive use, which have special requirements due to safety and accuracy reasons (compared to many other industrial applications). In addition, companies like Continental, Bosch and Autoliv are world leading radar providers, which are making EU very strong in this area.

New companies in the USA are entering the lidar market, with a completely different 2D scanning principle compared to EU suppliers. This might change the leadership in the sensor markets if the EU remains focused on their approach without introducing new emerging products.

Machine Intelligence

Since the number of sensors and systems in cars are steadily increasing, rule based classifiers cannot be flexible enough in the long term for processing big data alternative decision making. Academia in the USA and Japan have a long history in developing software based machine learning algorithms, which will have a significant role in C&AV. EU universities have also been developing artificial intelligence, but the field is very fragmented and a common goal is missing. Moreover, there is a lack of artificial intelligence focused companies at the EU level. The challenge in C&AD is the verification of the right procedure when machine intelligence takes a more important role in data processing inside the vehicle.

Vehicle controls

Actuator and vehicle control systems are mostly part of a company's IPR. Companies are not willing to share access to vehicle controls for safety and liability reasons. Adaptations to the control system is an area where development has been quite limited, even if stability controls and emergency braking systems have been intensively implemented. This is an area where cooperation between public organisations and the industry could be beneficial, but where the nature of closed development may limit this opportunity.

ITS systems

Today, authorities are in charge of the infrastructure side of ITS systems in almost all countries. New small and medium size companies have been introducing new services and applications, especially with the mobile business in mind. Strategies in the EU and the USA to open the data of the public systems have boosted the versatile use of data available in ITS systems. This open data is also valuable for C&AD since weather forecasts and congestion information is important for having smart automatic route planning systems. In addition to the public ITS infrastructure, the automotive industry should be encouraged to share in-vehicle data. Considering the possibility of win-win business models, an open environment would let companies find new revolutionary ways to use the data.

C-ITS and traffic management

Telecommunication has a good history in the EU. The mobile network infrastructure is well developed even if variation exists among Member States. This provides a good basis for information sharing between connected vehicles. However, the needs of automated vehicles are different. The aim is to extend the electronic horizon of the sensor system beyond 200 m. The short latency time (<10 ms) is an essential feature due to safety. In addition, very short latencies (< 5 ms) are needed in certain “hot spots” like tunnels and intersections and therefore, penetration of ITS-G5 devices in the market is one of the key enablers towards automated driving. Deployment of 5G outside of the cities is also needed, especially in areas where distances are long (e.g. motorways), in order to have sufficient coverage for low latency communication devices. In general, the EU is in a good position in connected driving compared to the USA and Asian competitors. However, governmental push to start deployment of ITS-G5 is highly recommended.

Efficient automated driving in mixed traffic (with automated and non-automated vehicles) can only be achieved through continuous coordination with traffic management. Traffic management can specify requirements related to maintaining traffic flow or to approve existing requirements for automated driving. Through traffic management, for example, a lane could be dynamically released for automated vehicles with precise specifications for speed and distance between vehicles.

In general, communication between vehicles and infrastructure is a decisive factor in making a comprehensive, forward-looking and detailed perception of the environment possible for individual vehicles. With the appropriate networking, accurate information about the current speed limits can be reliably transmitted directly to the vehicle.

Digital infrastructure and technologies

Digital infrastructure (for road automation) includes static and dynamic digital representations of the physical world with which CA&V will interact to operate. Issues to address include: sourcing, processing, quality control and information transmission. For the fast deployment of digital infrastructure, especially in combination with road automation, the following requirements are relevant: accurate data/position, data integration, reliability and supported levels of automated driving, liability, roles of static and dynamic data, privacy, roles for national governments, standards (e.g. interface standard), and map updates.

A C&AV will collect information, make a decision based on that information, and execute a decision. Information comes from vehicle equipment, physical infrastructure, and digital infrastructure, any of which may be public or private. These technologies already exist and are capable of guiding vehicles. In some cases, they are able to drive vehicles with minimal or no driver input in test situations and across diverse driving environments.

Some applications may benefit from specialised infrastructure. Physical infrastructure might include V2V and V2I communication equipment, ground-based units for global navigation systems, dedicated facilities comparable to bus and bicycle lanes, on-street parking restrictions, and specific roadway or pavement modifications. Digital infrastructure might include the maintenance of highly detailed roadway maps and pertinent traffic operations data. This specialised infrastructure, if actually required, could be limited to a manageable set of corridors actually used by a particular urban mobility system.

When it comes to the deployment of services and technologies, flexible and tailored solutions and specialised pilot projects are particularly important. Local, regional, and national actors can also facilitate the approach to automation by clarifying the legal status of non-conventional vehicles (such as low-speed neighbourhood shuttles) and services (e.g. ride sharing and alternatives to traditional taxi service) by identifying specific needs and opportunities, modifying physical and digital

infrastructures accordingly, and deploying particular resources, such as road space or taxi concessions strategically.

Connectivity vs automation

Vehicles must be aware of their environment in order to respond to it. Automated vehicles are limited to one-way line-of-sight scanning to assess their environment. Connected vehicles utilize connectivity to communicate with other nearby vehicles and with infrastructure. There are multiple possibilities of data communication between vehicles and central servers, but there are additional possibilities from V2V and V2I connectivity. The benefits of automated vehicles are primarily for passengers. A fully automated vehicle allows the driver to focus less on the driving and allows them to focus on other tasks. With partial vehicle automation, features such as automated cruise control, lane changing, automatic overtaking and parallel parking are primarily for driver convenience.

Selling partial or full automation is easier than selling vehicle connectivity. Buyers of new vehicles can already have adaptive cruise control and automatic parallel parking as features that benefit them. However, it is more difficult for a buyer to see benefits in vehicle connectivity if infrastructure and other vehicles are not yet connected. Governments need substantial funding in order to roll out connected and digital infrastructure, especially connected traffic signals that send messages to vehicles.

Communication technologies can be seen as a source of value for everyone who wants to get around in an urban environment. For people in vehicles, it can provide the best option to help get them where they want to go (through a combination of information about uncongested streets and pricing on congested ones). For pedestrians, it can be used to help give vehicles an incentive to stay away from certain areas that should be prioritised for people.

3.1.3 SWOT analysis of existing technologies in the market

Table 16: SWOT analysis for EU on existing technologies

Strengths		Weaknesses	
Main Point	Explanation	Main Point	Explanation
Premium quality, reputation and high-tech products with a strong science base	<ul style="list-style-type: none"> EU car industries are competing very successfully on the world stage through a broad range of models and excellence in the high-end segment. This positive image can help leverage sales and be an advantage when C&AV become mainstream. 	Lack of standards challenging the development of key enabling technologies	<ul style="list-style-type: none"> The automotive industry is facing a variety of challenges partly due to the fragmented industry: a lack of standards across manufacturers and suppliers hinders the identification and development of potential (key) technologies.
C&AV included in portfolios of European automotive companies	<ul style="list-style-type: none"> C&AV will be a major business pillar for the EU automotive industry. Many EU automotive companies already have C&AV in their portfolios. 	Weak internationalisation of R&D	<ul style="list-style-type: none"> Part of the R&D activities are done internally, which set challenges for EU wide and cross-disciplinary collaboration. The lack of collaboration may slow down the development of required technologies.
Opportunities		Threats	
Main Point	Explanation	Main Point	Explanation
Operations systems and software for C&AD	<ul style="list-style-type: none"> There is an opportunity to compete with USA companies and aim to develop more sophisticated operations systems for C&AV. 	Gaps between the needs of industry and research	<ul style="list-style-type: none"> There is a threat of the gap between the needs of the industry and research, which would reflect on the development of technology.
Public investments supported through pre-commercial procurement and agile and enabling testing	<ul style="list-style-type: none"> Pre-commercial procurement schemes could be defined to support public investments and the commercialization of promising technologies. Flexible legislation processes are required to enable rapid and agile testing and piloting of technologies and vehicles. 	Lack of planning and coordination in technology exploitation and deployment	<ul style="list-style-type: none"> The lack of a coordinated planning could negatively influence the impact of C&AV technologies on EU automotive R&D.
Commercial potential of key enabling technologies	<ul style="list-style-type: none"> Collaboration and partnerships between manufacturers, suppliers and research institutes on technology would strengthen the EU automotive industry. 		

STRENGTHS

Premium quality, reputation and high-tech products with a strong science base

EU car manufacturers are currently competing very successfully on the world stage. These have a broad range of models and excellence in the high-end segment. Most EU car manufactures (e.g. from France and Germany) produce world class vehicles containing state-of-the-art technologies (e.g. sensors, communication and actuators) that have a strong science base, especially needed in vehicle automation technologies. In addition to OEMs, tier one suppliers export many components to the USA and China automotive markets. In addition, Europe has strong researchers, especially on vehicle safety and fuel technology, which is a great strength in the face of the remaining challenges for C&AD.

Experts agree that the EU is well positioned regarding R&D for vehicle technologies (Question 2A.2). More than 75% of experts indicated that autonomous vehicle technologies are 'very developed' or 'developed' within Europe. This value is only surpassed by the 85% of experts who indicated the USA as having 'very developed' or 'developed' technologies. From the Asian countries (Japan, China and South Korea), Japan was indicated as the country with biggest technological developments: more than 65% answered they were 'very developed' or 'developed'. When questioned about the major players in C&AV development (Question 2A.3), Tesla and Google (both based out of the USA) were the most frequently indicated by experts, with more than 75% and 65% of all experts having indicated these two 'players'. Daimler/Mercedes (EU-based) was the third most indicated by experts, with 50%, followed by Volvo, with just over 45% of the responses.

C&AV as a part of the product portfolios

It is evident that C&AV will be one of the major business pillars for the EU automotive industry. C&AV will represent a long-term strategic focus. Many EU automotive manufacturers have already included C&AV in their portfolios. However, they still consider connected car technologies as an additional value to their actual core products without currently having a major impact on business development.

WEAKNESSES

Lack of standards challenging the development of key enabling technologies

To strengthen the market position of the EU automotive industry, collaboration between OEMs, suppliers, research and start-ups will be essential. Currently, the automotive industry is facing a variety of challenges partly due to a fragmented industry: a lack of standards across manufacturers and suppliers, which hinders the identification and development of potential (key) technologies. Consequently, this makes the integration of different technologies in the whole industry challenging. As the global competition increases and new competitors enter the market, the fragmented industry will have difficulties to respond to this factor.

Weak internationalisation of R&D

Even though the EU automotive industry considers C&AD essential and a global game changer, a major part of EU R&D activities are still done internally or nationally, which set challenges for a EU wide-scale and cross-disciplinary collaboration. This has the problem of potentially slowing down the development of technologies.

OPPORTUNITIES

Operations systems and software for C&AD

Software and operating systems will play an important role in the C&AV market and will become new core competencies. Currently, USA companies are working on changing this deficit and are mostly responsible for the development of software and operating systems for C&AV.

As mentioned, automotive companies frequently rely on in-house competencies. However, they are aware that they cannot develop all the necessary solutions and services exclusively on their own. This is an opportunity for EU technology providers to cooperate with manufacturers.

Public investments supported through pre-commercial procurement and agile and enabling testing

Pre-commercial procurement schemes could be set up to support public investments and the commercialization of promising technologies. A more flexible legislation process is required to enable

rapid and agile testing and piloting of technologies and vehicles, and to attract new non-European customers.

Commercial potential of key enabling technologies

Collaboration scenarios and partnerships between manufacturers, suppliers and research institutes would strengthen the EU vehicle industry and expand the EU expertise and business field. In addition to software development and real-life testing environments, the development of new security functionalities, advanced sensor and decision making technologies from ICT, photonics and electronics sectors would provide new possibilities.

THREATS

Lack of planning and coordination in both technology exploitation and deployment and between national and regional programmes

To maximise the impact of C&AD on EU automotive R&D, adequate planning linking research, innovation and (pre-) deployment based on industrial roadmaps and understanding of the main challenges for C&AV is necessary. However, there is a threat that a lack of planning occur in technology exploitation and deployment and between national and regional programmes.

Gaps between the needs of industry and research

The EU has a strong background and a proven track record in ICT and electronic technologies. Currently, the gap between industry and research has widened, which naturally reflects on, for example, the development and deployment of key enabling technologies as well as the holistic coordination of C&AD R&D at the EU level. Currently, technology exploitation and deployment within the USA and Japan are better planned and coordinated across a wider front than in the EU, especially in key technologies.

3.2 Subtask 2 – Automated and connected cars/ road vehicles technology analysis

Subtask 2 includes an analysis of the existing automated and connected cars/ road vehicle technologies how they are present in Europe, Member States and third-countries.

The reviewed information is used as a basis for the development of a comparative analysis, which is complemented by a detailed SWOT that analyses Europe compared to the third-countries. Additional information collected from experts is also used to justify the performed analysis.

3.2.1 Review of current automated and connected cars/ road vehicles technology

The maturity level for each technology is assessed according to the pre-existing knowledge in this area and also based on the distributed interview forms (Table 17).

Table 17: Technology Readiness Levels [180] [181]

Level	Description
1 – Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of technology's basic properties
2 – Technology concept and/or application formulated	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies
3 – Analytical and experimental critical function and/or characteristic proof of concept	Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative
4 – Component and/or breadboard validation in laboratory environment	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the future system. Examples include integration of "ad hoc" hardware in the laboratory.
5 – Component and/or breadboard validation in relevant environment	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components
6 – System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or a simulated operational environment
7 – System prototype demonstration in an operational environment	Prototype near or at planned operational system. Represents a major step up from TRL 6 by requiring demonstration of an actual system prototype in an operational environment (e.g. in an aircraft, in a vehicle, or in space)
8 – Actual system completed and qualified through test and demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation (DT&E) of the system in its intended weapon system to determine if it meets design specifications
9 – Actual system proven through successful mission operations	The actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational mission conditions

In addition, autonomous driving functions are categorised according to the automation levels, as defined by SAE International [4]. This section presents a number of different technologies currently

available for each automation level [112]. The extent of usage and particular benefits, and business model for each selected function or application are identified.^{29 182 183}

Automated/connected vehicle technology analysis

Current and future C&AV systems

LEVEL 0 systems:

Anti-lock Braking Systems (ABS)

Scenario	Urban, highway, rural
Function	Anti-lock Braking Systems (ABS)
Automation level	0: no automation
Description	Automobile safety system that enables the wheels on a motor vehicle to maintain tractive contact with the road surface according to driver inputs while braking, preventing the wheels from locking up (ceasing rotation), and avoiding uncontrolled skidding.
Benefits	ABS offers improved vehicle control during braking and decreases stopping distances on dry and slippery surfaces
Usage and value	Private: standard equipment in most of the new vehicles Commercial: standard equipment in most of the new vehicles
TRL	9

Traction Control System (TCS)

Scenario	Urban, highway, rural
Function	Traction Control System (TCS)
Automation level	0: no automation
Description	Designed to prevent loss of traction of driven road wheels. The system is activated when throttle input and engine torque are mismatched to road surface conditions.
Benefits	Traction control is not just used for improving acceleration under slippery conditions. It can also help a driver to corner more safely. If too much throttle is applied during cornering, the drive wheels will lose traction and slide sideways
Usage and value	Private: standard equipment in most of the new vehicles Commercial: standard equipment in most of the new vehicles
TRL	9

Electronic Stability Control (ESC)

Scenario	Urban, highway, rural
Function	Traction Control System (TCS)
Automation level	0: no automation
Description	Computerized technology that improves a vehicle's stability by detecting and reducing the loss of traction. When ESC detects loss of steering control, it automatically applies the brakes to help "steer" the vehicle where the driver intends to go. Braking is automatically applied to wheels individually. Some ESC systems also reduce engine power until control is regained
Benefits	ESC provides traction and anti-skid support in cases of oversteering and understeering
Usage and value	Private: standard equipment in most of the new vehicles Commercial: standard equipment in most of the new vehicles
TRL	9

²⁹ Bosch Mobility Solutions. <http://www.bosch-mobility-solutions.com/en/>

Park Distance Control (PDC)

Scenario	Urban
Function	Park Distance Control (PDC)
Automation level	0: no automation
Description	Ultrasound sensors (radar) integrated into the bumpers measures the distance to the nearest object behind the vehicle. As the object comes closer, the frequency of the warning tone increases.
Benefits	Parking becomes much easier when an acoustic warning signal lets a driver know how close the vehicle or object is.
Usage and value	Private: Willingness to pay Commercial: standard equipment in most of the new vehicles
TRL	9

Lane Change Assist (LCA)

Scenario	Urban, Highway
Function	Lane Change Assist (LCA)
Automation level	0: no automation
Description	Lane change assist can prevent critical situations from occurring when changing lanes. The system works by using two mid-range radar sensors in the rear of the vehicle to monitor the areas next to and diagonally behind the vehicle. The system works by using two mid-range radar sensors and monitors the areas next to and diagonally behind the vehicle.
Benefits	The lane change assistant supports the driver during lane change manoeuvres via detecting potential hazardous situations that result due to the driver failing to monitor the area around the vehicle adequately.
Usage and value	Private: Willingness to pay Commercial: Business case on decreased accident costs
TRL	8

Lane Departure Warning (LDW)

Scenario	Highway
Function	Lane Departure Warning (LDW)
Automation level	0: no automation
Description	Lane departure warning uses a video camera to detect lane markings ahead of the vehicle and to monitor the vehicle's position in its lane. When the function detects that the vehicle is about to move unintentionally out of the lane, it warns the driver using a visual, audible and/or haptic signal, such as steering wheel vibration.
Benefits	Warns of unintentional straying from the marked lane
Usage and value	Private vehicles: Willingness to pay Commercial: Business case on decreased accident costs
TRL	9

Forward Collision Warning (FCW)

Scenario	Urban, Highway
Function	Forward Collision Warning (FCW)
Automation level	0: no automation
Description	Forward collision warning alerts of an impending collision with a slower moving or stationary vehicle in front of the vehicle. Sensors located in the front of the vehicle can detect how close the vehicle behind is. These typically are camera- or radar-based. Warnings can come in the form of sounds, visuals, vibrations or a quick brake pulse; or, a mix of warnings
Benefits	Avoidance of dangerous situations caused by inattention
Usage and value	Private vehicles: Willingness to pay Commercial: Business case on decreased accident costs
TRL	9

LEVEL 1 systems:**Automatic Emergency Braking Systems (AEBS)**

Scenario	Urban, highway, rural
Function	Automatic Emergency Braking Systems (AEBS)
Automation level	1: Driver Assistance
Description	AEB uses radar, laser, or video to sense an impending collision. The software then primes the brakes or applies them if the situation is too far gone. The hope is that the safety tech will be particularly effective with front-end impacts, such as in heavy traffic. Besides stopping rear-ending crashes that clog up freeways, the required systems will also sense pedestrians in the roadway and apply the brakes before impact. The function works without V2x communication.
Benefits	Avoidance of dangerous situations caused by inattention
Usage and value	Private vehicles: Willingness to pay Commercial: Business case on decreased accident costs
TRL	9

Park Assist (PA)

Scenario	Urban
Function	Park Assist (PA)
Automation level	1: Driver Assistance
Description	The vehicle will practically park itself, cleverly steering into the tightest of spaces. Only working the pedals is required. System uses ultrasound, acoustic and optical sensor to detect obstacles
Benefits	With Park Assist on a vehicle is like having a personal parking attendant. Our parallel parking system helps a driver park with ease – even in tight spots.
Usage and value	Private vehicles: Willingness to pay
TRL	8

Lane Keeping Assist (LKA)

Scenario	Highway, Rural
Function	Lane Keeping Assist (LKA)
Automation level	1: Driver Assistance
Description	Active Lane Keeping Assistant System (LKAS) gives a smooth recommendation in the steering. The driver's decision takes priority at all times, but if no input is given the system follows the lane automatically. The function works without V2x communication.
Benefits	Avoidance of dangerous situations caused by inattention
Usage and value	Private vehicles: willingness to pay Commercial: Business case on decreased accident costs
TRL	8

Adaptive Cruise Control (ACC)

Scenario	Urban, highway, rural
Function	Adaptive Cruise Control (ACC)
Automation level	1: Driver Assistance
Description	An intelligent form of cruise control that slows down and speeds up automatically to keep pace with the vehicle in front of the vehicle. The driver sets the maximum speed — just as with cruise control — then a radar sensor watches for traffic ahead, locks on to the vehicle in a lane, and instructs the vehicle to stay appointed distance behind the vehicle ahead. This is achieved through a radar headway sensor, digital signal processor, and longitudinal controller.
Benefits	Increased safety and comfort for the drivers, and reduced congestions due to better utilization of lane area.
Usage and value	Private vehicles: willingness to pay
TRL	9

Co-operative ACC (CACC)

Scenario	Highway
Function	Co-operative ACC platooning (CACC)
Automation level	1: Driver Assistance
Description	Adding vehicle-to-vehicle (V2V) communications to an adaptive cruise control (ACC) system turns it into a cooperative ACC (CACC) system. Communication managed by using DSRC or WAVE technology (IEEE 802.11p)
Benefits	The result is that vehicles can follow more closely, accurately, and safely, with braking and accelerating done cooperatively and synchronously. There is a significant improvement in vehicles following stability compared to the vehicles with ACC.
Usage and value	Private vehicles: willingness to pay
TRL	7

LEVEL 2 and 3 system:**Automated Parking Assist System**

Scenario	Urban
Function	Automated Parking Assist System
Automation level	2: Partial automation
Description	Automatic parking is an autonomous car-maneuvring system that moves a vehicle from a traffic lane into a parking spot to perform parking. The system works by ultrasound sensors integrated into the side of the vehicle.
Benefits	Enhance the comfort and safety of driving in constrained environments where much attention and experience is required to steer the car.
Usage and value	Private vehicles: willingness to pay
TRL	8

Collision Avoidance – Braking and Steering (CA-BS)

Scenario	Urban, highway, rural
Function	Collision Avoidance – Braking and Steering (CA-BS)
Automation level	2: Partial automation
Description	Extension of the automatic emergency braking system that also steer as a mean to avoid accidents. The function works without V2x communication.
Benefits	Avoidance of dangerous situations caused by inattention
Usage and value	Private vehicles: willingness to pay Commercial: Business case on decreased accident costs
TRL	9

Traffic Jam Assistant / Traffic Jam Chauffeur

Scenario	Urban, Highway
Function	Traffic Jam Assistant
Automation level	2: Partial automation
Description	The danger of getting into a traffic jam is a daily issue. Rush-hour traffic in the morning and in the evening is especially likely to cause a traffic jam and increases the risk of accidents. The driver gets annoyed with the 'stop and go' and is pressed for time. Therefore, he pays less attention and needs assistance. The system can be seen as an extension of the ACC with Stop&Go functionality. The function controls the vehicle longitudinal and lateral to follow the traffic flow at low speeds (<30km). First without V2X, but V2X could lead shorter headways reducing congestion
Benefits	Safety: When driving in traffic jams space between vehicles is quite low and speed variations of vehicles in front happen quite fast, which augments the risk for rear-end collisions Comfort: Driver can relax Efficiency (commercial vehicles): driver can work
Usage and value	Private vehicles: Willingness to pay Commercial vehicles: efficiency, driver can work Road Authorities: efficiency, safety
TRL	9

Energy Efficiency Intersection Control

Scenario	Urban
Function	Energy Efficiency Intersection Control
Automation level	2: Driver Assistance to 3: partial automation
Description	An adaptive urban traffic control system controls traffic lights and gives speed advices that the vehicle follows automatically. The driver has the possibility to override the advices. V2I communication is needed.
Benefits	Less congestion and less total emission on a population of vehicles.
Usage and value	Road Authorities: Societal gain, need to be enforced with regulations
TRL	6-7

Dynamic Speed Adaptation

Scenario	Urban, Highway
Function	Dynamic Speed Adaptation
Automation level	3: partial automation
Description	This function adapts the vehicle speed and the distance to another vehicle with input from the infrastructure, i.e. V2I communication is needed. Works in combination with ACC and C-ACC.
Benefits	Less congestion and higher safety
Usage and value	Road Authorities: Societal gain, need to be enforced with regulations
TRL	7

Highway Chauffeur

Scenario	Urban, Highway
Function	Highway Chauffeur
Automation level	3: Conditional Automation
Description	The vehicle handles all of the management-related tasks, securely overtaking slower vehicles and even conquering complex situations such as changing highways, driving in tunnels, and toll booths. The driver does not have to take over again until exiting the highway.
Benefits	The driver can focus on talking on the phone, checking e-mails, or just relax and enjoy entertainment provided by the multimedia system.
Usage and value	Private vehicles: Comfort and improved safety where it supports the driver in monotonous traffic situations like long-distance driving which can lead to a lack of focus and increased accident risk. Commercial: Safety and efficiency Road Authorities: safety and efficiency
TRL	6

LEVEL 4 and 5 systems:**Automated intersection**

Scenario	Urban Environment
Function	Automated intersection
Automation level	5: Full automation
Description	Fully cooperative driving with adaptive speed control based on state estimation and state prediction in networks of intersections. Vehicles communicate their directions / destinations, speed, and position and will be fully controlled at intersection areas. The system combines infrastructure based state estimation with automated vehicle control.
Benefits	<ul style="list-style-type: none"> - Fewer investments in infrastructure based traffic equipment (including highly reduced maintenance costs) and seamless vehicle interactions; - More safety and efficiency in urban transport; - Options for prioritising dedicated traffic users aimed at more sustainable traffic in urban areas.
Usage and value	Societal benefits (reduced investments, increased control and safety); More comfort
TRL	5

Parking Garage Pilot

Scenario	Urban
Function	Parking Garage Pilot
Automation level	4: Highly automated
Description	At the garage entrance, the driver stops and turns on the system. In the garage, a central control unit manages the piloted parking process. The system makes WLAN contact with the garage management systems and calls up the primary data, from which it learns the car's size. The central computer then locates the nearest suitable parking bay and transmits a schematic route map to the car. Vehicles use existing series-production sensors (radars, cameras etc.) to identify its position and garage control unit monitors all the car's movement with highly accurate laser scanners.
Benefits	<ul style="list-style-type: none"> - Reduce unnecessary accidents and hence savings cost. - Saving time of finding suitable parking place
Usage and value	Private vehicles: willingness to pay Parking garage operators: Willingness to invest in new technology
TRL	8

Platooning

Scenario	Highway
Function	Platooning
Automation level	4: Highly automated
Description	<p>This function enables platooning in a specific lane. The vehicle should be able to keep its position in the platoon with a fixed distance or fixed time difference from the lead vehicle. The behaviour of the first vehicle (e.g. braking and steering) should be transmitted by V2V communication. The function should also handle a vehicle that wants to leave the platoon. Upscaling and deployment can be reached as follows:</p> <ol style="list-style-type: none"> 1. Start with trucks – there is a strong financial incentive due to 10%-15% fuel savings 2. Start with small platoons of only 2 trucks and co-operation with fleet owners in the high-density truck area. 3. Start with a system where drivers are still in the following truck, for legal reasons 4. Setup an (open) fleet management system for trip matching between equipped trucks of different fleet owners
Benefits	<ul style="list-style-type: none"> - Increased safety, reliability and comfort for the drivers. - Reduced environmental impact due to less aerodynamic drag. - Reduced congestions due to better utilization of lane area.
Usage and value	Truck: Increased fuel efficiency, resulting in lower operational costs.
TRL	6

Highway Pilot with ad-hoc platooning

Scenario	Highway
Function	Highway Pilot with ad-hoc platooning
Automation level	4: Highly automated
Description	<p>High automation in all conditions. Full automation in specific driving situations, fulfilling certain conditions. Example highway a low traffic and no exits. A Highway Pilot is a vehicle application which will support the driver on motorways and motorway similar roads with a high level of automation in longitudinal and lateral control of the vehicle at speeds between 0 and 130 km/h (no technological limit).</p> <p>Depending on the deployment of cooperative systems, ad-hoc convoys could also be created if V2V communication is available</p>
Benefits	<p>Private vehicles: Comfort and improved safety where it supports the driver in monotonous traffic situations like long-distance driving which can lead to a lack of focus and increased accident risk. Specific secondary tasks are allowed.</p> <p>Commercial</p> <ul style="list-style-type: none"> - Increased safety, reliability and comfort for the drivers. - Reduced environmental impact due to less aerodynamic drag. - Reduced congestions due to better utilization of lane area

Scenario	Highway
	Road Authorities: safety and efficiency
Usage and value	Private vehicles: willingness to pay Commercial: Business case for increased efficiency; Increased fuel efficiency and lower operational costs.
TRL	5

Automated emergency stop

Scenario	Urban, highway, rural
Function	Automated emergency stop
Automation level	5: Full automation
Description	Automatically bringing about a safe state with a minimum risk manoeuvre (e.g. lane change on the emergency lane with subsequent vehicle stop) if driver drops out. The driver's status is monitored continuously. The function works without V2x communication.
Benefits	Avoidance of dangerous situations caused by medical emergencies or drowsiness of the driver
Usage and value	Private vehicles: willingness to pay
TRL	6

Country analysis*Table 18. Review of emerging C&AD technologies in Europe and third-countries*

Country	Analysis findings
USA [112], [148], [149], [184], [185], [186]	<p>The US Department of Transportation (DoT) has released a national programme on vehicle automation. Its objective is to position the industry and public agencies for the wide-scale deployment of partially automated vehicle systems that improve safety, mobility and reduce environmental impacts by the end of the decade. The 5-years automation programme framework contains research and development at all levels of automation.</p> <p>A regulatory framework for the testing and operation of autonomous vehicles on public roads has already been started in California, in September 2014. Similar legislations are set, for example, in Nevada, Florida, the District of Columbia, as well as in Michigan. These novel regulations on autonomous vehicles will be adopted to enable the development of solutions especially for SAE levels 4 and 5 since the level 1 and 2 solutions are already available, and level 3 solutions are now on trial. These regulations will make testing autonomous vehicles on public roads possible. The mentioned regulatory framework in the USA allows foreign vehicle manufacturers to test automated driving solutions. Currently, various European-based OEMs are conducting tests on public roads in California.</p> <p>The testing of autonomous vehicles on public roads is possible in most of the states (North Dakota, California, Nevada, Tennessee, Florida, Michigan, Washington D.C., Arizona) when the driver is present and behind the wheel. Some states also have restrictions for testing regarding the conditions of testing (Michigan) or registration policies (California) just to name a few. When it comes to market and car manufacturers, Tesla is currently the leading USA the offer of partially automated (highway autopilot) systems in mass-produced vehicles (Tesla Model S). The future offering of USA car manufacturers focuses on level 3 features such as Tesla's autopilot 2.0 (2019 onwards) and Cadillac SuperCruise (semi-autonomous cruise control, 2017 onwards).</p>
Japan [112], [148], [187]	<p>Japanese OEMs have demonstrated a variety of automated driving functions in advanced prototype vehicles. Japanese OEMs are currently selling partially automated driver assistance systems mainly via their premium brands (Lexus by Toyota, Infiniti by Nissan). At least Toyota, Nissan, and Honda, who have already performed a test on public roads, are planning to release their first automated vehicles on the market by the 2020 Tokyo Olympic Games. The tests done in Tokyo's Shuto Expressways, includes entering and leaving the highway, maintaining and changing lane, as well as regulating speed and distance on other vehicles.</p>

Country	Analysis findings
South Korea [90], [153], [175], [188]	<p>The agenda of the Korean Ministry of Land, Infrastructure, and Transport (MOLIT) aims at the development of safety technologies in the transport sector to decrease the number of accidents on Korean roads. Simultaneously, the Korean automotive industry is promoting the relevance of automated driving. For example, Hyundai-Kia Motors runs a "Future Autonomous Technology Contest" in which vehicles have to accomplish a 3.4 km long track successfully. The track includes mixed paved and unpaved roads, hurdles, and obstacles that are typical for automation. The purpose of the track is to test obstacle avoidance, managing narrow road passes and vehicle avoidance, passenger recognition, as well as escaping in case of accidentally moving barriers and similar.</p> <p>Hyundai Motor Group announced in early November 2016 that it will develop the core operating system (OS) to run a fully autonomous vehicle. Hyundai aims to install its self-developed piloting software in new car models from 2020. This system will enable data transfer with other devices both inside as well as outside the vehicle to give the driver remote access to the car. The OS includes several features, such as deep-learning based navigation; seamless online and offline services; driver tailored services; and cyber security.</p>
China [38], [149], [189], [190]	<p>Analysis of traffic conditions in China related to the continuous growth of cars and other vehicles has led to a conclusion that in the future, automated systems will be necessary in order to increase road safety in China. Not only have different OEMs recognized this opportunity, but also the government sees automated driving as a reality by 2020. The government has announced that by the 2030, China will have a whole supply chain for automated vehicles. To achieve this, test sites and tracks are required. Near Beijing, in the city of Tianjin, first tests with the driverless GM EN-V 2.0 vehicle have taken place. Moreover, by 2020, three test sites will be opened in the Shanghai area. The first phase (2016-2017) of Shanghai testing ground will focus on the development of V2X communication system (e.g. 4G/LTE, Dedicated short-range communications (DSRC)) and traffic management. The second phase (2017-2018) will consist of laboratories and simulators. In 2020 when the third phase is ready, Shanghai should be a fully equipped test track for C&AV.</p> <p>As a huge Chinese telecommunication provider and developer, Huawei is already a leader in the emerging connected cars market. Naturally they provide network infrastructures (LTE and 5G), but are also actively involved in service development trials (e.g. video transmission based safety features and security services), and in the provision of networking modules (i.e. V2X). At their trials, Huawei has been working alongside China Mobile, SAIC Motor and the Xihu Electronics group to test six cellular-V2X (C-V2X) scenarios along a 3.2km road equipped with 34 base stations, including see-through services.</p>
France [112], [149]	<p>In 2014, the French government published a strategic review to define France's industrial policy priorities and roadmap: New Face for Industry Plan. The purpose is to revolutionize the French transportation with autonomous vehicles through the development of driver assistance systems. Automotive and transport industries strive to create a competitive offer for components, sensors, software, control systems, and services to put autonomous cars on the market before 2020. The overall objective of the programme is to make the French automotive industry a leader in designing and developing autonomous vehicles. The program has four sub-objectives:</p> <ul style="list-style-type: none"> • Study the socio-economic impacts of such vehicles in depth. • Develop relevant technologies. • Create a regulatory and material environment that allows experimentation to demonstrate its safety. • Remove regulatory, social, and physical obstacles to commercialization. <p>Through this plan, France could be considered as a place for autonomous vehicles experiments, as a centre of excellence for embedded intelligence technologies, and as a leader for complex systems safety and security. The French government is going through the current legislation that may constrain testing of automated vehicles. In 2014, they published a roadmap emphasizing the importance of pilot zones and authorizing experimental on-road testing of partial and highly automated vehicles.</p>

Country	Analysis findings
Germany [90], [112], [148], [191]	<p>The testing of automation technology in Germany has already been started by vehicle manufacturers. The German Federal Ministry of Transport and Digital Infrastructure strives to establish a test site for C&AD on the Bavarian A9 highway. In recent years, German ministries have funded multiple research and development projects on advanced driver assistance systems (ADAS) and cooperative systems. The intent is to continue to support technology-focused projects in the context of autonomous vehicles and systems. Most of the projects focus on the development of automated driving systems in SAE level 3 and testing methods.</p> <p>A new research program “New Vehicle and System Technologies” was published by the German Federal Ministry of Economic Affairs and Energy in 2015. The program provides support for the project in the areas of automated driving, innovative vehicles intelligent vehicles, advanced driver assistance systems and electric mobility. In the market, there is a high availability of partially automated driving functions in different model series produced by German premium and mass-market OEMs (Audi, BMW, Mercedes-Benz, etc.).</p> <p>Currently, testing of highly and fully automated vehicle technologies does not comply with the German law, although semi-automated technology testing is permitted. However, each Federal State can grant exemptions from German Road Traffic Licensing Regulations.</p>
Italy [178], [192]	<p>Research and development of autonomous vehicles and driving in Italy has mainly rested on a research centre named VisLab. VisLab performs basic and applied research developing machine vision algorithms and intelligent systems for the automotive field. It focuses on several areas such as machine vision, pattern recognition, low-level image processing, machine learning, artificial intelligence, robotics, and real-time systems. However, the main focus of the laboratory is to apply basic and advanced research to intelligent transportation systems and smart vehicles.</p> <p>VisLab is globally recognized for its know-how in monocular, stereo, trinocular, up to tetra-vision systems (daylight, Near Infrared, Far Infrared cameras), as well as analogue and digital cameras. VisLab actively collaborates with the automotive industry (e.g. Piaggio, Bosch, Daimler, Magneti Marelli) and research institutes (e.g. Oxford University) across the world for both passive and active safety systems, ADAS, and full automatic vehicles.</p> <p>Research on automated driving started in 1998, and they have built several prototypes of autonomous vehicles in the past 20 years. The best-known project is the VisLab Intercontinental Autonomous Challenge (VIAC)³⁰ in which two autonomous vans built by VisLab drove from Parma to Shanghai in 2010. The 13,000 km trip aimed to perform exhaustive and extreme tests of VisLab technologies and systems: lane detection, vehicle detection, pedestrian detection, terrain slope estimation, off-road sensing, waypoint following and dead reckoning, trajectory planning, actuation, and control.</p>
Spain	<p>In 2015, the Spanish Automated Road Transport Technical Forum was established by the Spanish Ministry of Economy and Competitiveness, and the Spanish Automotive and Mobility Technology Platform (M2F). The forum supports collaboration between different sectors and companies and aims to strengthen the Spanish position in the automated driving area.</p> <p>In 2012, the first 100 km autonomous route (between El Escorial and Madrid) was introduced. A group of 7 fully autonomous vehicles equipped with several V2X communications systems, sensors and cooperative systems were tested. Over the years, the research on V2X communications and assistance systems was supported by the EC and the Spanish Government (VICTORIA, iVANET, ONDA-F and GUIADE projects).</p> <p>A permanent cooperative corridor with over 100 km of roads was created to support the field operational tests of cooperative systems and applications on real roads. This cooperative corridor includes suburban and urban scenarios (in the city of Vigo) with more than 50 cooperative roadside units connected to local Traffic Management</p>

³⁰ VIAC – Intercontinental Challenge. 2010. <http://viac.vislab.it/>

Country	Analysis findings
	Centres.
Sweden [52] [112] [148] [193]	<p>The launch of the joint initiative "Drive Me – Automated cars for sustainable mobility", endorsed by the Swedish Government and motivated by the vision of zero traffic fatalities enables research within different areas associated with self-driving cars on public roads. An added value of the project lies in the fact that automated driving will be tested on typical commuter areas strained by congestion. The main objective of the project is to conduct necessary research on how autonomous driving will affect road transport (both vehicle and infrastructure), considering challenges such as safety, energy efficiency and traffic flow. The project will also explore all accompanying factors such as infrastructure requirements, traffic situations, and surrounding interactions and social benefits of autonomous driving.</p> <p>Scania is planning for automated transport using heavy trucks starting with a mining carriage in 2016. The next step will be automated platooning for long distance transport which is planned in 2018. Volvo is focusing on highway automation, automation in confined areas for trucks & construction equipment and highway platooning.</p> <p>The testing of highly automated vehicles on public roads in restricted areas in and around Gothenburg is permitted. Volvo is a partner of "Drive Me" project in Gothenburg, and hence the area plays a vital role in their development activities.</p>
United Kingdom	<p>Intelligent Mobility is one of five focus areas for the UK Automotive Council, established in 2009 to enhance collaboration between the UK government and the automotive sector. Also, the Transport Systems Catapult has also been created to accelerate innovation and commercialise new technologies and services in the field of intelligent mobility. For instance, the ULTRA driverless passenger transfer system at Heathrow Terminal 5 is one of the examples of these products. A recent study indicates there are no significant barriers for the testing of autonomous vehicles on UK roads. Following that review, the UK government supported innovative trials, such as the already-planned HGV platooning trials on the main roads in England. In addition, the cities of Greenwich, Milton Keynes, Coventry, and Bristol are conducting trials on how AV fit into everyday life.</p> <p>From a legal perspective, AV can be tested on UK roads. However, the current domestic regulations will be reviewed and amended to accommodate driverless technology by 2017. The intention is to interact at an international level in view of amending international regulations by 2018. During testing, the driver must be present in the car.</p>
EUROPE	<p>The EU automotive industry has actively been implementing new ADAS to vehicles. These functions are now evolving step-by-step taking responsibility from the human driver to the in-vehicle computer units. New players (e.g. Uber, Google, Apple, etc.) in C&AD have different approaches by taking the computer unit in centre and building the vehicle and driving environment around it. One of the crucial issues is the common testing and verification processes for the vehicle systems to be safe and comparable. In different parts of the EU, the new test centres are under development and have individual focus areas. Some countries are focusing on real traffic testing whereas others are considering adverse weather conditions or smart cities.</p>

3.2.2 Comparative analysis of automated and connected cars/ road vehicles technologies

Level 0-2 systems

The EU countries with strongest automotive industry (i.e. Germany, France, Sweden and Italy) have been active in supporting the development of the local automotive industry. The major motivation is that this industry has a strong impact on the economy and therefore, can also have an influence at the governmental level.

Level 0-2 systems are mostly more advanced driver assistance systems, which partly adopt driving responsibility in in-vehicle computer units. The OEMs in Japan and EU are leaders in ADAS systems and therefore, dominate the low-level vehicle autonomy market. These systems are already in the

market and the experience of human interaction with automation can be gathered and analysed to move to higher automation levels.

Level 3-4 systems

Truck platooning and autonomous highway overtaking functions are partly present in today's markets, and may become mainstream in the short-term (next 2-3 years). These represent level 3 automation where the driver can take his or her hands off the steering wheel for hours when riding on the highway. The biggest motivation for truck platooning is fuel savings which attract cargo companies to invest in new fleets. Highway overtaking automation is comfortable for the driver and also improves safety.

Level 4 automation will also assume driving responsibilities in urban and inter-urban areas. Urban automation is difficult due to complex traffic, which in many cases, also needs innovative adaptation to the actual driving environment (e.g. detours, pedestrian safety, traffic rule violations, etc.). This is difficult to pre-programme in the vehicle. If the vehicle too often requires assistance from the driver, driving with automation becomes uncomfortable. The EU could take the lead in higher-level automation with the introduction of new intelligent ways to ensure human-vehicle interaction.

Level 5 systems

Full automation is still far in the future, and can only be done in closed and limited areas where traffic environments can be adapted accordingly. Full automation cannot be reached by the automotive industry alone, and requires modifications from infrastructure system providers. The driving environment needs to fully digitise, thus representing smart cities where the traffic system is changed to support automation. Vehicles need information from ITS, especially unexpected incidences in the environment (e.g. an accident, error in the traffic light, etc.) and minor things like dynamic objects on the road (e.g. dropped cargo, etc.). This approach has been initiated in the EU and the USA, but lacks real implementation. Test facilities are still missing, with exception to closed test tracks.

Summary and future initiatives

This study assesses the development targets for the time span of 5-10 years and identifies where R&D investments are required to keep the EU competitive in the C&AV development race. The traditional automotive industry is considering relatively traditional applications (highway, parking, jam assistant, etc.) as seen above. Additional analysis is required in order to consider potential future application scenarios, such as the patent applications of new players. Vehicles could look and behave very differently and integration into the traffic system may change. One very significant trend is that people are willing to stop owning a car and would instead like to have mobility services. This would have a big influence on the automotive industry and would create new business models around travel services.

As discussed in subtask 1, major autonomous driving test site activities and the major global stakeholders involved are considered. The review focuses on what currently exists and aims at validating autonomous driving technologies or evaluating the performance of autonomous driving. These tests are needed to identify what new approaches are required for keeping traffic and transportation safe. Modern cars are collecting significant data via environment perception systems and transport authorities. The automotive industry and ITS service providers, including small start-up companies, are coming to the market to use, process, and offer this data for analytic purposes. Open data would be useful to ensure business opportunities from using the data, with new companies providing mobile applications and travelling services. However, this also increases security problems. The privacy and security against hacking is a mandatory aspect when addressing open data demands.

Standardising the cooperative and connected driving technologies and services has been accepted, especially by the ISO, CEN, CENELEC, and ETSI standardisation bodies. The iMobility forum is one of the major initiatives in Europe where the different standards have been reviewed. The situation is quite similar in the USA and Japan, but China is still behind in standardisation development. However, autonomous driving technologies have not been widely standardised, the main reason being their fast development. Standardisation normally takes 5-10 years, and as autonomous driving is still a young field, many solutions are still open and standardisation is slightly difficult.

The C-ITS platform [158] has identified three key items regarding standardisation from a C-ITS and autonomous driving point of view: (1) the need for elaboration of test standards; (2) the need for profiling of standards to ensure interoperability in implementation, and (3) the need for proper

maintenance of standards due to implementation needs. CEN and ISO [194] have identified 71 different standards that are needed to enable Day 1 services and applications.

Google is pushing the development towards machine and deep learning systems (i.e. artificial intelligence). This is an area where these big dominating players are ahead of EU companies. This approach is different compared to the current automotive development trends. Traditional OEMs see automation technology as an evolving path starting from active safety systems (ADAS) towards connected and automated driving. New USA players (Google, TESLA, Apple, etc.) see this as a revolution, where they intend to deploy full automation limited to the markets where transport infrastructure is ready.

3.2.3 SWOT analysis for EU on C&AD technologies

Table 19. SWOT analysis for EU on C&AD technologies

Strengths		Weaknesses	
Main Point	Explanation	Main Point	Explanation
State-of-the-art V2X communication	<ul style="list-style-type: none">• EU companies have a strong background and a proven track record in ICT and telecommunications which provide a competitive advantage on developing V2X communication.	Fragmented industry base and conservative approaches hinders the applying of innovative applications and EU policy formulation	<ul style="list-style-type: none">• There is a conservative approach in the EU to develop and innovate in new applications compared to the USA.• This partly relates to a weak incorporation of soft technology factors (know-how, new business strategies and models, and human resources) for example in EU policy formulation and long-term strategies.
Strong financial situation of EU OEMs occurring as an active development of C&AV	<ul style="list-style-type: none">• Most of EU OEMs are financially fit.• They have resources that can be used for product and technology development.		
Opportunities		Threats	
Main Point	Explanation	Main Point	Explanation
Investments in R&D infrastructure collaboration and co-development	<ul style="list-style-type: none">• The development of efficient R&D infrastructure and facilities is essential to enable collaboration as well as piloting and deployment of technologies and services.	Lack of European investment in C&AD	<ul style="list-style-type: none">• The interest of EU investors has been relatively low except for very recent years, which contrasts with the USA and Japan.
Attracting private investors to strengthen European SMEs and start-ups	<ul style="list-style-type: none">• Private investors and private equity firms are considered potential methods to speed up the development and commercialization of technologies and services.		
New trends in mobility and transport	<ul style="list-style-type: none">• New mobility megatrends (Mobility-as-a-service, ridesharing, car sharing) will focus on C&AVs.• EU cities provide excellent market opportunities for companies focusing on simplifying consumers’ journey challenges.	Unproven reliability, safety and robustness of technology	<ul style="list-style-type: none">• Demonstrating reliability, safety and robustness of technology for different parties is essential: authorities want to know if C&AV are worth allowing on streets and the industry wants to know if it is worth investment.
Development of integrated solutions	<ul style="list-style-type: none">• Integrated solutions emphasize the importance of cross-sectorial approaches and alliances can lead to specialized capabilities but also help differentiate companies’ offerings.		
Tax breaks and fiscal incentives	<ul style="list-style-type: none">• Taxation incentives could be considered to support investment in C&AD.		

STRENGTHS

State-of-the-art V2X Communication

C&AV development is currently shifting from in-car connectivity to V2X connectivity. Therefore, a major focus will be on the design and provision of third-party services. V2X connectivity covers different topics, such as remote service integration, security concepts or traffic management systems. Many of these services are still in a design or development phase and are expected to enter the market in forthcoming years. EU companies (e.g. Nokia, Ericsson) have a strong background and a proven track record in ICT and telecommunications, which provide a competitive advantage on developing specific V2X communication (e.g. ITS G5, cellular 5G, and satellite or hybrid solutions). Many companies (manufacturers and ICT developers) and national authorities are already investing in connected technologies and collaboration on this topic. This is taking place, for example, through cross-sectorial approaches (e.g. The European Automotive Telecom Alliance), where automotive, telecommunications and digital industries agree on a common approach/roadmap towards the fast deployment of C&AV.

Strong financial situation of European OEMs occurring as an active development of C&AV

Most EU OEMs are financially fit (compared to a number of USA OEMs). Resources have been made available that can be used for product and technology development. Major EU automotive OEMs are already developing, adopting and scouting for new C&AV technologies.

WEAKNESSES

Fragmented industry base and conservative approaches hinders the applying of innovative applications and EU policy formulation

There are some conservative approaches in the EU to develop and innovate new applications compared to the USA's fail fast culture. Thus, the EU has a relatively weak industrial application of key technologies (only 21% of European applications are rated as 'strong'). This partly relates to a weak incorporation of soft technology factors (e.g. know-how, new business strategies and models, and human resources) in EU policy formulation and long-term strategies. To address barriers, more efficient national and multi-national funding programmes and projects are required to support the deployment of C&AV and to reduce overlap through synergic benefits.

OPPORTUNITIES

Investments in R&D infrastructure (including facilities and test sites), collaboration and co-development

For the deployment of C&AV solutions, OEMs and suppliers will in the future increasingly rely on product and service co-development and collaboration with external service providers. This suggests a shortage of skills and human resources. The supplier side is especially expected to acquire know-how from third parties while manufacturers appear to be a bit more independent and insource IT and development capabilities. It is expected that vehicle manufacturers shift their core competencies in the direction of software development.

Attracting private investors to strengthen European SMEs and start-ups

New trends, process redesigns and cross-sectorial initiatives are possibilities to attract new investors (e.g. private equity firms) to Europe. These companies are considered a potential means to support and speed up the development and commercialization of technologies and services (which can be developed by SMEs and start-ups).

The development of software and advanced technologies will require a significant amount of testing. Thus, efficient R&D infrastructures and facilities are needed in Europe to enable cross-sectorial collaboration as well as piloting and deployment of technologies and services.

New trends in mobility and transport

New uprising megatrends in mobility (e.g. mobility-as-a-service, sharing economy, and shared electric connected automated vehicles) will focus on C&AV. The movement towards car-sharing and ride-sharing services will be largely driven by the dramatic reductions in transportation costs that are expected with CA&D. EU cities provide excellent market opportunities for companies focusing on simplifying consumers' journey challenges. With C&AD, e-mobility, growing shared economies, new requirements and difficulties emerge. These new trends force the automotive and mobility industry to

face and manage disruptive developments that will shape the future of transportation and communication concepts.

Development of integrated solutions

Integrated solutions emphasize the importance of cross-sectorial approaches and alliances that can lead to specialized capabilities but also help differentiate companies' offerings. The next-generation driver assistance systems will enable more advanced automated driving capabilities and will take over some driving tasks under controlled conditions.

Taxation incentives to boost ICT and digital infrastructure investments in C&AD

C&AD has captured, especially in the USA, the interest of investors looking for tax breaks as these new technologies promise to revolutionise the motor industry. Tax breaks may provide an incentive to investors to finance early-stage companies. In addition, because many of the benefits of C&AD accrue to those other than the buyer, taxes or subsidies would be an opportunity to increase social welfare by equalizing the public and private investments, cost and benefits [195].

THREATS

Lack of European investment funds in the C&AD

Due to the relatively high fixed costs and investments in R&D, and industries' shift towards emerging markets by building facilities and R&D centres in these markets, the EU has had challenges to maintain and improve their market position in high-tech sectors compared to the USA and Japan.

Currently, USA and Japanese stakeholders (private people, investors, and companies) are investing in future technologies but mainly in the domestic markets. The interest of EU investors can be said to have been relatively low, with exception to recent years. The first investment cycle for connected car solutions and services (i.e. infotainment, environmental information, etc.) is currently coming to an end. However, it seems that investors are already placing their investments in the next generation solutions (i.e. security, advanced driving assistance, etc.).

Also, C&AD is not the only area companies are currently working on, but one among many (e.g. e-mobility, lightweight bodywork or reusable and flexible chassis). Technology developers and vehicle manufacturers should be encouraged to invest in the development and creation of products with commercial potential. The more time this process takes, the more difficult it will be for the EU to match the USA and Japan, who are already engaged in strong support for C&AD related technologies.

Unproven reliability, safety and robustness of technology

Demonstrating reliability, safety and robustness of technology for different interested stakeholders is essential: authorities want to know if C&AD is worth allowing on roads; public acceptance depends on it; and the industry wants to know if it is worth investment.

Significant effort is required, for example, to create new tools and methods for the validation of complex C&AD systems. All critical safety situations and machines' ethical choices have to be tested as quickly as possible. Also, the impact of varying sensors and actuators, road conditions, traffic partners or implementing C&AD concepts must be covered.

3.3 Subtask 3 – Technical and non-technical barriers in the development of C&AD

This Task focuses on the latest steps taken towards the introduction of C&AV into real traffic. It also focuses on the acceptance of users to use fully autonomous cars when they become available. Time will be needed to explain the technology to citizens and decision makers. According to World Economic Forum (2015) [196] survey, the willingness to pay for more fully self-driving cars/road vehicles is the following:

- Global: 43 %
- China: 39 %
- France: 50 %
- Germany: 42 %
- Japan: 51 %
- India: 50 %
- The Netherlands: 42 %
- UK: 46 %
- USA: 38 %

The acceptance of self-driving cars/road vehicles is highest in the far-East. Japan and China have always been willing to try and use new technologies whereas people in Western Countries are more careful and first let others participate in trials. In any case, the figures indicate that user acceptance is not self-clear and active dissemination is needed.

3.3.1 Review of C&AD barriers

Technical barriers

One way to overcome barriers is to organise large field tests to show the potential of C&AV and how it can change mobility habits. The EU, USA and Japan have already recognised the need for these tests and have already launched public project calls to apply field operational tests. The main potential challenges and barriers that the automotive industry (OEMs, Tier 1, Tier 2, research organisation and universities) has identified include [197]:

- Safety concerns / fail-safe concepts : 73 %
- Regulatory mandates / legal restrictions; 61 %
- Liability issues: 54 %
- Cyber security: 48 %
- Social acceptance / critical perception of self-driving vehicles : 42 %
- Limitations with regards to infrastructure : 38 %
- HMI driver attention management : 24 %

The current major challenge is the reliability and robustness of vehicles' environment perception systems. C&AV need clear lane markings and information about incidences such as road works, accidents, potholes, and others to make a difference compared to the current way of doing things. The technical barriers to deploy new autonomous systems are partly overcoming capabilities of sensors, decision making algorithms, and control functions. The challenge is not the development of reliable sensors, but reaching the price level and robustness of the automotive industry demand.

In addition, the existing transport infrastructure needs to be updated, which is a challenge since road infrastructure is planned many years ahead. The other major challenge is that transport infrastructure not only consists of roads but also digital ICT services that enable the use of modern intelligent vehicles. Therefore, investment should also be focused on delivering digital information to vehicles.

Mixed traffic, where both C&AV and manually driven vehicles interact, will likely be a reality by 2040. Therefore, it is important to make vehicles connected and to have a data exchange channel in all vehicles to warn C&AV if non-C&AV make mistakes. Mixed traffic is also a challenge for pedestrians and cyclists since C&AV will react to vulnerable road users' (VRU) mistakes, whereas manually driven vehicles may not do so. In addition, liability will be a challenge when considering who is responsible in case of a failure with the system that disregards pedestrians or ultimately causes injuries or fatalities.

One of the new considerations in road and traffic network development is the physical internet in which the road network is used. The physical internet is especially important for transport and logistics industries where the optimised routes mean direct costs savings. Also, the physical Internet has a significant impact on the ecological footprint of the transportation industry. The physical internet is not only related to road transport, but also includes other transport modes, such as air traffic and maritime cargo handling.

The physical internet also has a global nature and does not recognise borders between countries. Moreover, the packages of one single delivery can be split to multiple encapsulations which make the use of cargo space more efficient. The final delivery is then recovered again in a final destination like the Internet does.

The major barriers today concerning the deployment of the physical internet concept are [198]:

- **Cargo companies have their stand-alone solutions** for optimising the routes without connection to centralised global units that exchange information with competitors.
- **Transport mode change** from truck to train or airplane still require a significant amount of manual management and cargo handling work that increases costs.
- The retailers, shops and producers have logistic contracts.
- **Smart labelling systems** of cargos are missing, which would enable splitting the cargos to multiple encapsulations to optimising logistics handling.
- Use of the existing standards and coverage of the standards concerning **interoperability of different transport modes** is not sufficient at the moment.

The benefits of the physical internet concept are well justified in terms of ecology and cost savings. The main actions to boost development are to ensure that digital infrastructure meets requirements of controlling large cargo streams. Also, this requires coordination between logistic companies to split and optimise cargos when delivering between terminals. Border crossing, automatic certification, tolling and paper control and handling also needs new processing and IT systems to be developed.

Weak national and international coordination and collaboration as a non-technical barrier for C&AV testing and deployment

One of the major changes in the development of C&AD is the emergence of new players in the sector (i.e. complex stakeholder ecosystems). However, the traditional automotive industry, including OEMs and Tier 1 suppliers, have not yet adapted to work with the new emerging players, which are mostly agile IT companies. This is another major challenge that public authorities should consider. Weak coordination of collaboration on testing and deployment of C&AV are interconnected with legislative and infrastructure barriers. In the end, to enable valuable, efficient and purposeful testing and deployment, a framework including a vision, objectives, strategy and roadmap for C&AV is needed so that the competencies of the whole ecosystem can be harnessed to serve the shared objectives.

In that sense, legislation and infrastructure are a small part of this process as other elements also impact testing and deployment. This includes public support, national/international agendas, local competencies, local niches, prevailing working methods, existing testing facilities, etc.

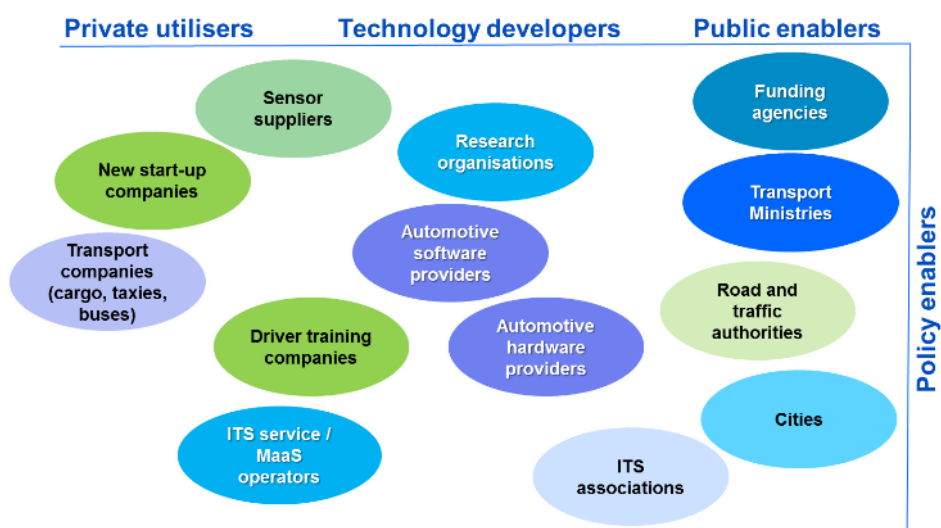


Figure 15: Ecosystem thinking in autonomous driving development

Independently of the type of vehicle, they all share a common need for physical road infrastructure. Around the globe, infrastructure is getting older and their condition is declining rapidly. Investments are needed to keep roads safe. Advancements in vehicle and communication technology result in new questions about possible investment: should roads be rebuilt or do they need to be redesigned to take into account the needs and capabilities of C&AV? Are separate lanes needed, and should communication equipment be installed along the road network?

There are no simple answers to these questions. After C&AD related technology has passed laboratory conditions, a significant amount of testing in the real world and on real roads is necessary. This aspect of C&AD revolution is still in its early stages. Streets and highways are very complex environments (technical and non-technical) where hundreds of agents interact with each other, directly or indirectly, in varying weather conditions. Continuous observation and prediction of immediate surroundings are required.

An obstacle to this level of testing is the limited number of environments where it can be undertaken. It requires wide-ranging cooperation between a variety of public and private stakeholders. This collaboration must be both vertical and horizontal. Vertical cooperation involves the whole chain, from authorities to end-users, with suppliers and manufacturers in the middle. Horizontally, suppliers have to work with other suppliers and manufacturer to make room for the creation and development of a sustainable business ecosystem, which is an economic community supported by a foundation of interacting organizations and participants.

In research and innovation activities, a strong focus has been put on developing ITS and cooperative systems. This has led to many research projects focussing on specific elements and technology (V2I and V2V communication, safety systems, etc.). Common pitfalls of these projects are a purist approach that focuses on theoretical research while neglecting deployment (e.g. demand side, customers, business and legislation). Therefore, test sites will play an essential role in ITS testing and deployment. A testing ground supports a variety of activities including field operational tests, pilots, methodology validation, impact assessment, simulation, user acceptance, product development and demonstration.

Well-coordinated and dedicated activities are needed to bring the many valuable results of research, development, and innovation activities together, and focus them on addressing today's mobility challenges. Many of these issues, benefits and activities can be better managed and further developed through test sites for ITS services and cooperative mobility. Often these test sites cannot be operated by or managed by individual organizations. Rather, it is a matter of business and collaboration networks to ensure the development and deployment of cooperative mobility and other ITS services.

To test the functionality of new technologies and to validate their performance in a realistic context, the availability of suitable test environments (e.g. closed circuits, real traffic, and indoor facilities) is crucial. However, many successful test sites environments currently do not exist. Although the ecosystems for cooperative mobility and automated driving vary across countries, research has revealed many similarities when it comes to the preconditions and benefits for establishing and

maintaining those ecosystems. Figure 16 represents the most important preconditions and advantages of setting up the test sites.

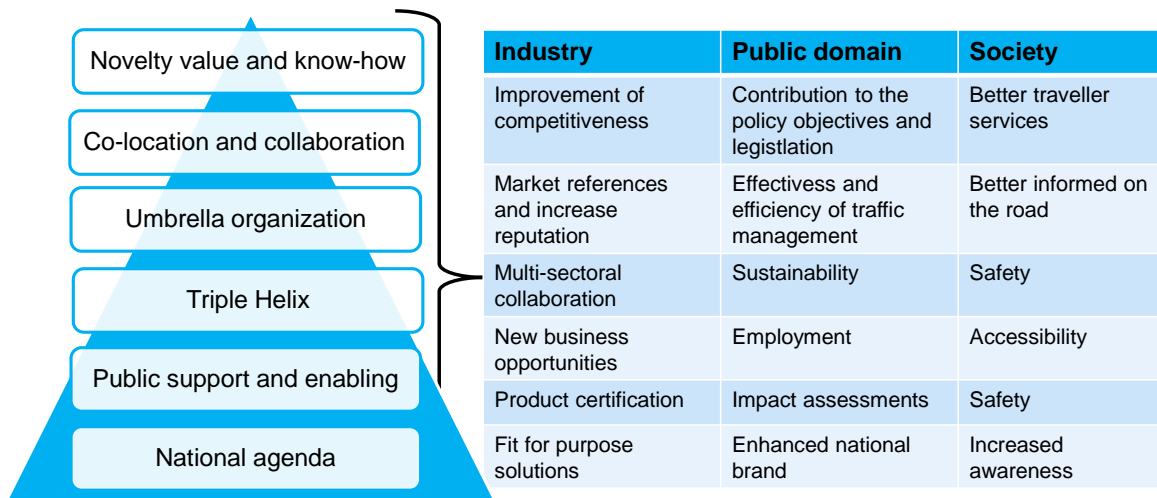


Figure 16: Preconditions for and advantages of setting up the test site [199]

Firstly, quite often everything seems to rest on national agendas that highlight the digitalization of transport as one of the most important focus areas. Because it is challenging or even impossible to know beforehand where developments are going to lead, setting up a fixed roadmap – such as making required political decisions or required future investments – for cooperative mobility cannot be done either.

Therefore, public support and cooperation with the national agenda and strategy (e.g. enabling legislation) can be considered the second main pillar on which the other preconditions rely. Public support and enabling means (i.e. financial support), mainly via national and international funding instruments, create a culture of experimentation and collaboration. Pilots make it possible to get information about the impacts of new technology and refine the vision based on this increased knowledge (i.e. verification and validation). Simultaneously, public funding also attracts private investments in test environments and facilities. This enables the emergence of new business activities.

Cooperative mobility and automated driving are broad and complex issues that cannot be solved separately. Thus, widespread collaboration throughout the supply chain (vehicle and mobility industry, infrastructure solutions and service providers, etc.) is needed. Collaboration increases the value of the offer and will likely provide ecosystem participants a competitive advantage against competitors. In the context of emerging and cross-cutting themes (e.g. cooperative mobility and automated driving), the triple helix approach is crucial to ensure the inclusion of views, perspectives, know-how, potential possibilities and requirements of different stakeholders.

In both observed cases, one of the most interesting findings was the coordination and facilitation of the triple helix collaboration, which was managed by umbrella organizations (e.g. DITCM in the Netherlands, and Test Site Sweden and Drive Sweden programmes in Sweden). Neutrality without own business interests was seen as essential to ensure impartiality. Naturally, the partners can better focus on their core competencies when they do not have to think about things like coordination, marketing and commercialization of the test site.

Test facilities should be commercially accessible and open to all for the following reasons: (1) private and commercial income becomes more important in the future when the share of public funding decreases, (2) part of the invested money can be recovered when the facilities are used by third parties, (3) commercial income enables additional investments in the test facilities, and (4) openness and accessibility ensure the permanence of the test site which ultimately attracts new participants to join in the ecosystem.

The inherent competitive advantage together with know-how is the final cornerstone. It rests on the fact that there is no point to develop everything at every test site: the greatest benefits come through specialization that takes niches, novelty, local assets and know-how into account. One way to ensure this is to develop solutions that solve real-life problems and focus on novel issues (e.g. extreme road conditions) that may provide a competitive advantage.

Lack of competence and know-how as a barrier to the development of CAD in Europe

In order to develop C&AD technology, rigorous research programmes need to be encouraged to increase competence and know-how of autonomous vehicle technology. Therefore, publicly subsidized research programmes are needed to support the extensive research on C&AD that require a substantial amount of resources.

The USA, through the Defence Advanced Projects Agency (DARPA)³¹ challenges, has become the pioneer in providing public funding to C&AD development. Started in 2004, this challenge offered USD 1 million to participants who managed to come up with fully autonomous ground vehicles capable of completing a substantial off-road course within a limited time. This kind of support from the public sector helps spur the development of C&AD.

Another important aspect that influences C&AD development in the USA is the amount of research centres initiated in order to further study the feasibility of C&AV. There have been many examples of research centres that focus on C&AD development, such as the University of Michigan's Mobility Transformation Centre along with its Toyota Research Centre, the Carnegie Mellon University Autonomous Driving Vehicle Research Group, the University of Virginia Centre for Transportation Studies, among others. The wide array of research centres shows the support from USA-based institutes in developing competences and know-how relating to C&AD. This is crucial in order to answer some of the most difficult questions relating to autonomous vehicles, not only in technical aspects, but also in safety, social, and regulations issues.

According to the January 2016 Roland Berger report on Automated Vehicles Index, there has been little change in the relative knowledge position of the automotive nations studied. The considerable importance of R&D in the field of automated driving for economic policy is reflected in factors such as the publicly subsidized research programmes announced [148].

The report also mentions that in Europe, especially in Germany, an increasing number of national and local test facilities for C&AD are being subsidized or started from scratch. Therefore, cooperation between automotive OEMs and scientific institutes is increasing, with R&D activities singling out the testing of automated driving functions as a central topic [148].

Therefore, it can be seen that competences are not a major difficulty faced by European manufacturers. However, public support in terms of R&D, especially at the EU level, is essential to increase the know-how of European manufacturers on C&AD related technology. This is important to increase the competitiveness of European car manufacturers and C&AD developers against other countries, especially the USA.

Country analysis on technical and non-technical barriers

Since technical challenges are similar in each country, most of the country specific challenges and barriers (mostly set by legislation) are related to testing, especially on public roads. Thus, this section focuses on analysing non-technical barriers for C&AV testing, development and deployment. Technical and non-technical barriers are separated as needed.

Table 20. Review of technical and non-technical barriers

Country	Analysis findings
USA [200], [201]	<p>Technical requirements:</p> <p>When it comes to testing, some general regulations exist:</p> <ul style="list-style-type: none"> • A person willing to test (a driver can be non-human) a vehicle must apply for a one-year license from the department of motor vehicles (DMV) by showing that the vehicle meets the relevant safety requirements, it holds a valid and covering insurance coverage • The vehicles have been tested and driven not less than 10,000 miles in autonomous mode in various conditions • Proposing geographic locations of testing and establishing the capability of its vehicles in those conditions,

³¹ Defence Advanced Projects Agency (DARPA). <http://www.darpa.mil/about-us/about-darpa>

Country	Analysis findings
	<ul style="list-style-type: none"> If approved, the DMV grants special license plates. <p>Non-technical challenges and requirements Presently, autonomous vehicle testing for R&D purposes is possible and legal in most of the USA, but commercial use and availability of automated vehicle is not. Since the laws vary among the states, this obviously causes problems for the wide-scale testing and deployment (e.g. interstate), and hence more consistent laws are required. In general, it has been found difficult to forge public-private partnerships in ITS for a number of reasons (e.g. legal, institutional, political, and leadership hurdles and insufficient guidelines).</p>
Japan [202]	<p>Non-technical challenges and requirements In Japan, the present regulations allow for performing public road testing of autonomous vehicles if they comply with the Japanese safety regulations for road vehicles. The relevant authorities (e.g. road administrator and district transport bureau) must be informed in advance about test plans and initiatives. The driving party must possess an ability to pay caused damages. There must be a person seated in the driver's seat and monitoring the traffic and conditions at all times. It is also required that the vehicle inform well in advance when the control and operation must be taken over (e.g. functional limit is reached).</p>
South Korea [201]	<p>Non-technical challenges and issues Similar to Japan, the increase in transportation in South Korea has challenged the capacity to expand current infrastructure. Japan and South Korea are highly constrained in terms of geography. This includes the lack of land and a steep terrain, which narrows the construction of new roadways. Despite the aforementioned challenges, automated driving as well as ITS initiatives are highly supported and driven by the public authorities. South Korea has a national ITS strategy which allows for a strong policy setting and coordination at the national level. At the moment, testing of fully autonomous vehicles on public roads is not possible. However, the Government announced that they would scrutinize regulations and set detailed criteria of autonomous vehicles by September 2015, so road tests would be possible.</p>
China [27], [149]	<p>Non-technical challenges and requirements China has not ratified the Vienna Convention. There is a lack of official plans for testing automated vehicles in China. However, some information is available: due to the laws and regulations, testing of fully autonomous vehicles is only allowed in specific areas and stretches of the country. The presence of a driver is also mandatory. Organizations wishing to test automated vehicles in China require a Chinese number plate and Chinese driving licenses for the test drivers.</p>
France [149]	<p>Non-technical challenges and requirements French laws and regulations set some constraints for the testing of autonomous vehicles, but the government is reviewing the regulations to make testing more flexible. A recently passed law of energetic transition and its article 9 states that the Government can pass new laws to allow autonomous vehicle experiments under certain conditions. If there is interest in conducting an experiment with an autonomous vehicle, it is necessary to submit a request to the Administration, which then registers the experimental vehicle. Registration consists of technical details of the vehicle and testing procedures and safety.</p>
Germany [46], [125], [149]	<p>At the moment, according to German laws, testing of (highly and fully) automated vehicles and technologies does not comply although semi-automated technology testing is allowed. Each Federal State can grant exemptions from German Road Traffic Licensing Regulations for testing automated vehicle technologies. German authorities have initiated discussions and started reviewing the current legislation in order to harmonize positions on core issues concerning automated driving with a focus on the transition from partial to high automation. The overall goal of the Federal Ministry of Transport and Digital Infrastructure is to establish a legal framework in which C&AV can autonomously take over driving tasks, without the driver having to constantly monitor the system.</p>
Italy [27], [48]	<p>Technical requirements and objectives: To ensure the maximum deployment of ITS, the design and implementation of such systems are inspired by the following principles and requirements:</p>

Country	Analysis findings
	<ul style="list-style-type: none"> • Focus on solving the key transportation issues, particularly on roads, such as traffic congestion, harmful emissions, energy efficiency carriers and the safety of road users. • Ensure interoperability through the appropriate certification procedures and systems, and information and data sharing capabilities etc. • Enabling and supporting the development of applications and services for road users; • Taking local, regional and national aspects and characteristics into account (e.g. the sizes of the traffic volumes and the weather conditions on the roads) and supporting the best use of national networks and existing infrastructure. • Ensure the compatibility of the solutions adopted, guarantee the capability for ITS systems to work with existing systems <p>Non-technical challenges and requirements</p> <p>In Italy, automated activities are not allowed on public roads for safety reasons, though some very special tests may be performed on short road sections after the area has been secured. For example, automated vehicles in Italy may be considered legal if they are certified according to technical standards that have been developed for rail systems. Although some plans exist, none of the regulatory acts deal with automated driving (meaning driverless vehicles on the road), despite some mentions about cooperative mobility (i.e., connected mobility, supportive vehicular applications). Thus, the legislation must be scrutinized and reviewed if the testing of autonomous vehicles is to be executed on a wider scale.</p>
Spain [125]	<p>Non-technical challenges and requirements</p> <p>The Spanish law and regulations are quite flexible when it comes to the testing of autonomous vehicles. At the moment, no current laws need to be modified even though the focus is on SAE levels 3, 4 and 5. If testing conditions are fulfilled, DGT (Dirección General de Tráfico) will provide a license exemption for the duration and location of the tests. Other requirements are as follows:</p> <ul style="list-style-type: none"> • Information about the trials, location and timing, driver experience, vehicle technology, evidence of functional safety methodologies used must be presented. • The vehicle will be able to pass some tests in a closed testing. • The vehicle will be allowed to drive in automated mode only in the areas in which the vehicle requested the exemption.
Sweden [27], [51]	<p>Non-technical challenges and requirements</p> <p>Swedish requirements include establishing real-life test sites (e.g. Drive Me program by Volvo and Lindholmen Science Park; Astezero test track) for testing and demonstrations of automated vehicles and technologies (V2V2I). All the programmes dealing with autonomous driving rely on and promote the triple helix approach by involving: legislators, transport authorities, a major city, a vehicle manufacturer and real customers.</p> <p>The current vehicle legislation driver's license liability rules might need amending to allow the testing of vehicles using information systems, which might be considered beyond those cars offering only assistance for the driver. Vehicle regulations and roadworthiness testing would have to be amended to cover the hardware and software used for automated vehicles. Driver's licenses could be given to those with impairments for fully automated vehicles only.</p>
United Kingdom [125], [203]	<p>Technical requirements and objectives:</p> <p>Despite the fact that driverless vehicles can legally be tested on public roads in the UK today, the UK government has nevertheless published a code of practice for testing. The document guides anyone wishing to conduct testing of automated vehicle technologies on public roads or in other public places in the UK. It provides details of recommendations for minimising potential risks and maintaining safety. The code applies to the testing of a wide range of vehicles, from smaller automated pods and shuttles, through to cars, vans and heavy-duty vehicles. However, the UK legislation has set some regulations and even constraints for the testing of higher level vehicles:</p> <ul style="list-style-type: none"> • There must be a responsible qualified driver (or operator) present. • The driver must be: <ul style="list-style-type: none"> ◦ Attentive and able to take control if needed;

Country	Analysis findings
	<ul style="list-style-type: none"> ○ Possess an appropriate licence for the vehicle category; • The driver or operator must be appropriately trained on the vehicle, systems and functionality. • Vehicles: <ul style="list-style-type: none"> ○ Must be road worthy; ○ Should be fitted with a data recorder; ○ Should be protected from hacking; ○ Technology should have been proven on closed roads or test tracks.
EUROPE	<p>Making C&AD possible is a cross-cutting mission for transport and economic policy. The C&AV demands a high- performance infrastructure, which is also one of the objectives of the Connecting Europe Facility (CEF) and the Investment Plan for Europe. These instruments aim at promoting and stimulating investment in broadband networks and transport infrastructure, which are necessary for effective C-ITS.</p> <p>The ITS Directive (Directive 2010/40/EC) enables the European Commission to adopt technical, functional, organisational and service provision specifications for the interoperable ITS across the whole European Union. One of the first priorities of the ITS action plan was the travel and traffic information systems and the eCall emergency system. There are several working groups and initiatives like the iMobility Forum and the C-ITS Platform through which the EC involves private and public stakeholders to collaborate and coordinate the technical developments at the European level and to ensure interoperability and deployment of the systems. In the framework of Horizon 2020³², a dedicated call for automated road transport was launched, with a budget of over €100 million over two years.</p> <p>The European Commissioner for Transport together with Transport Ministers of the G7 countries (the United Kingdom, the USA, Canada, Japan, Germany, France and Italy) have agreed on a declaration on connected and automated driving. It has being underlined that appropriate steps are needed to establish a harmonised regulatory framework, enabling safe deployment of (key enabling) technologies across the countries. Sustained collaboration between Europe and other countries seems to be focused on at least in the following areas:</p> <ul style="list-style-type: none"> • Coordinating research and cross-cutting triple-helix collaboration • Promoting international standardisation within an international regulatory framework, • Evolving and setting technical regulations and, • Ensuring data protection and cyber security • Setting legal and regulatory framework to allow for testing of highly automated vehicles (short-term focus); • Setting legal and regulatory framework to allow for the commercialisation and use of highly automated vehicles (mid – long term focus); • Clarify roles and responsibilities of all stakeholders. <p>EU Member States are already working within their own jurisdictions, but support for a harmonised approach across the European Union to adapt regulations allowing for innovation is required. Hence, a common strategy at the EU level is also needed, because otherwise fragmented markets and varying approaches in Europe will set obstacles for C&AD and jeopardize European competitiveness. Since C&AD depends on the competitiveness of the industry, the strategies and regulatory frameworks need to be done together with authorities, industry and academia.</p> <p>As automated driving evolves, liability issues need to be properly addressed by all stakeholders (e.g. drivers/travellers, automotive industry, insurance companies, public sector, academia) and best practices from the automotive industry and other related sectors can provide useful recommendations. Ongoing activities may provide the initial grounds for the required adaptation of regulations (e.g. GEAR 2030, RESPONSE4 within AdaptIVe, WP26 of Citymobil2, and the EC C-ITS platform).</p> <p>Public authorities have recently presented action plans to facilitate the development and introduction of C&AV. In addition to Europe, recent developments in the USA and in Japan are of particular importance. South Korea, China, Singapore and Australia have also presented their national programmes and initiatives in the C&AV landscape.</p>

³² Horizon 2020. <https://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020>

3.3.2 Comparative analysis of technical and non-technical barriers

It is expected that C&AV will improve road and traffic safety, reduce traffic congestion and reduce air pollution. However, to achieve these scenarios, public authorities and the automotive industry must overcome challenges related to poor infrastructure, bad weather, extreme conditions, the inadequate spectrum of testing and standards, cyber security, and public and user acceptance. The technology to tackle these barriers has advanced and developed rapidly in the past few years, and some of this technology is almost ready for commercial deployment. However, to make deployment possible, each country needs to address and solve particular issues regarding, for example, public investments, policies and regulations.

From an EU point of view, it will be essential to increase and strengthen the artificial intelligence capability of C&AV. For the EU, this can be a major issue, since there is a lack of EU companies capable of working on artificial intelligence. However, non-EU technology companies such as Google in the USA and Baidu in China have moved into transportation. These companies consider transportation an opportunity to apply the processing insights and rapid learning capabilities developed through search engine technology. To be competitive in C&AD, EU automotive manufacturers (e.g. BMW, Mercedes-Benz and Volvo) need specific human resources with knowledge on artificial intelligence and computing because of the role it will play in C&AV development.

Many EU countries (e.g. Spain, Germany, France, and the UK) have either published or are about to publish plans, legislative frameworks and roadmaps for C&AD. The UK has even published a code of practice for C&AV. The plans mostly aim at strengthening the national automotive industry and building the future of transport equipped with C&AV that may revolutionize individual, collective and industrial transports. The development is built on cross-sectoral collaboration where representatives from different sectors can discuss and the most competitive application areas and solutions can be found.

In Italy, Japan and South Korea, authorities and car manufacturers have been relatively careful about C&AD so far. However, OEMs such as Fiat, Toyota, Honda, Nissan, Kia, and Hyundai have started to invest in the sector. They are following the ongoing initiatives in other countries and are gradually carrying out more demanding and large-scale pilot projects. Currently, China is making efforts to develop a national policy framework for C&AD. Since there are some overlapping jurisdictions, the process involves multiple ministries responsible for the supervision of C&AD. The purpose is to clarify who regulates what and how regulation is done. Also, the government and authorities have to invest in highway infrastructure and communication technologies for C&AV, and remove current national obstacles for public road testing.

In the USA, even though the National Highway Traffic Safety Administration (NHTSA) has issued its Federal Automated Vehicles Policy, the regulatory fragmentation caused by 50 States and their differing regulations is a challenge. Currently, manufacturers (e.g. Ford, General Motors, Tesla, Google, etc.) and software developers face different rules and regulations in different States. This obstructs innovation and solutions because manufacturers would like to build vehicles for both the national and international markets. In addition, more clarity in terms of legal liability and data protection, and legislation to penalize the malicious disruption of C&AVs is required.

Generally, in each country, governments and authorities as well as business representatives, have to solve these issues. In the near future, the technology will likely have developed to the point where C&AV will spread into key niches such as ride-sharing, taxis, delivery, industrial applications, and transport for special groups. There will be driverless options for taking people safely to their destinations. It is vital for authorities to provide reasonable guidance on how to commercialize and apply advanced technologies in transportation. Common challenges for all nations can be summarized into the following:

- Environmental detection and perception.
- Demonstrating reliability, safety and the robustness of the technology.
- Legal and regulatory Framework.
- Users' and societal acceptance.
- Common Validation Procedures and Testing Requirements.
- Infrastructure requirements.
- Industrialisation and mass manufacturing.
- Robustness of the current sensor devices when operating in hard weather conditions is not sufficient. This prevents autonomous functions especially during the winter time in Nordic countries.

- Intelligence for smart trajectory planning compared to the human driver is still insufficient. The human driver can adapt to situations when e.g. someone violates traffic rules which is hard to train for computer units.

As discussed, most of the regulatory discussion is on C&AV and testing. However intelligent transport and mobility services (e.g. eCall) seem to be wrongly forgotten, and require that the following factors be considered:

- The applicable legislation.
- Governance and certification.
- Stakeholders and organisational framework.
- Overview of the global system architecture.
- System modules and functions and specifying sensor.
- Application programming interfaces.
- Application data.
- Data communication.
- Security.
- Architecture.
- Data storage.
- In-vehicle processing requirements.

It should be recognised that the deployment conditions of services can create contradicting requirements. Regulatory applications in general require secure positioning, fraud-proof data storage and communication. Regulatory applications also are likely to require product life cycles which are often aligned with vehicle life-cycles. The ITS Action Plan [204] has given eight recommendations to the EC to strengthen the market opportunities of in-vehicle services.

1. Steer industry initiatives and encourage the development of standards on wired and wireless data communication between components and devices within the vehicle. Encourage the development of standards on powering and mounting of nomadic devices within the vehicle.
2. Encourage the development of standards on generic in-vehicle services for the provision of reliable and up-to-date basic vehicle information (e.g. location, speed, date and time, etc.) by certified in-vehicle sensors and receivers.
3. Use the opportunity of the revision of the tachograph specification (Council Regulation (EEC) No 1360/2002) to define the digital tachograph as an essential core telematics element in the ITS station of the concerned vehicle.
4. Use the opportunity to consolidate the regulatory framework and operational set-up in order to better align the governance across different (regulatory) telematics measures, such as the Digital Tachograph, EETS and eCall.
5. Consider a services model for regulatory applications and investigate whether applications, such as Digital Tachograph, EETS and eCall, can be migrated to a services model.
6. Leave the implementation of eCall to the industry and not mandate eCall as an open platform for other applications.
7. Create a supportive environment without any infrastructural, legal or institutional obstacles for the industry (vehicle manufacturers, service providers, road operators...) that allows the introduction of cooperative systems.

3.3.3 SWOT – Analysis for EU on technical and non-technical barriers

Table 21. SWOT analysis for EU on technical and non-technical barriers

Strengths		Weaknesses	
Main Point	Explanation	Main Point	Explanation
Wide-ranging support for R&D through national agendas and commitment of the automotive industry to C&AD	<ul style="list-style-type: none">The automotive industry agrees that political support is decisive for establishing C&AD as a new market driver.Different organisations across Europe (EC, national authorities, etc.) are providing support for R&D projects.	A lack of coordinated foresight policy at the EU level for C&AD	<ul style="list-style-type: none">National foresight programmes have been in existence for some years. However, there is a lack of coordinated foresight policy at the EU level.
		No common coordinated legislation for C&AD	<ul style="list-style-type: none">There is no EU-wide legislation for C&AD. Every country has their own legislation, which creates obstacles for both R&D and vehicle operation.
		Weaknesses in knowledge transfer	<ul style="list-style-type: none">Examples include fragmentation of technology research, slow responsiveness by research institutes to rapidly-evolving technologies and in some cases a poor response to industry needs.
Opportunities		Threats	
Main Point	Explanation	Main Point	Explanation
International collaboration	<ul style="list-style-type: none">Considering the EU status on C&AD, international collaboration has been identified as a high priority, but still needs to be implemented and developed.	Fragmented and protectionist EU markets	<ul style="list-style-type: none">The development of C&AD may take more time than expected, not because of the technology, but of the fragmentation and nationalization of EU efforts.
Finding national niches and exploiting their potentials in open and commercial test sites	<ul style="list-style-type: none">There is an opportunity to focus R&D according to a speciality that considers niches, novelty and know-how.	Driver and social acceptance of new technologies	<ul style="list-style-type: none">Customer and social acceptance will influence the extent to which C&AD are successful in the market.
Enabling innovation policies, funding, incentives and infrastructure investments	<ul style="list-style-type: none">Coordinating national and EU-level activities by combining strengths would benefit the entire EU automotive business.The development and deployment of C&AD requires significant public and private funding as well as supporting tools and policies.	A lack of patenting and standardization by European automotive industry	<ul style="list-style-type: none">There are obstacles in standardization since it will likely have an impact on companies’ market shares and competitive advantages.Standardization and harmonization issues that are unavoidable concerning

New business model for C&AD offering	<ul style="list-style-type: none">• The introduction of C&AD allows companies to adapt their business model and focus on other aspects of vehicles.		technologies in- and outside the vehicle should be taken into account to facilitate market introduction and distribution of research results.
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STRENGTHS

Wide-ranging support for R&D through national agendas and commitment of the automotive industry to C&AD

The automotive industry agrees that political support is crucial for establishing C&AD services and to overcome many existing hurdles. Several EU Member States are currently scrutinizing their road traffic regulation and legislation frameworks to support and allow the development and testing of C&AV on public roads, even though a driver is still usually required. However, in many Member States, domestic testing permissions have been difficult to apply for, even for EU companies.

WEAKNESSES

A lack of coordinated foresight policy at EU level for C&AD

Investments in communication and transportation infrastructure are needed. Automotive companies feel that governments are responsible for these investments. The industry has also shown interest in incentivized tax breaks to free up budgets for R&D and to increase research collaboration. Different organisations across the EU provide support for C&AD R&D projects. Although national programmes have been in existence for some years; there is still a lack of coordinated foresight policy at the EU level, which obstructs the establishment of EU wide policies and guidelines.

No common coordinated legislation for C&AD

Currently, there is no EU-wide legislation for testing and implementing C&AD, which is a significant obstacle that needs to be overcome. Various Member States have their own legislation, which creates obstacles for both C&AD R&D and the operation of vehicles.

Furthermore, a shared vision is lacking on the importance of C&AD and how it is going to impact the EU. Policies and regulations have typically lagged behind technological progress. It is expected that regulators respond to new technology with laws ensuring the safety of driverless vehicles, once that technology is available.

Fast adoption and modification of the Vienna Convention into national regulations would enable Member States to keep up with competing regions. Also, legal issues and regulations (e.g. liability in case of accidents, and data security and privacy in the cloud) are of high priority for insurance companies. The harmonization of laws and smart solutions such as an insurance fund are of great importance for a wider acceptance of C&AD. Lastly, ethical issues of decision making by machines also have to be considered.

Weaknesses in knowledge transfer

The lack of a common EU legislation and policies is believed to have a significant impact on the technology research at different levels (i.e. EU, national, regional). Even though various research institutes are already involved in the development of C&AD, research is quite fragmented within the EU. In some cases, this leads to slow responsiveness and a poor response to industry needs.

OPPORTUNITIES

International collaboration (especially within Member States)

EU automotive companies are facing business and technological challenges. These can be quite heterogeneous and require close cooperation between manufacturers and their suppliers, which might also be external to the traditional automotive industry. International cooperation, especially within Member States (but also with key players such as the USA and China) are a high priority. However, industry-wide standards for technologies, software development, security and service provision must also be developed and accepted.

Finding national niches and exploiting their potentials in open and commercial test sites

Setting up public and commercial test sites for C&AD could bring value to many sectors and industries (i.e. automotive, accommodation, research, society). However, duplication can be avoided by not developing everything at every test site. The greatest benefits come through specialization that takes niches, novelty, local assets and know-how into account. It is also possible to match research/science and technology policies with the competitive advantages of each Member State's industry.

Enabling innovation policies, funding, incentives and infrastructure investments

Political barriers are seen as a major obstacle. Thus, political support and legalization are requested to enable piloted driving and testing, as R&D activities in Europe are considered to be overly fragmented at the EU and national levels. Coordinating national-level and EU-level activities Europe-wide by combining strengths would benefit the entire EU automotive business. The development and deployment of C&AD requires both public and private funding as well as supporting tool and policies. The Connecting Europe Facility (CEF) funding instrument is a good example of public funding at EU level. CEF combines the development of transport, energy and telecommunications infrastructure under the same instrument, with €24 billion having been allocated for transport sector.

New business model for C&AD offering

Companies are likely going to focus on the business aspects and models of C&AV (including revenue and user experience). Thus far, activities are mostly focused on technological implementation alone. However, as companies rethink their strategies and portfolios, new opportunities from C&AD must also be taken into account.

To some extent, OEMs and top-tier manufacturers have started to act like venture capitalists, snapping up start-ups to have a potential competitive advantage and to achieve a result before other manufacturers. The favourable economic environment for many OEMs has made this possible.

THREATS

Fragmented and protectionist EU markets

The development of C&AD may take more time than expected, even though many technologies are already available. Possible reasons for this delay is the fragmentation and nationalization of EU efforts (e.g. the benefits of collaboration are still denied), and the non-integrated EU market that obstructs trade and cooperation between nations. This contributes to unnecessary competition instead of complementary networks.

Driver and social acceptance of new technologies

As vehicle automation is still being developed, the speed at which solutions become mainstream will also be determined by customer and societal acceptance of new technologies. Many drivers do not accept or want autonomous vehicles since they do not trust the technology and still prefer the traditional driving experience.

A lack of patenting and standardization by European automotive industry

Standardization is also an agreed method to make collaboration easier. However, there are obstacles in standardization as well, since standardization will probably have an impact on market shares and the competitive advantages of companies. Big companies consider standardization a potential risk to their individual business. Since large companies are involved in EU standardization committees, the pace of an industry-wide standardization remains a parameter of individual corporate business development. Currently, most of the patents and standards considering C&AD originate from the USA or Japan. This obviously gives them a competitive advantage and dominant position.

Standardization and harmonization issues that are unavoidable concerning technologies in- and outside the vehicle should be considered to facilitate the market introduction and distribution of research results. Harmonization of standards is needed to avoid fragmented solutions, loss of public funding as well reduced industrial investments.

04. Operational Approach – Task 3

4 Operational Approach – Task 3: Assessment of the existence of a global level playing field and of the effectiveness of instruments available for supporting the development of C&AD

This task focuses on assessing the existence of a global level playing field regarding the support measures and programmes. The effectiveness of the measures put in place in the EU to support the development of the C&AD market is also analysed. This includes existing barriers, duplication of problems and the potential lack of a common medium- to- long- term coherent approach by Member States and the EU.

Concrete proposals on how to reinforce the global coherence and effectiveness of existing support actions and instruments in the EU are presented. In this context, actions to support stakeholders' investment in developing and testing automated vehicle technologies in Europe are developed. Such actions include, for example:

- The development of a harmonised approach for temporary ad-hoc permits for testing automated vehicles.
- The setting up of a platform for sharing and exploiting data in national/European/international field operation tests.
- The development of standards for C&AV and their use, aiming at setting up a coherent approach in urban and interurban areas for connecting vehicles to other transport elements (e.g. data privacy, accessibility for people with disabilities, reduced gas emissions, etc.).

The possible applications in the domain of C&AV and the new State aid rules adopted by the EC in June 2014 to support important projects of common European interest (IPCEIs) are also analysed in detail.

Introduction to Methodology

This task aims to assess the support measures identified in Task 1 and Task 2 in order to understand how they affect competition and whether they are compatible with World Trade Organization (WTO) Rules. It also aims to analyse their effectiveness and propose ways in which support measures might be improved.

The activities have been divided into sub-tasks that address the different components of the abovementioned objectives:

- Subtask 1 – Assess the existence of a global level playing field
- Subtask 2 – Analyse the effectiveness of EU support measures
- Subtask 3 – Proposals to reinforce existing support actions and instruments in the EU
- Subtask 4 – Conclusions and policy implications

For sub-task 1, the approach draws on extensive desk research as well as expert opinions. The task examines the result of the subtasks pertaining to Task 1 and Task 2 and the present day status regarding a global playing field, and whether some countries are at an inherent advantage compared to their counterparts.

For sub-task 2, the approach draws on data from desk research as well as expert opinions. It searches for evidence of correlation between support provided using public funds and market outcomes. It also examines the significance of these outcomes. Support for different types of activities have been investigated at EU and Member State level. Issues such as duplication and coordination of activities have been addressed.

For sub-task 3, these activities have been followed by the preparation of proposals for future support to the testing and deployment of C&AD, and the use of questionnaires to ensure that they address the needs of EU stakeholders along the value chain in a coherent and integrated way across the EU.

Finally, sub-task 4 aggregates the findings of the project and provides recommendations and considerations of policy implications regarding future support to C&AD.

4.1 Subtask 1 – Assessment of the existence of a global level playing field

Subtask 1 aims to assess the existence of a global level playing field or of a distortion of competition, notably in relation to the level of the subsidies provided in third countries to support and attract major industrial investments in C&AD. The focus is on the harmonisation of vehicles' regulation and on the distortion of competition related with the level of the subsidies provided in large scale industrial and research support programmes.

4.1.1 Impact of the fragmented regulations in the EU on the existence of a global level playing field

Based on the analysis and discussions presented in Section 2.3 and Section 2.4, it is agreeable that while individual Member States have moved forward with their own revisions to facilitate the development, testing and deployment of C&AD, there is still differences between Member States.

Currently, there is a visible fragmentation in regulations in the EU. Fragmentation is visible in regard to research focus, with Member States focusing on their own priorities. Fragmentation also exists in terms of policy, legal and regulatory issues, as different Member States have specific laws related to, for example, how and if testing can be performed. Fragmentation also exists in the digital and telecommunication landscape, which is also crucial for both the autonomous and connected elements of the vehicle.

Although in the short term this may not be of particular concern (as vehicles' level of automation is still low), in the long-term (and as vehicles reach higher automation levels), this may affect the extent to which the EU is capable of competing equally with other countries. **This is in fact a challenge because, while the EU is made up of various countries, it competes as a whole against individual countries.**

However, it must be noted that fragmentation is not exclusive to the EU. **The USA and China, for example, which the study shows have several strengths, also show some signs of fragmentation.** In the USA, there is still a challenge of harmonising the differences found at State level, which have the authority to make specific road legislation and can differ among States. In China, responsibilities for C&AD are distributed amongst different organisations, which also creates issues of fragmented responsibilities.

To better identify the way forward for a harmonised regulatory approach for road transport automation and connectivity, the following topics at the EU level are addressed [90]:

- Adapting the legal and regulatory framework to allow for the testing of highly automated vehicles, on a European scale (short term).
- Adapting the legal and regulatory framework to allow for the commercialisation and use of highly automated vehicles at a European level (mid – long term).
- Clarifying roles and responsibilities of all stakeholders.

Road traffic is a highly regulated area as it carries huge risks not only for the driver and passengers, but to other road users in a public space setting. C&AV change the driving risks in many ways and thus an assessment of all traffic and vehicle related regulation is required. This is not an easy task, considering that different national jurisdictions may hinder the development and deployment of new technologies for systems and vehicles. The harmonization of the legal framework concerning road safety across European Member States and other countries therefore becomes essential in extending the effort of C&AD.

The fundamental principles that became an obstacle to C&AD development are found in Article 8 of the Vienna Convention, which stipulates the presence of a driver who is always fully in control and responsible for a vehicle in traffic. This stipulation holds a detrimental effect on the development of C&AD, especially at level 5 of vehicle automation where a driver's attention is no longer required. In March 2014, WP.1 amended the Vienna Convention saying that 'systems which influence the way vehicles are driven' [205], as well as other systems that can be overridden or switched off by the driver, are considered to be in accordance with Article 8. However, the presence of a driver is still required as the amendment only extends the understanding of the driver without clearly allowing vehicles to be driverless. Therefore, an additional amendment process is necessary to allow for driverless vehicles. Most vehicle systems with high or full automation are still incompatible with the

Vienna Convention, even with the 2014 amendment due to the requirement of a driver in these systems.

The fact that the majority of Member States are signatories of the Convention leaves them limited to its principles and obstructions to C&AD. This is not the case for the third-countries considered in this study. As these are not signatories, they have the freedom to define regulations as they see fit. In this sense, and while further amendments to the Convention are not made, the EU can be considered to be at a disadvantage.

To overcome this limitation, one of the major steps towards the implementation of C&AD in Europe was signed in 14 April 2016 in what is known as the Declaration of Amsterdam. This document, signed by all transport ministers of EU Member States, laid out the agenda for collaborative work to produce a coherent European framework for the deployment of C&AD, and set 2019 as the year when automated vehicles should be available [159].

More importantly, the declaration also mentioned the goal of removing barriers and promoting legal consistency across all Member States in order to facilitate the introduction of C&A vehicles in the market and enable their cross-border use. This declaration tasks the EC to review and adapt the EU regulatory framework in order to support the development and use of C&AD, and to support a more coordinated approach at EU level that will result in added value on the joint learning process. Moreover, this declaration also orders Member States to identify and remove legal barriers to the testing and deployment of C&A vehicles, facilitating their development.

Therefore, the Declaration of Amsterdam is a significant step forward to provide a coherent legal framework that allows for further development of C&AD and approximation to its competitors.

However, serious efforts are still needed in order to harmonize and eliminate barriers on C&AD regulations. This needs to be done in order to draw level with other regions and countries that have a high research intensity on C&AD. Through this framework, several studies have been launched in determining the legal readiness of European countries to carry out C&AD on their roads.

Traffic accidents involving automated vehicles are one of the main regulatory discussions surrounding C&AD development. In case of an incident, it is important to determine whether the liability falls upon the driver, manufacturer or system provider. In the European Union, product liability is strongly harmonised by the Directive on liability for defective products (Council Directive 85/374/EEC). A manufacturer is liable for any damage caused by a defect in his product; a product is defective when it does not provide the safety the consumer is entitled to expect.

The issue on liability with C&AD is important since most liability regimes in the EU use the concept of causality in regulating liability. When the vehicle automation feature is active, it becomes hard to determine the exact cause of an accident and to prove if it is due to a defect with the vehicle or the behaviour of the driver. This new potential cause created by automation might create a difficulty in determining liability under the current legal framework. **Therefore, adoption and harmonization of regulations concerning liability of owners and/or drivers is necessary.**

A concept paper on liability for highly automated and connected vehicles written by the GEAR 2030 Working Group mentions the need to differentiate the autonomous car based on its classification between partial to highly automated (level 1-4) and fully automated vehicles (level 5). According to this document, the simplified view on liability transfer is that when in fully autonomous mode and where the attention of the driver is not required, the liability of any accident occurred will be transferred from the driver to the manufacturer. However, the driver is still responsible for ensuring the vehicle is used according to the manufacturer's operating instructions (e.g. keeping sensors clean, downloading software updates and ensuring regular servicing).

Due to the heavy reliance of C&AD on integrated ICT services, the regulatory condition related to cybersecurity and data privacy (including the management of big data) is also subject to a major discussion. Connected vehicles are equipped with extensive IT communication capabilities that include in-vehicle networks for information and entertainment. Automated vehicles have external software and hardware extensions that are developed, implemented and managed by the vehicle manufacture. Thus, the security of the connection between the vehicle system and the manufacturer's central server has to be secure, so that all data transfers take place in a protected environment from unauthorized disclosure and manipulation. This is important considering that uncontrolled, unrestricted access to vehicle data may compromise the safety of the vehicle, occupants, and other road users.

As C&AV become mainstream, the amount of data that is collected from vehicles and passengers will increase, and the management and privacy of (big) data will become a major concern. The debate on data privacy revolves around the ability of connected vehicles to generate, store, and transmit user's personal data, such as the route to a destination, time of driving, average speed, appointments, and other private data. These data have a significant potential for other uses as third parties can access and use sensitive driver and driving data.

A 2012 study ordered by the EC assessed potential measures for guaranteeing data protection and data privacy in intelligent transport systems. In 2014, the Article 29 Data Protection Working Party, an independent European advisory body on data protection and privacy, published an opinion on recent developments on the Internet of Things (IoT). The current data protection framework dates back to 1995. The new General Data Protection Regulation proposed in 2012 by the Commission and informally agreed by the Council and European Parliament in December 2015, established a single set of rules on data protection, also with regard to digital technologies and valid across the EU. A specific regulation on big data, its management and guaranteeing its security is thus necessary. The EC expects to address this issue as early as 2018, with a proposal of initial guidelines on the matter.

The third major regulatory aspect currently under discussion is the introduction of technical provisions for self-steering systems. These include systems that, under specific driving circumstances, will take over the control of the vehicle under the permanent supervision of the driver, such as Lane Keeping Assist Systems (e.g. when the car/road vehicles will take corrective measures if it detects that it is about to cross a lane accidentally); self-parking functions and highway autopilots (e.g. when the vehicle would be self-driving at high speeds on highways).

This will also include removing the current limitation of automatic steering functions to driving conditions below 10km/h contained in UN Regulation No. 79. In 2014, experts started evaluating the technical requirements that innovations for enabling automated driving will need to comply with to ensure safety. This work was expected to be completed in September 2016, with the perspective of being adopted by the World Forum for harmonization of vehicle regulations in 2017 [206].

Addressing these regulatory items is important since the slow process of law harmonization in Europe adds to the difficulties of the European manufacturers in developing C&AD. While competitors (e.g. Japan) have better regulation towards C&AD, Europe still lacks regulations that allows European manufacturers to further research and develop C&AD technology.

Related to regulations, there is also a lack of coordinated foresight policy at EU level. While some countries have begun to develop guidelines on C&AD technology, the foresight policy coming from the EU level is still relatively weak. This has led to the lack of EU-wide legislations as well as a clear and measured target for developing C&AD in Europe.

This situation is in contrast with, for example, the announcement of a USA nationwide legislative framework by the USDOT NHTSA and proposals for a Model Policy that can be used by its 50 states to ensure greater harmonisation. Therefore, the lack of regulation that is still faced by European manufacturers has created an un-level playing field in the development of C&AD.

Also relevant to consider is the EU's position in regard to regulation on mobility services. It appears that a comprehensive legal framework for mobility services is still to be developed. However, the EU has already defined key areas on which regulation should focus: (1) customer protection, (2) mobility solution providers, (3) the newly emerging data layer, (4) inter-modality and intermodal competition, and (5) the infrastructure layer and guaranteeing a stable legal framework to favour investments. Outside of the EU, the USA is apparently a step ahead in this regard, namely through the work of the Federal Transit Administration (part of the USDOT).

The European lag in the field of regulations is also reflected in experts' opinions. Regarding the countries that have specific national policies to counter the technical and non-technical barriers in development and deployment of C&AD (Question 3A.9), the USA is regarded as the leader in the national policies with more than 45% of experts answering 'yes' and more than 20% answering 'no'. The EU comes second, with more than 35% experts answered 'yes'. Experts indicated South Korea as being the country with smallest number of national policies: less than 10%. However it should be noted that the majority of experts did not provide a specific answer to this question.

Lastly, regarding the extent to which technical regulations limit innovation in C&AD, more than 20% of the experts answered 'largely', and approximately 35% answered 'moderately'. For those who answered 'largely' and 'moderately', the justifications were mainly focused in evolving regulation and innovation together. Experts consider regulation as a boundary condition on which to build safe

technology while at the same time regulation should be flexible to adapt to new proven technologies through sound and well established research programmes.

From this review, the current regulatory status leaves the EU at an unlevel playing field compared to key competitors. With the majority of Member States signing the Vienna Convention, they already face limitations not incurred by non-signatories, many being non-EU countries. As C&AV reach higher levels of automation, existing fragmentation will increasingly be problematic. As discussed, steps have been made to address this problem. It is important to build on the principles of the Declaration of Amsterdam and to reach a well-regulated C&AD sector, where issues of testing, safety, liability, security and others relevant are common to all Member States.

4.1.2 Impact of the different level of public support received by the main players in the C&AD market on the existence of a global level playing field

In terms of economic opportunities, C&AD developments in Europe are in need of substantial support to be able to compete with other countries. While key EU C&AD players have the potential to become industry leaders, their position has been foreshadowed by other competitors outside of Europe.

The automotive industry accounts for the biggest investment in R&D in the EU. In 2015 alone, automotive companies invested around €50 billion in R&D. Worldwide, EU automotive manufacturers are in the top-five companies that invest the most in R&D. This investment increased by approximately 8% in 2015 due to large companies that invested above the average investment value. For example, Peugeot's increase in investment was 14.9%, Continental's was 14.4% and Mahle's increase was 64.3%.

This shows that EU automotive industries have a strong potential in the development of C&AD. With the significant and increasing funds allocated to R&D, the EU industry has the advantage and potential to become a global leader in C&AD innovation.

However, most of the patents relevant to C&AD originate from the USA or Japan, giving them a competitive advantage and dominant position in the sector. The USA is the leader in system sensors and platforms for environment 3D mapping, among others. Japan leads the race in technologies for vehicle controlling, artificial intelligence and passenger safety systems. **Thus, while EU automotive industries are strong, they are still behind other countries in technology development.**

With IT at the core of C&AD developments, ICT based service providers play a significant role in C&AD. In terms of their R&D investment, five USA companies (i.e. Apple, Microsoft, Google, Cisco and Oracle) hold cash reserves of nearly €500 billion together. Apple alone holds more than €200 billion, which is much more than the stock market value of many European automotive companies. This shows the vast amount of resources that USA (private) companies can be allocated into C&AD R&D.

This huge private investment is accompanied, triggered and leveraged by substantial public investments. For example, there are intentions in the USA to allocate as much as up to \$4 billion USD (€3.79 billion) for C&AD in the next 10 years, although this is still pending Congressional approval [207]. This amount would be used for R&D projects and to improve national infrastructure. The Japanese Cross-Ministerial Strategic Innovation Promotion Programme has prioritised "Automated Driving Systems" as its main funding focus. Meanwhile, the Autopilot System Council has announced that highly automated driving will be on Japanese highways by 2020, as stated in the EPoSS Roadmap on Smart Systems for Automated Driving from 2015 [153].

Another challenge faced by EU C&AD stakeholders is the limited investment in ICT companies and the financial difficulties these may face. This is a major challenge considering the development of C&AD requires a substantial amount of knowledge and expertise from the ICT sector. This is the case, for example, in the development of rich-detailed 3D maps that enable autonomous vehicles to survey their surrounding and drive accordingly. Artificial intelligence is another area where the EU is behind competing third-countries, but which is a vital element of the vehicle's operating system. C&AD technologies require vehicles to stay connected to ICT infrastructure such as servers, satellites and GPS. Therefore, strong support to ICT companies is important to ensure an equal playing field.

This suggests some limitations currently being faced by EU automotive manufacturers and ICT system providers. USA based companies have a substantial advantage compared to European companies considering the amount of public support allocated for R&D. Moreover, Chinese, South Korean, and Japanese manufacturers are also increasingly becoming key players in the development of C&AD, and are further threatening European manufacturers' position as the pioneers in self-driving technology.

Experts also confirmed the inherent advantage of the USA, Japan, and South Korea compared to the EU regarding public support measures for C&AD (Question 3A.1). More than 35% of experts indicated that European counterparts are at a disadvantage in public support of C&AD development. Most experts specified the USA's legal framework as being more advanced compared to other countries studied in this report. Other experts referred to the Japanese, South Korean, and Chinese governmental structure as being more centralized, and thus have the ability to directly promote the development in C&AD technologies.

This leaves European C&AD stakeholders in an unlevel playing field from the global context. One way to address this issue is using public support from both the national and EU level in

order to foster C&AD development. This is an important step considering the many obstacles still faced by European manufacturers in the field of C&AD. Furthermore, the development of a more coherent funding strategy, focused on a limited number of programmes (e.g. cPPP, IPCEI), alignment of priorities at national level and an increase of funding could be a step forward in balancing the playing field.

4.2 Subtask 2 – Analysis of the effectiveness of EU support measures

Subtask 2 aims to analyse the effectiveness of the EU support measures identified in Task 1, particularly regarding existing barriers, duplication problems and the potential lack of a common medium- to- long- term coherent approach put in place by Member States and the EU.

According to the European Better Regulation "Toolbox" [208], analysis of effectiveness should consider how successful the EU action has been in achieving or progressing towards the defined objectives. It should provide not only an opinion about the progress made to date, but also the role of the EU in delivering the observed changes.

Thus, effectiveness can be described as the success of the resources used to support the competitive deployment of C&AD through public support or the establishment of a favourable regulatory framework. The consortium has identified various factors that contribute to competitiveness and categorised support measures according to their contributions to the different factors in Task 1.

For each of the evaluation questions, the objective has been to quantify the answers as much as possible. However, despite the fact that it is difficult to disaggregate the effect of the support measure from the myriad of other influences on the particular aspect of competitiveness, it is considered that the consortium has been able to make relative comparisons in most cases.

At the EU level, evaluation studies and impact assessments of policy measures – including the introduction of regulations and funding programmes – are increasingly carried out and often include an assessment of the associated costs and benefits [209]. In the same way, at national level, policy measures are increasingly evaluated. The study has aimed to access any evaluation materials associated with the support measures identified, as well as other relevant materials, such as market studies and reports on consumer surveys. In addition, the evolution of the global competitive situation of Europe's main players (OEMs and suppliers) in the field of C&AD (including use of specific indicators and a SWOT analysis) has been analysed in the study. Furthermore, the possible role, within these strategies, of a potential IPCEI has been analysed, with assistance of the input received from the experts.

The importance of support measures at the technical and market level is reinforced through a study from Roland Berger and fka [148]. The study combines two indicators in the "Automated Vehicles" quarterly index to demonstrate the competitive position of the relevant automotive nations (the USA, Germany, China, Sweden, the UK, South Korea, France, Italy and Japan). They conclude that the ability to lead is dependent on the state of technological development including research activities as well as market characteristics, such as the demand for advanced driver assistance systems and the legal framework.

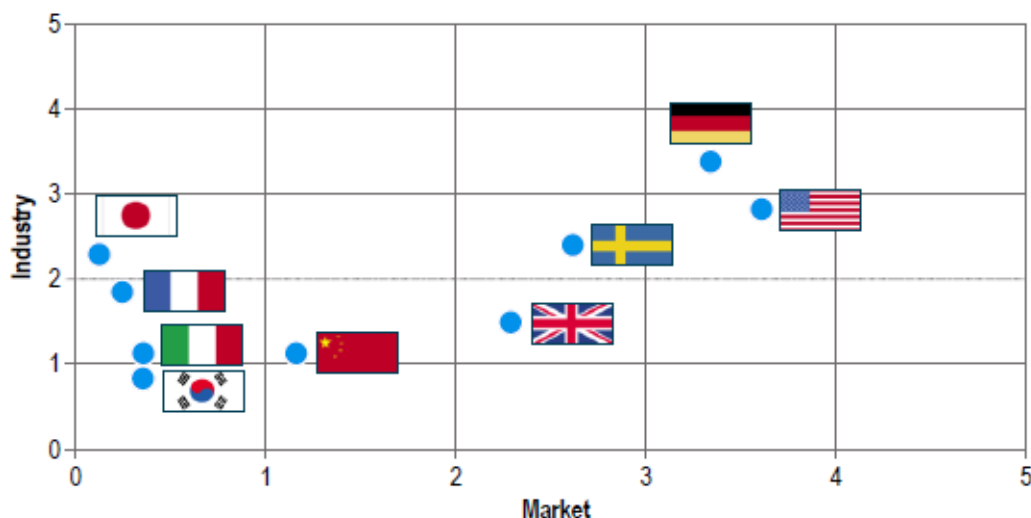
Industry indicator

Figure 17: Industry Indicator for Automated Vehicle Index (Q1 2016)

Source: Roland Berger & fka

In terms of industry, fka and Roland Berger [148] reported that Germany continues to be in the lead, ahead of the USA and Sweden. This position is rooted in Germany's OEMs' leading competitive position in advanced driver assistance system (ADAS) as well as in automated driving functions. The report also notes the increasing technology development of the USA, Japanese, and South Korean OEM that could threaten Germany's position as the leader in C&AD development. The USA's industrial expansion of C&AD is boosted by the development of vehicle prototypes by Google and Uber that are more focused on inner-city applications. Tesla is adopting an alternative strategy to increase the availability of C&AD features, namely through paid software updates to vehicles that are equipped with the appropriate sensors.

The report also highlights the role of expertise in fostering C&AD development. The extensive R&D done by universities across the USA and Germany has helped these countries lead in terms of expertise in C&AD. Germany and the USA have also benefitted from scientific collaboration between automotive OEMs and universities in the form of bilateral research projects [148]. For example, Toyota's announcement of a research centre to be set up in cooperation with Stanford University and MIT has a project value of approximately \$ 50 million USD (€47.3 million) [210]. This type of cooperation increases the development of C&AD since it is backed with academic knowledge and expertise.

In terms of expertise and know-how, C&D R&D also considers the aspect of subsidized research programmes. In Germany, several government agencies like the Federal Ministry for Economic Affairs and Energy (BMWi) are currently supporting various large-scale projects. One example is the Ko-HAF project for cooperative highly automated driving [211]. Subsidies have also been set aside for test facilities and pilot projects for automated vehicles in the UK (budget of £10 million GBP; approximately €11.7 million) and Germany (budget of € 28 million). [148]

Market indicator

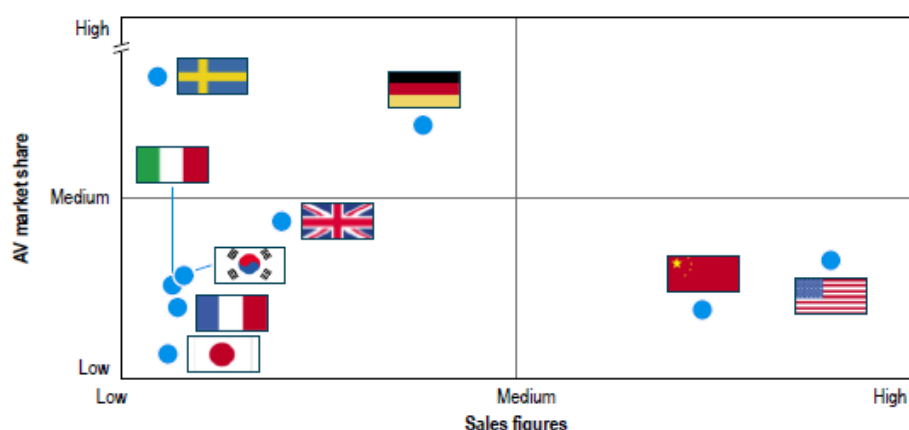


Figure 18: Market Indicator for Automated Vehicle Index (Q1 2016)

Source: HIS, fka, Roland Berger

For the market indicator, the USA's leading position is supported by a very large market volume for vehicles fitted with relevant assistance systems. The Rolland Berger and fka report noted that Germany has access to a very high share of commercial vehicles fitted with these systems [148]. Therefore, the German population is enough to put it in second place in terms of the market indicator. Sweden is a particularly interesting case considering that despite its small market compared to the USA and Germany, it has achieved the third position in the market indicator.

Lastly, this report presents and discusses the legal framework as one of the most challenging non-technical aspect of C&AD development. The existing simplified licensing procedures that exists in some of the USA States put Germany behind the USA in terms of the existing legal framework. However, the report notes that the draft bill on automated vehicles proposed in the State of California contains rather conservative technological stipulations and legal provisions. For example, this draft bill still requires a steering wheel and a driver who can take control of the vehicle at any time [212]. This stipulation may become an obstacle for Google, who wants to launch vehicles without steering wheels or drivers in the medium term.

The report also highlights the work done by the German government to tackle the legal challenges. They have prepared a legal framework for automated driving based on the preparatory work from the "Automated Driving" round table. Key action areas have been defined in the government's "Strategy for Automated and Connected Driving" (BMVi 2015) in order to prepare Germany for both the legal and technological challenges that lie ahead [148]. However, the fact that the German government has yet to publish a concrete timeframe is part of the reason why Germany has not improved its legal framework score compared to the USA.

4.2.1 Measuring the contribution to increasing public awareness /acceptance

There are a number of studies that regularly measure consumer opinions about C&AD. For example, this topic was recently covered as part of the Special Eurobarometer 422a on the quality of transport published in 2014. Furthermore, reports such as the annual GMSA reports on the mobile economy, or those published by consultancies such as Accenture and McKinsey provide data on consumer expectations and perspectives in this area. These studies provide information regarding the changing views and increasing awareness of C&AD.

A survey on the public opinion regarding C&AD was carried out by the Transportation Research Institute of University of Michigan in 2014. This survey compares public opinion in the USA and the UK, among others. This survey showed that 66% of the UK respondents said that they "never heard of autonomous or self-driving vehicles before participating in this survey" [213]. This shows a relatively low degree of awareness of UK respondents.

In terms of public acceptance, the survey showed that UK respondents were the least likely to have a "very positive" opinion regarding self-driving vehicles. At the same time, they were the least likely to

be “very concerned” about level 3 or level 4 automated cars, where the needs of human drivers could be compromised. Regarding system security, vehicle security, and interaction with pedestrians and bicyclists, UK respondents were “moderately concerned”.

The Automated Road Transport System (ARTS) demonstration, which includes a fleet of 6 automated buses, station/stop facilities and a control centre in La Rochelle of France provides an opportunity to assess public opinion on the implementation of C&AD technology. The survey was held in April 2016 and out of the 500 people surveyed during the demonstration, 87% indicated having heard of automated vehicles before participating in the survey [214]. Regarding safety concerns, 25% of the respondents indicated that automated vehicles are safer than traditional vehicles, while 46% believe that they are equally safe.

The increase in R&D funding for C&AD has helped in mainstreaming automated vehicles among the public. The growing presence of C&AD in the media has contributed to an increase in public awareness. This is complemented by an increase in R&D funding for C&AD, as well as projects and initiatives started by the European public and private sector.

However, the increase in public awareness does not always result in a higher level of public acceptance. The vague regulations on liability, data safety, and other moral issues have created an obstacle to public acceptance of autonomous vehicles. Although major industry leaders such as Google and Volvo have declared they will be responsible for traffic accidents involving their autonomous vehicles, rules and regulations that vary from one country to another make it difficult for these companies to further evolve [215]. Therefore, accelerating the process of harmonizing regulations should be prioritised, especially in the EU, in order to increase public acceptance on C&AD technologies.

This finding is reflected in the experts’ opinions regarding ‘public awareness/acceptance’. More than 80% of experts indicated that organising and promoting initiatives that increase the public’s awareness and acceptance of C&AD is ‘very important’ or ‘important’. Before user acceptance can be an issue, it is important that EU citizens become aware of what C&AD actually is. As demonstrated in Section 4.2.1, the level of awareness differs from country to country, and the media will play a role in generating awareness. Regarding acceptance, and as previously discussed (Question 1D.5A and 1D.5B), users and society have various concerns in regard to C&AD. This includes safety, security and privacy of data, reliability of the vehicles, among others. Thus, it is important that forthcoming measures efficiently address an increase in awareness (e.g. campaigns, new projects) and equally provide an answer to users’ concerns (e.g. testing extended to general public, limited within specific roads).

4.2.2 Measuring the contribution to reducing market barriers

With the huge impact that C&AD can have on revolutionizing the automotive industry, many countries, especially the USA, Japan, South Korea and China are investing resources in building infrastructure that will support research and streamline laws and regulations that will help the commercialization of C&AV. Public sector support for C&AD is important considering that the innovation introduced by developments in C&AD may clash with existing laws and regulations. Harmonization through the amendment of some of the existing regulations needs to be done. Thus, government support is vital to ensure that the development of C&AD is in line with existing legislation. Moreover, public investment in the creation of infrastructure that can support additional developments of C&AV is also needed, considering the substantial amount of technological advancements required.

Regarding the ‘reduction of market barriers’, experts’ opinions were divided among the need to reduce barriers as being ‘very important’, ‘important’, and ‘slightly important’. No expert indicated that it was ‘not at all important’. From the analysis, no specific tendency was observed: EU and non-EU experts did not answer more favourably one answer than the other. As more than 65% of experts indicate that reducing barriers is ‘very important’ or ‘important’, this suggests that additional efforts are required in this area. As discussed before, barriers may be related to legislation and infrastructure. From experts’ opinions, these are two issues that must also be managed (i.e. harmonisation of an EU-wide regulation/ legislation, improvement/ development of connected-capable infrastructure). Thus, and considering this alignment in answers, the reduction of existing barriers must be considered and pushed at the EU level.

As analysed in Task 1 (Section 2), non-EU countries have been moving forward with improvements in infrastructure and modifications to legislation and regulations.

In the EU, the creation of the Declaration of Amsterdam has created a momentum that is expected to push forward a harmonised legislations that will further support C&AD R&D in the EU. The Declaration also works as a political tool from EU leaders in working towards the fruition of C&AV. This is vital as it could also affect Member States' position on C&AD.

However, it should also be noted that the complexity of the legislation that needs to be harmonized (both in Member States and at the EU level) may become a major challenge. In terms of reforming regulations, the focus is still directed at amending the Vienna Convention on Road Traffic of 1968. While other key players such as the USA, Japan, and South Korea are already working on regulating the testing of C&AV on public roads, the EU has not done much in this area.

According to the DG Internal Policies report of March 2016, there is a lack of regulatory actions being taken to address the potential usage of C&AV on a large scale [112]. This report also points out the need for more assessment to be done on insurance and safety, as has been laid out in previous sections. It should be noted that while in the testing phase any liability would fall under the manufacturer, it is more difficult to say who will be liable when private C&AV are allowed to circulate on public roads. Therefore, the report urges governments to review and coordinate regulations on liability issues as well as on insurances.

Thus, the slow progress of streamlining the laws and regulations supporting C&AD at the European level has created an obstacle that needs to be addressed before greater progress towards the commercialization of automated vehicles is possible.

Amendments to existing legislations that are in conflict with current and future features of C&AV need to be done. Nevertheless, additional directives on enabling C&AV to be tested on public roads also need to be given more attention. This needs to be done considering that manufacturers can obtain approval for a new vehicle type in a Member State only if it meets the EU technical requirements [205]. Regarding infrastructure, roads need to be improved and changed before the deployment of vehicles is possible. Another action needed is the standardisation of frequency ranges used for communication equipment. Lastly, the advance of communication network standards move towards 5G, even if ITS G5 should also be supported as the bandwidth of the current internet infrastructure.

4.2.3 Measuring the contribution to technology development

In order to put Europe at the forefront in the development of C&AD, funding that comes from the EU, Member States and private companies is crucial, considering the size of the task that needs to be done. One of the most important funding schemes that can be used to advance the progress of C&AD development is Horizon 2020, which is the EU's biggest R&D programme with nearly €80 billion of funding available over 7 years (2014 to 2020).

Within H2020, the 2016-2017 Automated Road Transport (ART) call supports the short term introduction of passenger cars at automated driving level 3 and of truck platooning in real traffic conditions from 2020 onwards [216]. The 2016-2017 ART call consists of seven topics covering various aspects of C&AD with a budget of €114 million. This is the EU's biggest funding channel for C&AD in a single call. Under H2020, other calls also address aspects related to innovation in transportation. The total funding allocated to the development of C&AD coming from the EU is €200 million for the period of 2016-2017. This funding has created a momentum for European stakeholders to pool their resources into C&AD. Related to H2020, at least six projects related to C&AD have already been approved (e.g. ADASANDME, VI-DAS, MAVEN, AutoMate, CARTRE and SCOUT. These projects started in 2016 and will run until 2018 or 2019.

The significant funding allocated by the EU also meets research funding coming from its Member States. As discussed in Section 2.2, Germany, the UK and Sweden, among others, have also injected public funds into C&AD. This allocation of budget for C&AD in the EU illustrates the eagerness of the EU and its Member States to become leaders in producing C&AV. With the funding provided by the EU and Member States, there has been an increase in the development of C&AD. The EU is taking a more collaborative approach in addressing several C&AD technology barriers. This can be seen in its approach to increase the collaboration between European OEMs, technology suppliers (notably in the field of ICT), civil society organizations, and universities.

More generally, the 'GEAR 2030' High Level Group, launched in October 2015, aims to contribute to a coordinated approach at the EU level in order to address the challenges faced by the automotive industry due to technological changes, globalisation and an overall new approach to mobility.

On the other hand, the USA approach in developing C&AD is less fragmented. Although there is a federal budget for public funding related to the development of C&AD, OEM in the USA have partnered with technology suppliers and universities with minimal support from the government. This occurs considering funds are directed to financing research projects and infrastructure improvements tied to C&AD technology, leaving commercial OEM to establish partnerships with technology suppliers and universities themselves. This is the case, for example, with Google's autonomous driving technology development centre. The centre is built in the Greater Detroit Area, in order to align its collaborations with Fiat Chrysler Automobiles [217]. A similar approach was also taken by Uber who created its Uber Advanced Technologies Centre in Pittsburgh (February 2015). Partnered with Carnegie Mellon University, the centre focuses on the development of long-term technologies that advance Uber's mission [218].

This is reflected in experts' views regarding 'technology development required for deployment of C&A vehicles. More than 85% of experts indicated that these initiatives are 'very important' or 'important'. This majority is understandable, as the technology behind C&AV is one of the core items in the sector and has direct influence on all other aspects. As discussed, a number of funding schemes already exist that promote the improvement of existing technology or support the emergence of new innovative technologies for C&AD. For Europe and its Member States to continue to progress and compete with non-EU countries in this sector, the EU must continue to support and fund research for C&AD or facilitate the establishment of other inter-country mechanisms (e.g. IPCEI, as will be discussed in Section 4.3).

4.2.4 Measuring the European effort in C&AD development

Considering that C&AD is of strategic importance to the EU's competitiveness and industrial leadership, and has the possibility of addressing economic, societal and environmental challenges, the EC has made significant efforts in the C&AD sector. The complexity of C&AD must be recognised. C&AD does not only focus on technical, research or innovation aspects. It also includes far-reaching aspects, such as legislation, safety and security, insurance and liability, development of ICT and big data, as well as user awareness and acceptance.

Within the EC, the C&AD spectrum is the responsibility of many Directorates-General (DG). The DG for Internal Market, Industry, Entrepreneurship and SMEs (DG GROWTH) is responsible for vehicles legislation, competitiveness of the automotive sector, product liability, Key Emerging Technologies (KETs) and intellectual property. The DG for Mobility and Transport (DG MOVE) is responsible for traffic management and road safety. The DG for Communications Networks, Content and Technology (DG CONNECT) is in charge of opportunities and synergies with the IT and telecom sectors. Lastly, the DG for Research and Innovation (DG RTD) is responsible for research and funding. This shows a complex and interconnected network designed to cover the key aspects of C&AD and to support its implementation and growth in the EU.

The EU itself is a complex ecosystem, made up of various Member States that alone cannot single-handedly solve all these issues. For example, the trans-border journey across Member States would increase the effectiveness of truck platooning, but this requires a harmonised legislation across all interested Member States. It is in these and other scenarios where the EC has the capacity to play a significant role in the C&AD.

Thus, while some fragmentation exists (as discussed in Section 4.1.1), this is also due to the complex nature of the EU, where Member States have their own identities and priorities. However, and in addition to the more recent Declaration of Amsterdam from 2016, which is a step forward in creating a harmonised EU sector, other efforts have been made in this direction.

First, the High Level Group on Automotive Industry 'GEAR 2030' was founded to debate the main challenges for the automotive industry in the next 15 years and establish recommendations to reinforce the competitiveness of the EU automotive value chain. It will in particular consider specific measures for the smooth rollout of C&AV. GEAR 2030 is also tasked with analysing and discussing the key trends that will affect the automotive industry in the future and come up with jointly agreed roadmaps that should set objectives, specify milestones and clearly define responsibilities of different stakeholders. The group is expected to clearly define the adaptation of the value chain to new global challenges, supporting the research and development of C&AV, as well as working on trade, international harmonisation and global competitiveness. Although GEAR 2030 is not a permanent group in essence, it has nonetheless paved the way for better efforts in the EU transport and automotive sectors.

The second initiative is the Connected and Automated Driving (C-ITS) Platform, which was conceived in early 2014 as a cooperative framework. C-ITS includes national authorities, C-ITS stakeholders and the Commission. The group works on the development of a shared vision on the interoperable deployment of C-ITS in the EU. It is expected to provide policy recommendations for the development of a roadmap and a deployment strategy for C-ITS in the EU and to identify potential solutions to critical cross-cutting issues. In January 2016, the platform published a report that addressed the main technical and legal issues with C&AD, as well as standardisation, cost benefit analysis, business models, public acceptance, road safety and other implementation topics. It has also managed to create the common technical framework necessary for the deployment of C-ITS, addressed the legal questions related to C-ITS and the legitimacy of the deployment of C-ITS.

Third, in February 2016, the EC started an extensive consultation process involving various stakeholders and experts to define a Strategic Transport Research and Innovation Agenda (STRIA). The STRIA is built on and integrates seven thematic transport research areas: electrification, alternative fuels, vehicle design and manufacturing, C&A transport, transport infrastructure, network and traffic management systems, and smart transport and mobility services. As such, STRIA is an inseparable part of the EU research and innovation sector. In coordination with Member States and transport stakeholders, STRIA also aims to set out common priorities and deploy innovative solutions to address the Energy Union and other policy goals. STRIA will outline the steps needed to support and speed-up the research, innovation and deployment process leading to radical technology changes in transportation.

The STRIA's research areas are closely related with the development of C&AD. The most evident is the C&A transport research area that focuses on technologies for system and vehicles as well as data handling and cybersecurity. This focus is important for the further development of C&AD. Another important transport research area in the STRIA is the digitalisation of vehicles. Digitalisation will help the progress towards multimodality, achieving a more efficient use of transport infrastructures and capacities, changing the concept of mobility and shifting from ownership to assets sharing. The STRIA initiative also foresees dependence on big data as one of the emerging trends in vehicle development. This is in line with the needs of C&AD development, which also relies on IT development and big data. In fact, one of the prerequisites for fully autonomous vehicles is a robust communication network (e.g. 5G), which is currently under development. Hence, the STRIA roadmap is of significant importance to the development of C&AD in the EU.

Recognising the role of ICT and the digital ecosystem, the EU has also launched the Digital Single Market³³ strategy, which aims to create digital opportunities for people and businesses and improve Europe's position as a world leader in the digital economy. As discussed in this study, C&AD and the supporting value chain is an extensively digital sector. For this reason, the Digital Single Market strategy is also an important effort for the development of C&AD.

In fact, the progress in digital technologies is at the core of the progress made to date in C&AD, either linked to the vehicles or the supporting infrastructure. However, as full deployment of vehicles is years away and progress and improvements are necessary, it is still important to take advantage of all upcoming digital opportunities. Especially for industry actors in the C&AD value chain, it is important that they are able to fully benefit from digital innovations. Thus, the EC expects that the Digital Single Market strategy be able to mobilise over €50 billion up to 2020, part of which will also support C&AD, and thus contribute to the EU's competitiveness [219].

Within this framework, and to contribute to the EU's competitiveness, public private partnerships (PPP) are considered a relevant approach. PPP are an approach to coordinate current fragmented R&D&I efforts in key digital technology fields (C&AD included). They are considered enablers of EU-wide digital industrial strategies, and capable of ensuring closer links between R&D&I and standardisation efforts, namely the work on a 5G Action Plan (essential to ensure seamless connectivity in C&AD) [219]. In addition to PPP, the EC recognises IPCEI as an important instrument for large-scale implementations, which is also the case of C&AD.

The EC also envisions the implementation of initiatives supporting the building of the digital industrial platforms of the future. Examples include the combination of IoT, big data and cloud, autonomous systems and artificial-intelligence into integration platforms addressing cross-sector challenges, of which C&AD is an example. In fact, the proposed 'Leadership in IoT' platform will invest, through the

³³ Digital Single Market. <https://ec.europa.eu/digital-single-market/en/digital-single-market>

H2020 budget, in large-scale initiatives, including driverless cars, while also keep a focus on the challenges related to standardisation and regulation.

Within this strategy, the EC also highlights existing work on C&AD. The EC expects to foster cooperation between the telecommunication and automotive industry to accelerate the deployment of C&AD, namely through joint large-scale projects across borders.

With this in mind, the EU Ministers signed on March 23, 2017, a Letter of Intent on the testing and large scale demonstrations of C&AD. The Letter of Intent acknowledges many relevant aspects, including many addressed in this study, such as developing a 'learning by experience approach' to make mobility safer, more efficient and sustainable; to foster synergies among functionalities and technologies (e.g. ITS-5G, LTE and 5G), and consequently implement tests and demonstrations; to engage in cross-border cooperation. Having acknowledged and recognised these and other relevant aspects, the Ministers of 29 European countries that signed the Letter of Intent have agreed to:

- Support the implementation and cooperation on cross-border initiatives and extend existing ones on which research and large scale testing can be done, focusing on road safety, data access, data quantity and liability, connectivity and digital technologies.
- Support the availability of spectrum to ensure that the aforementioned experimentation is based on advanced communication technologies.
- Continue to work with the EC to identify short-term actions (September 2017) for C&AD testing and large scale demonstrations.

It is expected that by implementing the items under this Letter of Intent, the EU automotive, technology and telecommunications industries will gain a competitive advantage in the sector.

The importance of the EU effort in C&AD development can also be assessed from experts' feedback. More than 75% of experts indicated that 'facilitation and testing of C&A vehicles' is 'very important'. This value increases to 85% when considering 'very important' or 'important'. In fact, just as important as developing the technology and the vehicles themselves, is the possibility to legally test them on closed and open-roads. Testing and simulation in a real-life environment is imperative for quality assurance and to ensure C&A vehicles operate as they were designed to.

EU priorities for C&AD

Considering the current status of C&AD in the EU, several priorities have been defined. At the end of 2016, the EC presented its strategy for cooperative intelligent transport systems, in what they considered a milestone towards cooperative, connected and automated mobility [58]. It takes into close consideration the recommendations of the C-ITS Platform final report of January 2016 [158] and defines the short-term objectives for ensuring a coordinated deployment of C-ITS services and C&AD by 2019. The key priorities for the EU and for which funding should be channelled are identified as the following [220]:

- **Deployment of C-ITS services:** The EC aims to see the quick deployment of harmonised and highly beneficial C-ITS services by its Member States, which will be facilitated by the EC's own financial instruments to support research and infrastructure development. The plan includes two lists of priorities: Day 1 C-ITS services and the Day 1.5 C-ITS services (already outlined in Table 13).
- **Security of vehicles and communications:** Cybersecurity is one of the biggest challenges for C&AD. Ensuring the security of vehicles and transport systems is essential as these become increasingly automated, digitised and connected. Tests have shown the possible outcomes and risks of a vehicle being attacked. The initial work of ENISA [130] has already set some guidelines to improve vehicles' security. A coordinated effort with the industry and other stakeholders is important to develop a common and harmonised approach on security and certificate policy for the deployment and operation of C-ITS in the EU.
- **Guaranteeing privacy and data protection:** Connected (and automated) vehicles produce large amounts of data for various purposes. When managed together, they can result in big data, which can also be exploited for multiple purposes. The same can be said about the driver, passengers and pedestrians. The EC considers that data coming from the vehicles and users is personal data. For that reason, there are several data protection regulations that must be considered. It is therefore important to discuss in detail issues of managing vehicle and user data, including how C-ITS providers can ask and obtain consent from drivers regarding their personal information.

- **Ensuring a hybrid approach for telecommunications:** With C&AD, it is important that the send/receive process of information from vehicles to vehicle/infrastructure is established in a safe and seamless way, independently of their location. The EC favours an approach that involves mixing the benefits of complementary communication technologies: a hybrid approach. The EC has already defined the standards and spectrum frequencies it prefers, which implies that road authorities, service providers, vehicle manufacturers and the industry are expected to adopt the EC's strategy for hybrid communication.
- **Ensuring interoperability:** A vehicle is only connected if it is able to *connect* and communicate with other vehicles and infrastructure, independently of their location. Vehicle's systems need to be able to interact with each other at all levels: infrastructure, data, services, applications and networks. This requires an EU level standardisation process and the definition of specifications transversal to all C-ITS initiatives. In parallel, it is also important to consider the possibility of interoperability at the international level.

Many of these priorities are also shared by other key stakeholders in the C&AD value chain, including automotive manufacturers and the telecommunications industry [221]. Their priorities focus on connectivity (i.e. ensuring higher performance levels in terms of latency, throughput and reliability of the network), standardisation (i.e. to ensure a timely and cost efficient market development of C&AD) and security (i.e. to ensure customer trust and safety of data).

The impact of delay in development and deployment of C&AD in the EU

Within the larger discussion of the EU effort to support the development and deployment of C&AD, it is also important to reflect if the EU is lagging behind its competitors and if this in fact has an impact on the EU's competitiveness.

There are two distinct visions that need to be considered when analysing the impact of delaying development and deployment of C&AD: manufacturer and consumer.

From an EU automotive manufacturer's point of view, time is of essence when competing for a global market share. Just like with any product, the advantage of first entry is very evident for C&AV as well. In technologically intensive sector like these, where the cycle of design to deployment can be very erratic, being the first to market can be the difference between commercial success and failure. Thus, from an economic perspective, manufactures may well consider that falling behind in the race for development and deployment can have a direct negative impact on their competitiveness, as well as an indirect impact on the competitiveness of the EU automotive industry. However, on occasion, speed may often be the enemy of accuracy. In such cases, the will to be faster than the competition may neglect special attention to safety and security.

From the consumer perspective, these are likely the two most critical points, which can also influence acceptance and interest in buying these vehicles. While many consumers may prefer high performance vehicles, with C&AV, a driver's safety, that of the passengers and other pedestrians is more important. As vehicles are connected to digital infrastructure, there is also the concern of knowing their information is safe, and not accessible by unwanted third parties. In case of an accident, they are also concerned of who is liable.

These perspectives may to some extent be incompatible. However, in the long term, investing in defining a comprehensive and solid regulation (addressing vehicle requirements, testing, communications, management and security of data, etc.), applicable to all Member States, will likely provide an advantage to the EU compared to its main competitors. The EU must focus on doing C&AD correctly and thoroughly rather than doing it more quickly than other competitors.

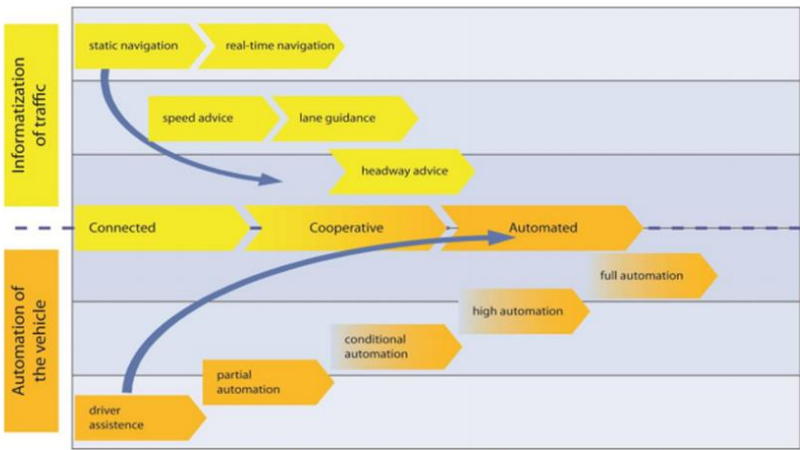
4.3 Subtask 3 – Proposals to reinforce existing support actions and instruments in the EU

Subtask 3 aims at developing proposals to reinforce existing support actions and instruments in the EU. The consortium has attempted to analyse where there are possibilities for Member States to more closely collaborate to avoid duplicating support actions and reinforce coherence within their regulatory actions.

The aim has been to achieve an economy of scale and limit the fragmentation of existing activities (e.g. via fora for dissemination and exchange of results and pooling of resources), improve harmonization and fill existing gaps in support with “responsible competitiveness”, and look to prepare an IPCEI. For this purpose, the major issues linked to a possible application of an IPCEI in the field of C&AD has been analysed in order to make a clear contribution to economic growth, jobs and the competitiveness of the EU.

The EU has moved forward in advancing towards autonomous road travel. The Declaration of Amsterdam “Cooperation in the field of connected and automated driving” [159] signed in April 2016 by the 28 EU Transport Ministers lays out a strong vision for the future of roads. The commitment shown shows determination to see a driverless ground transport infrastructure materialize soon [222]. Table 22 summarizes key points of the Declaration of Amsterdam.

Table 22. Proposals from the Declaration of Amsterdam

Key item	Description
Context for the Declaration of Amsterdam	 <p>Connected, cooperative and automated driving developments should come together to harvest societal benefits.</p> <p>Member States support the development of C&AD through a range of initiatives, such as truck platooning, autopilot on the highway and the establishment of ITS corridors. C&AV are already being tested on public roads and are gradually being introduced in the market for commercial use. In the early stages of this transition, open competition between different models and initiatives is needed to instigate creativity and innovation. However, both industry and users demand that new services and systems should be interoperable and compatible when crossing borders. The EC has taken important steps with the Cooperative Intelligent Transport Systems (C-ITS) platform, the Round Table on Connected and Automated Driving and the Gear 2030 initiative. Nevertheless, a more coordinated approach is necessary between Member States and at a European level to remove barriers and to promote a step-by-step learning-by-experience approach. It is essential to support an exchange of information of results and best practices by linking and integrating such initiatives.</p>
Shared objectives	<ol style="list-style-type: none"> 1. To work towards a coherent European framework for the deployment of interoperable connected and automated driving, which should be available, if possible, by 2019.

Key item	Description
	<ol style="list-style-type: none"> To bring together developments of C&AD in order to reach their full potential to improve road safety, human health, traffic flows, and to reduce the environmental impact of road transport. To adopt a “learning-by-experience” approach, including, where possible, cross-border cooperation, sharing and expanding knowledge on C&AD and to develop practical guidelines to ensure interoperability of systems and services. To support further innovation in C&AV technologies to strengthen the global market position of European industry. To ensure data protection and privacy.
Joint Agenda	<p>This agenda should identify deployment paths for C&AD in passenger and freight transport. The joint agenda should include the following topics:</p> <ol style="list-style-type: none"> Coherent international, European and national rules. The aim is to work towards the removal of barriers and to promote legal consistency. The legal framework should offer sufficient flexibility to accommodate innovation, facilitate the introduction of C&AV on the market and enable their cross-border use. Use of data generated through the use of C&AV can serve public and private value-added services. Clarification is needed on the availability for public and private use and responsibilities of the parties involved. Ensure privacy and data protection respecting existing legislation on privacy and data protection, the conditions for the (re-) use and sharing of data generated by C&AV need to be clarified. Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. In order to maximise benefits in road safety and environmental performance, it is essential to ensure that new services and systems are compatible and interoperable at European level and to coordinate investments towards reliable communication coverage, exploit the full potential of hybrid communications, where relevant, and improve the performance of location accuracy, benefiting in particular from the use of GALILEO and EGNOS. Security in the light of the increase in cyber-threats and serious vulnerabilities. It is essential to ensure security and reliability of C&AV communications and systems. Common trust models and certification policies should be developed to prevent risks and support cybersecurity, whilst ensuring safe and interoperable deployment. Public awareness and acceptance. It is important to manage societal expectations, to raise awareness and increase acceptance and appreciation of C&AV technologies. Common definitions of connected and automated driving should be developed and updated, based on the Society of Automotive Engineering levels (SAE levels) as a starting point. International cooperation. It is important to develop and maintain close cooperation with other regions, particularly the USA and Japan, to work towards a global framework and international standards for C&AV.

4.3.1 Potential role for an IPCEI for the deployment of C&AD in the Union

Important Projects of Common European Interest (IPCEI), as the name suggests, are a mechanism to support projects of common EU interest. They aim to bring together knowledge, expertise, financial resources and economic actors throughout the EU, in order to overcome important market or systemic failures and societal challenges which could not otherwise be addressed.

While IPCEI are considered to be a valuable instrument for the EU's competitiveness in various sectors, there are very few examples of previous projects. One example is the IPCEI on High Performance Computing and Big Data enabled Applications, which is coordinated by the Luxembourg Ministry of the Economy [223].

The High Level Group on Key Enabling Technologies²²⁴ recommended to the EC and Member States the use of large scale funding instruments such as IPCEI in strategic industrial domains such as C&AD. The EC highlighted the importance of this new funding instrument, having given guidance on the implementation of IPCEIs [225].

Many stakeholders promote the idea to build on existing activities at all levels and to use an IPCEI to realize an integrated European strategy for C&AD. This can be done by combining private and public efforts and financial resources in a transparent and consistent way. The EC has adopted a Communication on IPCEIs aimed at encouraging Member States to channel their public spending to large projects that make a clear contribution to economic growth, the creation of jobs and the competitiveness of Europe. Where private initiatives fail to materialise because of the significant risks and the transnational cooperation they involve, Member States may fill the funding gap to overcome these market failures and boost the realisation of projects that otherwise would not have taken off.

The EC has defined criteria under which Member States can support transnational projects of strategic significance for the EU and for the achievement of the Europe 2020 objectives, in line with EU state aid rules. This is part of the EC's State Aid Modernisation (SAM) initiative, aimed at fostering growth and competitiveness in the EU. The communication entered into force on 1 July 2014. This opens up avenues of potential ambitious transnational projects on C&AD which qualify under these rules. Key features of the IPCEI communication are [226]:

1. Extending existing provisions on IPCEIs to any sector of the economy: EU state aid rules on research (see IP/06/1600 and MEMO/06/441) and the environment (see IP/08/80 and MEMO/08/31) already contained some provisions on IPCEIs, which are replaced by the Communication. The new provisions are neutral as to the sector where the IPCEI project is realised. This will make it much easier to support important projects with a clear European dimension in areas such as R&D, cross-border transport, or energy that would otherwise have needed to be assessed under several different sets of rules.
2. Diversifying forms of support: Member States may grant repayable advances, loans, guarantees or grants to IPCEIs.
3. Increasing aid intensity: where justified, public support may cover up to 100% of the funding gap on the basis of a large set of eligible costs.
4. Allowing aid for the first industrial deployment of an R&D project: i.e. during the up-scaling of the pilot facilities and the testing phase.

As indicated in this study, the EU and its Member States are supporting the development of C&AD through a range of initiatives. Some vehicles are already being tested on public roads and are gradually being introduced in the market for commercial use.

The research developed within the field includes important industrial deployments, which would deliver new products and new services. These new products and services can increase traffic safety, reduce CO₂ emissions, give new possibilities for elderly or impaired people, and boost Europe's economy by increasing its technological advance, safeguarding current jobs, increasing Key Enable Technologies skills in education and developing new business models.

It is expected that the successful development of C&AD will have a significant positive spill over effect at societal and economic level. It will import compelling added value of R&D&I, create industrial and innovative value across the EU, and thus contribute to Europe's sustainable growth while addressing societal challenges with new products and services such as traffic management, car sharing and others.

The development of C&AD should be considered as a highly strategic issue particularly important to assure the maintenance of global leadership of Europe's car industry.

To ensure a highly competitive automotive manufacturing sector in Europe, a successful strategy must build on existing strengths and assets of the C&AD value chain. It is important to reduce fragmentation of existing activities and look to improve harmonization by filling existing gaps in the field of C&AD. It is also important to bear in mind that, as stated by the European Automotive Research Partners Association, the strategic importance of C&AD for the competitiveness of the EU automotive industry requires the joint effort of all stakeholders, beyond even the classical collaborative research and innovation projects.

To retain and further develop C&AD in the EU framework means that public and key industrial stakeholders work closely together. It is vital to establish an inclusive governance structure involving

public authorities at national and regional level and private stakeholders. As referred by the GEAR 2030 Discussion Paper, there is a strong need for a C&AD coordinated approach and priority setting for funding research, demonstration and deployment activities at EU and national levels in order to maximise synergies and avoid fragmentation between different programmes and regulations. The successful deployment of C&AD and its application to the EU market needs to overcome legal and infrastructure barriers as well as consider the new merged challenges for the traditional automotive value chain.

4.3.2 Opportunities and Threats of IPCEI for C&AD development

In addition to involving a considerable level of technological and innovation development, C&AD also entails financial risks especially due to a degree of uncertainty regarding the future of the C&AD industry. An IPCEI on C&AD could facilitate and promote combined funding to overcome financial gaps, by combining private and public efforts and financial resources in a transparent and consistent way.

An IPCEI will be able to leverage industrial investments and push the development of technologies, infrastructures, service, business models and normative measures. It is expected that an IPCEI will enable Member States to offer a diversified portfolio of support mechanisms and, in justified cases, allow public support for funding gap on the basis of a large set of eligible costs.

It could also encourage companies to work on projects of EU dimension to enhance competition in the C&AD sector, as well as facilitate market utilisation of products and services developed within the field. Most importantly, a C&AD IPCEI could make a clear contribution to overcome European barriers and challenges.

An IPCEI on C&AD would enable the build-up of significant industrial capacity by initiating and harmonizing critical R&D efforts across the Member States and with the EC. It will be able to compromise and put together different automotive stakeholders from the car industry, as well as the IT industry, the insurers, interested groups such as the European Automotive Research Partners Association, the GEAR 2030 Group and policy makers at national level (Ministers, Commissioners) and at the EC DG interested.

The IPCEI would enable the exchange of data and experience between EU countries, addressing legal and infrastructure barriers and challenges, being able to focus on different pillars such as connectivity, liability, road safety and testing. It will also contribute to the development of a better understanding of the economic and social impact of the rise of automated vehicles and digital platforms in the EU automotive value chain, and support EU stakeholders to deliver the best results at societal and economic levels.

The IPCEI, as an appropriate tool to finance this particular large transnational project of strategic importance, can contribute to overcome emerging societal challenges due to C&AD development, such as driver acceptance, data issues, interaction driver/vehicle/other users, ethical issues, environmental issues, and social inclusion, as well as have a clear idea of the economic issues in terms of impact on Europe's economic activities. It can contribute to overcome market failure of private initiatives and generate benefits for a multitude of EU stakeholders, not only those that have already been working on this specific field, but a wide range of actors from various sectors such as IT, law, and insurance.

Added value of an IPCEI on C&AD

Creating a specific IPCEI on C&AD would enable Member States to put more significant resources in the development of C&AD technology, including its implementation towards mass deployment. Proposing C&AD as an IPCEI creates a significant advantage in increasing the funding available for R&D of C&AD.

Compared to other existing EU financial instruments, a C&AD IPCEI would allow Member States to pool their resources, expertise, and technologies in order to develop technology that would benefit all Member States. This is highly important considering the disparity of C&AD technology from one Member State to another. The creation of a C&AD IPCEI will stimulate less-advanced Member States to also start their R&D programme focusing on C&AD technology.

Since IPCEI projects are also funded through state aid mechanisms, it would not only improve the level of expertise and technology, but also holds the potential of an economy and societal spill over effect. One of these spill over effects is accelerating the provision of regulations and laws needed for the deployment of new technologies. With the currently problematic condition of C&AD regulations, the IPCEI could trigger the provision of the necessary laws and regulations.

In terms of financial sources, under the current provision, state aid mechanisms allow for an IPCEI to be extended to any sector of the economy. The new provisions are neutral as to the sector where the IPCEI project is realised. This will make it much easier to support important projects with a clear EU dimension in areas such as R&D, cross-border transport, or energy that would otherwise have needed to be assessed under several different sets of rules. Member States supporting the IPCEI may grant repayable advances, loans, guarantees, or grants to IPCEIs. This allows for a greater variety of state funding to be directed into the R&D&I of IPCEI.

Moreover, a C&AD IPCEI would allow Member States to cover up to 100% of the funding gap on the basis of a large set of eligible costs. This is important considering the current state of C&AD that still needs research, including pilot testing and pre-deployment feasibility studies. Financial support at this phase is critical since the market value of the technology might still be unknown.

Thus, the implementation of a C&AD IPCEI will expectedly bring significant support both in the research and deployment phase as well as in answering obstacles related to legal and regulation aspects. The wide range of opportunities foreseeable by the C&AD market development make C&AD one of the top priorities in the European transport strategy.

However, it is important to note that, in parallel to public funds coming from Member States³⁴, in the context of a potential IPCEI, other EU financial instruments should continue to be used. In this context, monitoring the synergies and coherence among the different national and EU instruments will be essential in order to increase the global effectiveness of C&AD support in the EU. This monitoring should be linked to the implementation of a global vision and strategy to be developed in relation to the objectives of the Declaration of Amsterdam and the GEAR 2030 conclusions. Based on this review, the following opportunities and threats can be considered for a C&AD IPCEI.

Opportunities

- **Promoting cooperation among Member States on strategic cross-border projects:** A C&AD IPCEI would concentrate on well identified investment projects that Member States cannot support alone because of the high level of risk or important financial dimension.
- **High involvement of private stakeholders along the whole value chain:** A C&AD IPCEI would allow the involvement of private stakeholders willing to be a part of the C&AD ecosystem, and allow them to put forward their legitimate interests and to defend their arguments. This is also an opportunity to involve smaller companies and start-ups (including those linked to the innovative transport sector) which, by being involved in a project of this size, will have more business opportunities and growth potential. This is particularly important for smaller companies in this sector who constantly face the challenges of the 'valley of death' because of the high risks involved and the long waiting periods before revenues are a reality.
- **Alignment with the EU's objectives:** A C&AD IPCEI would help the EU face the important transportation challenges it is facing. It can be aligned with several of the EU's objectives and strategies, namely Europe 2020 strategy, European strategy for KETs, Energy Strategy for Europe, Electronics Strategy for Europe, Trans, European Transport and Energy networks, European Union's land transport policy.
- **Advance European manufacturers:** The EU has some of the world's leading manufacturer in the automotive industry, which have been investing a considerable amount into R&D. A C&AD IPCEI can contribute to developing cooperation and synergies that are needed to achieve the economy of scale essential for remaining competitive in the global market.
- **Reinforcing EU coherence in funding mechanism:** An IPCEI is a new instrument that could be put in place in the context of a global EU C&AD support strategy and reinforce the synergies with other existing support actions and funding mechanisms at EU or national level. The establishment of an IPCEI, which entails a significantly high project budget, will likely be more appealing to many European companies from the C&AD sector. Many larger companies do not consider existing funding programmes (e.g. H2020) sufficiently appealing to their

³⁴ The lack of publicly available information on IPCEI does not give ample reference with regards to Member states stance on their willingness to cooperate and fund projects having such a European dimension. However, this is a crucial discussion and plays an essential role in their industrial strategies towards C&AD and hence should be deliberated in the Expert Workshop.

business development, and are also not aware of other alternative instruments (e.g. CEF, EIB) that can meet their needs. An IPCEI would constitute an interesting solution in such cases.

- **Contribute to the priorities of the Declaration of Amsterdam:** Under the auspices of Netherlands's presidency, the EU has called for greater cooperation across stakeholders in the field of C&AD. This has created a momentum conducive for the C&AD IPCEI to which it can contribute. Not only can the IPCEI contribute to the priority of greater cooperation (addressing use of data, security, communication, and support to awareness and acceptance), through its mobilisation capacity, it can also contribute to an accelerated change of regulations and policies to facilitate C&AD development and deployment. As the IPCEI can (and ideally should) involve various companies (e.g. technology-focused start-ups, SMEs, large companies), a change in legislation and regulations can facilitate their operations and their growth.

Threats

- **Disparity of C&AD technology level:** Levels of C&AD development and deployment across EU countries are currently very different. Countries with strong automotive manufacturers such as Germany, Sweden or France have considerably more advanced technology in C&AD compared to other Member States. This could limit the number of Member States willing to be involved in such an initiative.
- **Disparity in infrastructure development:** Since the possible Member States and stakeholders to be involved in the IPCEI may come from varied infrastructure conditions, the likelihood of implementation of the project in Member States with less developed infrastructure might adversely impact/ delay the execution of the desired activities at the same pace.
- **Extensive preparation and implementation process:** Considering the scale of the project, the preparation and implementation of the C&AD IPCEI may take at least three years. This is a considerably extensive process in a dynamic sector like C&AD.
- **Public opinion of C&AD:** The issue of insurance and liability as well as safety and security is still one of the main obstacles for pre-deployment of C&AD. Without addressing these issues at the EU level as well as involving the wider public in C&AD research and innovation, it might impact potential C&AD deployment.
- **Lack of integration of the regulatory framework and common standards:** A possible threat is the disintegrated regulatory framework/ philosophy governing the participating Member States and their inclination towards continuing to favour the original national regulations and standards as compared to an EU-wide framework.
- **Cybersecurity risks:** Cybersecurity risks are a major concern when cross country projects like the IPCEI need to be executed. Regular and transparent procedures with regard to the sharing of information amongst the concerned national agencies needs to be done.

4.3.3 Possible use of other existing financial instruments

An IPCEI may help C&AD acquire stable financial sources. However, the existence of several financial instruments provided by European institutions such as a contractual PPP (cPPP) in Horizon 2020, EIB loans, Eureka, ERA-NET EFSI, as well as CEF should also be considered to support the development of this technology. Using these different instruments would allow a more inclusive and beneficial deployment of C&AD that would impact Member States across the EU.

First, the **Connecting Europe Facility** (CEF)³⁵ is a key EU funding instrument to promote growth, jobs and competitiveness through targeted infrastructure investments at the EU level. It supports the development of high performing, sustainable and efficiently interconnected trans-European networks in the fields of transport, energy and digital services. CEF investments fill the missing links in the EU's energy, transport and digital backbone.

The CEF benefits people across all Member States, as it makes travel easier and more sustainable, enhances the EU's energy security while enabling wider use of renewables, and facilitates cross-border interaction between public administrations, businesses and citizens. In addition to grants, the CEF offers financial support to projects through innovative financial instruments such as guarantees and

³⁵ Connecting Europe Facility. <https://ec.europa.eu/inea/en/connecting-europe-facility>

project bonds. These instruments create significant leverage in their use of EU budget and act as a catalyst to attract further funding from the private sector and other public sector actors.

The CEF is divided into three sectors, namely CEF Energy, CEF Telecom, and CEF Transport. CEF Transport is the funding instrument to realise EU transport infrastructure policy. It aims at supporting investments in building new transport infrastructure in Europe or rehabilitating and upgrading existing infrastructure. It focuses on cross-border projects aiming at removing bottlenecks or bridging missing links in various sections of the Core Network and on the Comprehensive Network, as well as for horizontal priorities such as traffic management systems. CEF Transport also supports innovation in the transport system in order to improve the use of infrastructure, reduce the environmental impact of transport, enhance energy efficiency and increase safety. The total budget for CEF Transport is €24.05 billion for the period of 2014-2020. Therefore, it can be seen that C&AD development could greatly benefit from CEF Transport cluster in order to foster its development across Europe.

The **ERA-NET** instrument under Horizon 2020 is designed to support public-public partnerships and could also be used as a resource to foster C&AD development. The ERA-NET instrument focuses mainly in the preparation, establishment of networking structures, design, implementation and coordination of joint activities as well as topping up of single joint calls and actions of transnational nature.³⁶

ERA-NET merges the former ERA-NET and ERA-NET Plus into a single instrument with the central and compulsory element of implementing one substantial call with top-up funding from the EC. The focus of ERA-NET is therefore shifting from the funding of networks to the top-up funding of single joint calls for transnational research and innovation in selected areas with high European added value and relevance for Horizon 2020.

Another major channel that can be use in fostering C&AD development is through the **public-private partnership** (PPP) approach that is made possible through Horizon 2020. This concept has been further developed to also include improvements regarding simplifying the involvement of participants, increasing support for SMEs and putting more of the focus on industry and research institutions to identify potential innovative solutions to the different challenges.

The **contractual public-private partnerships** (cPPP)³⁷ in Horizon 2020, which provide an introduction to the PPP scheme under Horizon 2020 funding, state that for a PPP to be supported under Horizon 2020, it must prove that the results will provide added value at the EU level and boost industrial competitiveness and sustainable growth. It must also have a convincing long-term roadmap for research and innovation activities. With the potential of C&AD in advancing the automotive and ICT sectors, it aligns with the cPPP goals under Horizon 2020. Therefore, with the great impact of C&AD development for the automotive, transportation, and logistic industry in Europe, it can already be seen that C&AD has the potential to be funded by Horizon 2020 using the PPP scheme. [227]

This allows a new perspective for the development of C&AD where both public and private sectors have a role in further developing and increasing the possibility of deployment of C&AD in the future. The PPP scheme also helps answer not only funding and research issues, but also legal and regulation aspects that have been considered one of the biggest challenges to the development of C&AD in Europe. With the participation of the public sector in C&AD, it will increase the know-how as well as the expertise that can influence law makers in EU to create regulations in favour of C&AD.

A **European Technology Platform** (ETP)³⁸ is also an alternative instrument. ETP are industry-led stakeholder fora recognised by the EC as key actors in driving innovation, knowledge transfer and European competitiveness. ETPs develop research and innovation agendas and roadmaps for action at EU and national level to be supported by both private and public funding. They mobilise stakeholders to deliver on agreed priorities and share information across the EU. By working effectively together, they also help deliver solutions to major challenges of key concern to citizens. ETP are independent and self-financing entities. They conduct their activities in a transparent manner and are open to new members.

The C&AD IPCEI could also benefit from funding provided by the **European Investment Bank** (EIB) under the scheme of European Fund for Strategic Investments (EFSI). EFSI is a €16 billion guarantee

³⁶ ERA-NET Instrument (Horizon 2020). http://ec.europa.eu/research/era/era-net-in-horizon-2020_en.html

³⁷ Contractual Public-Private Partnerships. http://ec.europa.eu/research/industrial_technologies/ppp-in-research_en.html

³⁸ European Technology Platforms. http://ec.europa.eu/research/innovation-union/index_en.cfm?pg=etp

from the EU budget, complemented by a €5 billion allocation of the EIB's own capital. EFSI has been integrated into the EIB Group and projects supported by EFSI are subject to the normal EIB project cycle and governance. It has its own dedicated governance structure which has been defined to ensure that the investments made under EFSI remain focused on the specific objective of addressing the market failure in risk-taking which obstruct investment in Europe. In doing so, EFSI would also increase the volume of higher risk projects supported by the EIB Group. The EIB Group also focus on sectors of key importance where proven expertise and the capacity to deliver a positive impact on the EU economy exists. This includes strategic infrastructure in the digital, transport and energy sectors; education, research, development and innovation; expansion of renewable energy and resource efficiency; as well as support for smaller businesses and midcap companies.³⁹ From these examples, it can be seen that there are various opportunities upon which the development of C&AD can be financially supported. Some of the financial instruments at the EU level are directly related with the goals and objectives that C&AD addresses.

4.3.4 Alignment of C&AD IPCEI with the IPCEI Criteria

Considering the presentation regarding the basis for an IPCEI, this section outlines how the proposed C&AD IPCEI would be defined and how it is aligned with the IPCEI criteria. The IPCEI is based on the Communication from the Commission 'Criteria for the analysis of the compatibility with the internal market of State aid to promote the execution of important projects of common European interest' (2014/C 188/02) [225].

Project definition

Table 23: C&AD IPCEI project definition

Criteria	Justification
Objectives	The C&AD IPCEI should be a single project with clearly defined objectives and implementation methods, including its participants and its funding.
Implementation	It could notably focus on large scale demonstrations, pre-deployment projects and pilot initiatives involving all relevant stakeholders to accelerate the implementation of C&AD and identify and address barriers. A C&AD IPCEI could be launched in parallel with a contractual Public-Private Partnerships (PPP) or a specific European Technology platform. This is important to address at the same time some of the most basic challenges in C&AD technology, especially concerning laws and regulations. Considering the nature of C&AD technology that affects many sectors, utilizing PPP will also facilitate the setting of clear objectives in terms of research sectors and coordination across several research themes. PPP will also help create a long-term strategy that will put all European market players into consideration and thus develop research and innovation projects to support the competitiveness of European automotive and ICT industries.
Participants	A C&AD IPCEI should involve participants from the public and private sectors from Europe. These can include private companies developing vehicle R&D, technology and equipment manufacturers, and companies connected to infrastructure development, for example. It can also include public entities responsible for legislation, regulation and standardisation, entities responsible for road safety, driving and vehicles, and entities responsible for transport infrastructures. Initial participants of the IPCEI will be those motivated by the project of common European interest. New participants from initially represented Member States or new participants from other Member States will also be welcomed to join if their objectives are aligned with those proposed.
Funding	A C&AD IPCEI should enable further development of C&AD using state aid mechanisms that could provide public support to cover the funding gap on the basis of a large set of eligible costs. A C&AD IPCEI may also allow aid to be disbursed for the first industrial deployment, which is important in order to further develop C&AD technology. Considering the significant investments required, a

³⁹ What is the European Fund for Strategic Investments (EFSI)? <http://www.eib.org/efsi/what-is-efsi/index.htm>

Criteria	Justification
	C&AD IPCEI and related potential c-PPP should also seek to complement public investments with private investments (national and international), and financial support from European Institutions and programmes such as, EIB loans, Eureka, ERA-NET, EFSI, as well as CEF. This is justified with the ability of the C&AD IPCEI in promoting growth, jobs and competitiveness through targeted infrastructure investment at European level.

Project of Common European Interest: Eligibility Criteria

The criteria that define a project of common European interest includes (1) general cumulative criteria, (2) general positive indicators and (3) specific criteria. Each of these main criteria points includes various sub criteria.

- General cumulative criteria (items 1-5);
- General positive indicators (items 6-10);
- Specific criteria (items 11-13).

Table 24 details how the proposed C&AD IPCEI is aligned with each of these three criteria items.

Table 24: Common European Interest Criteria

Criteria to be considered	Justification
General Cumulative Criteria	
1. Contribution to one or more Union objectives; significant impact on the competitiveness of the Union, sustainable growth, addressing societal challenges or value creation across the Union.	<p>A C&AD IPCEI is aligned with several of the EU's objectives and strategies. Within each of these, it contributes to one or more of their specific objectives and/or priorities, as detailed below:</p> <p><u>Europe 2020 strategy</u> [228]</p> <ul style="list-style-type: none"> • Smart growth – developing an economy based on knowledge and innovation: R&D on C&A vehicles, electronics and other components, IT security, data, and planning and infrastructure represent a fundamental source of new knowledge within the area and with great innovation potential. However, this knowledge and innovation can also be linked to other relevant areas at the EU level: electronics (see Electronics Strategy for Europe, below), big data, ICT and the Digital Single Market, among others. • Sustainable growth – promoting a more resource efficient, greener and more competitive economy In the various processes leading to the development of C&A vehicles, development of technology, equipment and components, and the upgrade or development of infrastructure, these will be done while aiming for a reduced carbon footprint. Vehicles and their multiple components should be based on greener and more efficient materials. Greener manufacturing processes should also be targeted. <p><u>European strategy for KETs (Pillars)</u> [229]</p> <p>As previously mentioned, the High Level Group on KETs had recommended an IPCEI on C&AD. The proposed IPCEI will be aligned with the European Strategy for KETs and its three pillars:</p> <ul style="list-style-type: none"> • Technological research C&AD vehicles, their equipment and components, the data they generate and collect, and their link to infrastructure involve intensive technological research that, as previously mentioned, can be later absorbed by other sectors and markets (and is thus

Criteria to be considered	Justification
	<p>of wider relevance to and application to the EU economy/society).</p> <ul style="list-style-type: none"> Product demonstration After technological research and development, C&AV will be subject to extensive demonstration (and testing) at TRL level 5. The IPCEI could contribute to creating the conditions for demonstration and validation reaching TRL 9. Developing competitive manufacturing activities Manufacturing activities linked to the deployment of C&AV and infrastructures are one of the main activities that could be financed within an integrated C&AD IPCEI. <p><u>Energy Strategy for Europe</u> [230]</p> <ul style="list-style-type: none"> Achieving an energy-efficient Europe (Action 1 – Tapping into the biggest energy-saving potential – buildings and transport) Within the priority of ‘achieving an energy-efficient Europe’, action 1 addresses the transport sector. While C&A vehicles do not have to be fully electric (i.e. vehicles can run using internal combustion engines), the IPCEI can prioritise vehicle R&D that use electric vehicles. <p><u>Electronics Strategy for Europe</u> [231]</p> <ul style="list-style-type: none"> Setting up an EU-level mechanism to combine and focus support to micro- and nano-electronics R&D&I by Member States, the EU and the private sector A C&AD IPCEI, while not directly supporting the establishment of an EU-mechanism for micro- and nano-electronics R&D&I, could look at creating synergies with such a mechanism. C&A vehicles, their electronics and components, and road infrastructure depend on the R&D&I in these two segments of electronics. Thus, an IPCEI can involve participants from the private sector from the electronics field. <p><u>Trans-European Transport and Energy networks</u> [232]</p> <ul style="list-style-type: none"> Transport (Road travel) A C&AD IPCEI can take advantage of Member States’ five million km of paved road for the deployment of C&A vehicles. <p><u>European Union’s land transport policy</u> [233]</p> <ul style="list-style-type: none"> Promote mobility that is efficient, safe, secure and environmentally friendly Driver and citizen safety is a major concern with the development and deployment of C&A vehicles. On the other hand, the deployment of C&AD has the capacity of decreasing the number of road traffic accidents caused by human error. Thus, activities within the IPCEI can look to develop increasingly safe and secure connected vehicles, not only regarding road use, but also the safe and secure management of driver data. Also, and aligned with the Energy Strategy for Europe, the IPCEI can also be related to R&D on greener C&AV, favouring (whenever possible) electric or hybrid vehicles over those with internal combustion engines.
2. Involves more than one Member State, and its	Considering the high number of Member States that are already involved in the development and deployment, an IPCEI could reach

Criteria to be considered	Justification
benefits not confined to the financing Member States, but extend to a wide part of the Union. The benefits of the project must be clearly defined in a concrete and identifiable manner.	the dimension of a Europe-wide project. The IPCEI can involve Member States as well as its local governments and its results could be extendable to other Member States and the European Union. Member States can witness the multiple benefits with the expansion of the IPCEI to their respective country. Benefits vary according to the level of deployment and if they are short or long-term. Assuming a large deployment of C&A vehicles, short to long-term benefits include: improvements in road infrastructure, reduction in traffic accidents (and related casualties), improved congestion in large cities, improved environmental conditions, among others.
3. Benefits of the project must be of wider relevance and application to the European economy or society through positive spill over effects.	A C&AD IPCEI could be of relevance to other areas outside of C&AD, with spill over effects and impacts in other sectors. Beyond C&AD and road transport, positive spill overs are expected in other transport modes and sectors, with new knowledge and innovations related to electronics, big data, security, manufacturing, and others.
4. Involves co-financing by the beneficiary	All participants involved in a C&AD IPCEI would normally be required to contribute and co-finance the project.
5. The project must respect the principle of the phasing out of environmental harmful subsidies, recalled by the Resource Efficiency Roadmap [234] as well as several Council conclusions.	In developing C&A vehicles and the necessary infrastructure to ensure its successful deployment, participants of the IPCEI will be required to respect the principle of phasing out of environmental harmful subsidies.
General Positive Indicators	
6. Project must be designed to allow for the participation of all interested member states.	To respect the principle of 'common European interest', all Member States that are interested in developing and/or deploying C&AD in their countries will be allowed to participate in the project. Member States interested in joining will be required to present their strategy for participating in the IPCEI.
7. Design of the project involves the Commission or any legal body to which the Commission has delegated its powers.	The design of a C&AD IPCEI will benefit from the work of GEAR 2030, launched by the EC in February 2016. Under Working Group 2, GEAR 2030 was specifically tasked with identifying the instruments to be mobilized for the development and deployment of C&AV, among which an IPCEI. The involvement of the Commission within the development of a potential C&AD IPCEI could be done already in the context of the pre-notification phase.
8. Governance structure of the project involves the commission and several MS.	The governance structure could involve the most concerned Member States and Commission services.
9. Involves important collaborative interactions in terms of number of partners, involvement of organisations from different sectors, or involvement of undertakings of different	A C&AD IPCEI should be a Europe-wide coordinated project between various partners from participating Member States, but open to new participants and Member States during its implementation. It will involve and welcome partners from the private sector and public entities from all Member States. Partners will necessarily be linked to vehicle R&D, technology and equipment manufacturing, regulatory and standardisation bodies and infrastructure.

Criteria to be considered	Justification
sizes.	
10. Involves co-financing by a Union fund.	In addition to funding originating from the participants involved in the project, and national funds (e.g. regional and structural) approved through state-aid, additional EU funds will be targeted, namely those from the ERDF, EIB, EFSI and H2020.
Specific Criteria	
11. R&D&I projects must be of a major innovative nature or constitute an important added value in terms of R & D&I in the light of the state of the art in the sector concerned.	<p>The automotive industry has witnessed numerous innovative advances since its establishment. Currently, one of the industry's main challenges is the development of C&AV at different automation levels, respecting the safety of road users. This challenge has already led to multiple R&D endeavours and many innovative solutions.</p> <p>The C&AD IPCEI should try to combine efforts in this area to further develop highly innovative solutions for vehicles, electronics and other components and infrastructure. It should demonstrate its contribution to important EU societal challenges and policy objectives such as injury and fatality reduction. In particular, it should aim to develop and deploy innovative solutions in line with EU environmental standards. This is done by allowing the production of C&AV with greener materials and processes. Also, the deployment of C&AD may reduce emissions from vehicles due to an increase in fuel economy (e.g. with truck platooning) and increase citizen safety on the roads.</p>
12. Projects comprising of industrial deployment must allow for the development of a new product or service with high research and innovation content and/or the deployment of a fundamentally innovative production process.	<p>A C&AD IPCEI can contribute to the transformation of the transportation system and its management in cities across the EU via the deployment of substantial innovation in the automotive and manufacturing industries. This transformation could concern not only the use of vehicles for personal usage, but also other vehicles including buses, trucks, and taxis.</p> <p>In addition, due to the nature of this project, it will not only impact the automotive and manufacturing value chain but also significantly increase ICT development. With a C&AD IPCEI, obstacles related to cyber security will need to be addressed and further developed to ensure the security and safety of automated vehicles. Therefore, the proposed C&AD IPCEI could certainly result in the deployment of innovative production process.</p>
13. Environmental, energy or transport projects must either be of great importance for the environmental, energy, including security of energy supply, or transport strategy of the Union or contribute significantly to the internal market, including, but not limited to those specific sectors.	<p>As mentioned in Point 1, the C&AD IPCEI can be aligned with several of the Union's objectives and/or strategies, including some related to energy and transport. While the project will be important for the EU's environmental/energy strategy, it will be of great importance to the EU's transport strategy, namely the land transport strategy. The EU's land transport policy aims to promote mobility that is efficient, safe, secure and environmentally friendly.</p> <p>Activities within the C&AD IPCEI can contribute to develop increasingly safe and secure connected vehicles. Safety and security will not be limited to the vehicle, but also to the collection and management of user data. Likewise, and to promote more environmentally friendly transport, the IPCEI can privilege greener vehicles, equipment and other components, using whenever possible greener processes.</p> <p>Moreover, the deployment of C&AD could reduce emissions due to a more efficient fuel usage, less traffic congestion, and smoother driving and traffic flow.</p>

4.3.5 Proposal for a Connected and Automated Driving (C&AD) City Challenge

As discussed in the Background section of the study (see Section 1.2.5), C&AD can introduce several novelties to cities, namely their transport systems and how they can shift from traditional cities to *smarter* cities. Considering the role C&AD can play on the dynamics of modern cities, a specific deployment action can also be considered, based on the successful execution of the USDOT Smart City Challenge in the USA.

Background context: The USDOT Smart City Challenge

On October 13, 2016, Columbus (Ohio) was selected as the winner of the US Department of Transportation's (USDOT) Smart City Challenge. As the winner of the challenge, Columbus will receive \$40 million USD from the USDOT and \$10 million USD from Vulcan Inc. to supplement the \$90 million that the city has already raised from other private partners to carry out its plan. Using these resources, Columbus will work to reshape its transportation system to become part of a fully-integrated city that harnesses the power and potential of data, technology, and creativity to reimagine how people and goods move throughout their city.

Although only Columbus will be funded through this challenge, experts are of the opinion that this challenge has been able to create a conducive environment for C&AD in the remaining 77 candidate cities. When a city makes the effort to propose an entire smart transport system, not winning the prize might not stop them from trying to look for alternative source of funding to make the proposal a reality. This expected ripple effect of the USDOT Smart City Challenge makes it an interesting option to increase research and its replicability in the EU.

Figure 19 summarises the important participation numbers and geographic reach of the US DOT Smart City Challenge.

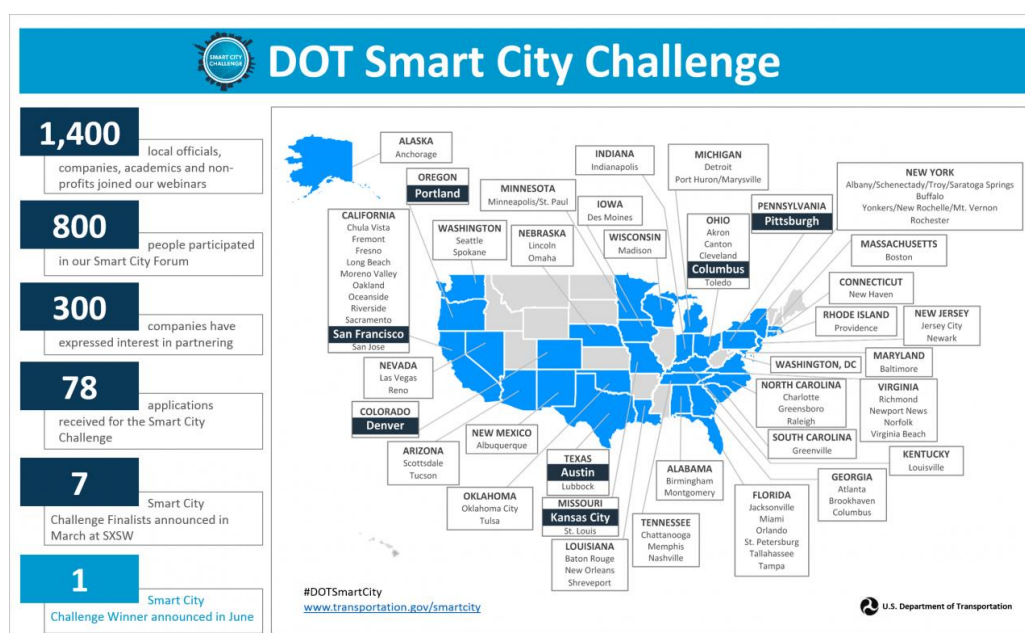


Figure 19: US DOT Smart City Challenge

Source: US Department of Transportation

Through the C&AD City Challenge, the EC would encourage cities to present their best and most creative and innovative ideas for addressing the transportation challenges they are facing. The vision of the C&AD City Challenge would be to demonstrate and evaluate a holistic, integrated approach to improving driving and transportation performance within a city.

The challenge would be to address how emerging transportation data, technologies, and applications can be integrated with existing systems in a city to address transportation challenges. The EC would expect bold and innovative ideas for proposed demonstrations to effectively test, evaluate, and demonstrate the significant benefits of C&AD City concepts.

05. Key findings and policy implications

5 Key findings and policy implications

This section provides the **key findings of the study** and **recommendations** to support future assessment of support measures in the area of C&AD.

First, the section presents a summary of the most important findings and results of the study. Taking into account these findings and results, recommendations are provided to support additional funding, cooperation, testing and deployment of C&AD (either by the EC or by Member states) in the future. Other aspects such as potential information gaps are considered in the development of the recommendations.

The recommendations have been validated with key experts. This has been done to verify that the study has been conducted according to a relevant scope, using appropriate methods, and reliable data.

A workshop was also organised at the end of the project to validate the key findings and recommendations.

5.1 Key findings from the study

Based on the primary information collected through the questionnaire and interviews and secondary information available in process of literature review, a series of key findings have been identified. Table 25 lists the key findings of the study. These are presented for each of the Tasks and sub-tasks.

Task 1: Comparative analysis of public support measures, programmes and regulations put in place in USA, Japan, South Korea, China and the EU

Table 25. Task 1 – Key findings of the Study

Sub-Task	Key findings (KF)
General strategies for promoting C&AD	<p>KF_01. Several EU Member States have implemented regulatory initiatives, mostly focusing on the rules and conditions for testing C&A vehicles on national roads. This is linked to a strong concern in ensuring strict legal conditions during testing and to guarantee the safety of drivers, passengers and pedestrians, both on and off public roads. Beyond testing, other issues should be considered, notably at the European level (e.g. data privacy and security, insurance and liability, among others).</p> <p>KF_02. There is a lack of a more comprehensive strategic policy framework regarding the development of C&AD in Europe (which would allow a clearer definition of long-term goals, priorities and actions). There are many initiatives, but mainly done at the Member State level (e.g. revision of legislation, testing, support to infrastructure). Thus, Europe is somewhat fragmented in the sector. However, recent initiatives (e.g. Declaration of Amsterdam, C-ITS) or the Letter of Intent on the testing and large scale demonstration of C&AD are positive signs of the EU's intentions for the C&AD sector and development of a coherent strategic framework. Japan and South Korea have more coherent policy frameworks, mainly because of a longer past linked to ITS that has supported initiatives with a focus on C&AD. The USA, for example, also shows some policy differences across States.</p> <p>KF_03. Many EU countries have to make strategic choices in terms of public investment to comply with EU-defined budgetary standards. Thus, their investment capacity in the C&AD sector is limited. This limits the country's own competitiveness and parity to other countries in the sector and the EU's competitiveness compared to other leading players. Therefore, it is important to develop PPP with the private sector, from SMEs to large multinationals to support investments along the overall value chain (vehicle R&D, technology and component manufacturing, infrastructure).</p> <p><u>Supporting Evidence from Primary Information:</u></p> <p>Q1A.1: The majority of experts indicated one or more C&AD related strategies being implemented in their country.</p> <p>Q1A.2: According to experts, the most important factors for C&AD deployment are 'technology development' (100% very important or important), 'sustainability and regulation' (>80% very important or important) and 'initiatives to promote public awareness and acceptance' (~60% very important or important).</p> <p>Q1A.3: The safety of citizens, whether drivers or pedestrians, was the most common advantage of C&AD indicated by experts. Other advantages related to human well-being (e.g. increased productivity, social inclusion and greater mobility for people) and environmental benefits were also frequently indicated.</p> <p>Q1A.4: More than 75% of experts strongly agree or agree that both the public and private sector should pay equal attention to the development and</p>

Sub-Task	Key findings (KF)
<p>Major research and large scale industrial programmes/ projects co-financed with public funds from 2011-2016</p>	<p>deployment of C&AD.</p> <p>KF_04. The EU as a whole and individual Member States have established R&D programmes (e.g. Automated Road Transport topic under Europe's Horizon 2020 programme) to support C&AD research activities or alike. However, many of the national and EU programmes do not foster synergies between themselves or contribute to a reduction of the existing fragmentation and duplication levels.</p> <p>KF_05. Existing projects and programmes often include both public and private funds. However, considering the important resources needed to promote the development of C&AD in Europe, there is a need to reinforce the leveraging effect of public financial support to implement related programmes. Therefore, additional private funding at national level and EU levels are also important. Some of the EU's biggest automotive manufacturers (e.g. Mercedes Benz, BMW and Volvo) are involved in important C&AD projects. In cooperation with a general PPP approach, this private investment can act as catalyst for increased public and private investment efforts coming also from the ICT sector.</p> <p>KF_06. The USA is a leading country in C&AD. There are plans to allocate \$4 billion USD (€3.79 billion) over a 10-year period (~\$400 million/year) in C&AD R&D. However, this investment is still pending approval in the USA congress. Yet, in comparison, EU-funds allocated to research on vehicles/mobility/C&AD (through, e.g. Horizon 2020) represent €200 million for two years.</p> <p>KF_07. Despite some EU fragmentation in the sector, a common political understanding is being developed. The Declaration of Amsterdam envisions advances in the development of C&AD in Europe, representing the political will of European leaders in realizing connected and automated vehicles. Thus, in relation also to the GEAR 2030 initiative, which will highlight the major challenges in C&AD ahead, it could be expected that additional funding dedicated to C&AD programmes/ projects will be available in the future.</p> <p><u>Supporting Evidence from Primary Information:</u></p> <p>Q1B.1: Experts indicated one or more projects and/or programmes being implemented in their country. Most of the projects indicated are in line with those identified in the literature review.</p> <p>Q1B.2: The majority of experts indicated being aware of at least one project/ programme outside of their own country. Some experts referred to collaborative EU projects as being external to their country.</p> <p>Q1B.3: The majority of experts (>85%) agree that existing projects/ programmes will help speed up (either largely or moderately) the development and diffusion of C&AD. Justifications include projects/ programmes being 'catalysts for additional activities', 'being crucial to put new technology/concepts into the real world' and being 'important to understand if the concept works.' The majority of experts do not believe that these projects/ programmes would be an obstacle to C&AD.</p>
<p>New regulations or standards</p>	<p>KF_08. Many European countries (e.g. France, Spain, and Sweden) have taken action to review the regulatory issues related to C&AD, including the testing of vehicles. Other EU countries (e.g. UK) have regulations favourable to testing and others (e.g. Italy and Germany) using a case-by-case approach. This suggests that different EU Member States are at different levels in terms of development, testing and deployment of C&AD. Countries</p>

Sub-Task	Key findings (KF)
	<p>outside of the EU (e.g. USA, Japan, South Korea and China) often face fewer limitations in terms of vehicle testing. At the EU level, this may influence the speed at which the industry can develop and compete.</p> <p>KF_09. Although some Member States are moving forward individually with changes in regulations, there is still some lack of harmonisation in C&AD at the EU-level. This may create some difficulties, such as cross-border testing between countries with different regulations.</p> <p>KF_10. Many Member States (except Spain and the UK) are signatories of the Vienna Convention, which makes it mandatory for a driver to be able to control the car (Article 8). As C&AD development moves towards full automation, an amendment or reinterpretation to the Vienna Convention will be necessary to avoid problems in the development process.</p> <p><u>Supporting Evidence from Primary Information:</u></p> <p>Q1C.1: Approximately 60% of experts indicated that they keep themselves updated with the detailed regulatory frameworks for testing autonomous vehicles in their country.</p> <p>Q1C.2: Similarly, approximately 60% of experts indicated that there are differences between their national regulations and those of other EU countries. In some cases, this is related to the SAE level at which it is possible to carry out testing.</p>
Legislative and infrastructure barriers to the deployment of C&AD	<p>KF_11. Many of Europe's leading car manufacturers are developing C&A vehicles and have made efforts to reduce existing limitations for testing. One approach has been the development of specialized test facilities, which allow more exhaustive testing.</p> <p>KF_12. There are regulatory differences for testing C&A vehicles across many Member States. Thus, there is a challenge to implement a Europe-wide legal system considering many countries may have conflicting views.</p> <p>KF_13. European road infrastructure is in variable condition across Member States, with some countries requiring more improvements than others. In principle, the main infrastructure upgrades would focus on installing technology which would allow communication between vehicles and infrastructure. The Connecting Europe Facility (CEF) for Transport instrument, with a budget of more than €24 billion from 2014-2020 would be an important contribution. However, it is not clear the extent of the investment required, which would depend on the number of countries to receive infrastructure improvements and the extension of roads. This in turn would influence the technological infrastructure required.</p> <p><u>Supporting Evidence from Primary Information:</u></p> <p>Q1D.3: Considering 'legislative' and 'infrastructure' specific challenges, experts identify 'liability in the case of accidents' and 'public acceptance' as two relevant items.</p> <p>Q3A.5: Experts have divided opinions in regard to the extent some countries tackle more effectively challenges and are better positioned. Experts that believe some countries are at an advantage compared to others refer that these are mostly the countries outside of Europe or countries with their own vehicle manufacturing.</p> <p>Q3A.7: The majority of experts are aware of technical/ non-technical barriers in the development of C&AD. The most common answers are related to social acceptance of C&A vehicles, (cyber) security, the lack of</p>

Sub-Task	Key findings (KF)
	<p>harmonised EU approach and international standards, among others.</p> <p>Q3A.8: More than 70% of experts pay attention to the existing technical/ non-technical barriers in the deployment of C&AD. The most common answers are related to potentially dangerous traffic situations (including co-existence with non C&A vehicles, the regulatory environment and user acceptance.</p> <p>Q3A.9: Experts consider that the USA (~45% agree), Europe (~40%) and Japan (~35%) are those that have specific policies to counter technical/ non-technical barriers to the development/ deployment of C&AD.</p>

Task 2: Comparative assessment of technological and commercialisation readiness level of C&AD in USA, Japan, South Korea, China and the EU

Table 26. Task 2 – Key findings of the Study

Sub-Task	Key findings (KF)
Review of the existing technologies in markets	<p>KF_14. Many EU car makers develop world class vehicles containing state-of-the-art technologies (e.g. ADAS, travel services). The science base is strong in most of the required vehicle automation technologies. The European car industry has a good reputation and is currently competing very successfully on the world stage.</p> <p>KF_15. New vehicles need more advanced sensor and decision making technologies from the ICT, photonics and electronics sectors. Currently, USA based companies are those most responsible for the development of Operating Systems for C&AD. This may be related to USA (and Japanese) technology exploitation and deployment being better planned and coordinated.</p> <p>KF_16. Part of C&AD R&D activities are done internally or at a national level. This leads to some challenges for an EU wide-scale and cross-disciplinary collaboration (triple helix) and may also slow down the development of technologies. Improved collaboration is expected through recent EU efforts, such as the Declaration of Amsterdam and Letter of Intent on the testing and large scale demonstration of C&AD. To strengthen the European car industry, further developments on operating systems are required. It may be possible to enable rapid and agile testing and piloting of technologies and vehicles in real-life environment through flexible legislation processes and public alignments.</p> <p><u>Supporting Evidence from Primary Information:</u></p> <p>Q2A.2: Experts agree that the US is the most developed country for C&A vehicle technologies. More than 85% of experts agree that the USA is 'very developed' or 'developed' in this sector. The US is followed by the EU (~80%) and Japan (~65%).</p>
Automated and connected cars/ road vehicles technology analysis	<p>KF_17. Many EU companies are strong in ICT and telecommunications, which provides a competitive advantage for developing V2X communication. Most EU OEMs are actively developing, adopting and scouting for new C&AD technologies. The development of high-level basic and applied research that enables collaboration, piloting and deployment of technologies and services is essential. However, there are EU companies at a disadvantage in regard to, for example, artificial intelligence.</p> <p>KF_18. There is a limited incorporation of soft technology factors (e.g. knowledge transfer) and industrial application of key technologies.</p>

Sub-Task	Key findings (KF)
	<p>Europe shows a somewhat conservative approach in developing new applications. This could become a challenge in automated vehicle technology research.</p> <p>KF_19. The EU has sometimes failed to maintain and improve its market position in high-tech sectors. It is necessary for the European C&AV industry to become more attractive for both European and non-European investors. Additional field trials and publicly funded challenges are important to enable European companies and academics to demonstrate their technological knowledge at a global level.</p> <p><u>Supporting Evidence from Primary Information:</u></p> <p>Q2A.2: Experts agree that the USA is the most developed country for C&A vehicle technologies. More than 85% of experts agree that the USA is 'very developed' or 'developed' in this sector. The USA is followed by the EU (~80%) and Japan (~65%). Experts consider that China is comparatively less developed country in the sector.</p>
Technical and non-technical barriers in development of C&AD	<p>KF_20. Different types of organisations are involved and collaborate in technology research at different levels, with C&AD development having been identified as a high priority by them. However, there is limited, although increasing, coordinated foresight policy at EU level. This has created some fragmentation in research technology, reduced responsiveness of research institutes, and insufficient response to industry needs. Also, with most patents and standards in C&AD originating in the USA or Japan, non-integrated markets increase competition instead of complementary networks of research in C&AD technology.</p> <p>KF_21. Several Member States are reviewing their road traffic regulation and legislation frameworks to support and allow the development and testing of connected and partly autonomous vehicles on public roads. For improved research and vehicle operation testing, an EU-wide legislations for C&AV is required.</p> <p>KF_22. Different bodies across Europe (EC, national authorities, etc.) provide support (e.g. financial) for R&D projects. The development and deployment of C&A vehicles requires public and private funding which may take more time than expected even though the technology is already available.</p> <p><u>Supporting Evidence from Primary Information:</u></p> <p>Q3A.7: Experts agree that one of the key barriers for the development of C&AD at the EU level is related to the lack of a European harmonised approach for testing and validation, the lack of standards as well as the current legal framework.</p> <p>Q3A.8: With regard to barriers for deployment, experts agree that the regulatory environment, a non-harmonised regulatory framework, lack of a European harmonised approach for vehicles in Europe and the legal framework are barriers.</p>

Task 3: Assessment of the existence of a global level playing field and of the effectiveness of instruments available for supporting the development of C&AD

Table 27. Task 3 – Key findings of the Study

Sub-Task	Key findings (KF)
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Sub-Task	Key findings (KF)
Existence of a global level playing field	<p>KF_23. ICT services providers play an increasingly significant role in C&AD. Many USA ICT companies are investing in C&AD related activities. This reflects the significant level of private investment in the USA, which is also able to leverage public investment. The level of investment of EU ICT companies has been more limited, although very good examples are apparent. This has created an adverse impact on the development of C&AD technology in Europe compared to other countries.</p> <p>KF_24. The capacity for European manufacturers to develop C&AD technology can also depend on the speed at which the EU establishes harmonised regulations and laws. While the USA and Japan have more formal regulations for C&AD technology, this is not yet fully true in Europe. The somewhat weak foresight policy in Europe has limited the development of an EU-wide legislation on C&AD development. This contrasts with the USA, Japan and South Korea, which have set goals and clear frameworks on C&AD development in their respective countries.</p> <p><u>Supporting Evidence from Primary Information:</u></p> <p>Q3A.1: Approximately 60% of experts indicate that non-EU countries are at an advantage compared to the EU with regard to public support measures. The 40% that feel the EU is at a disadvantage indicated that one or more of the non-EU countries are ahead and have a more supportive public framework.</p> <p>Q3A.6: Experts are somewhat divided regarding the extent to which existing technologies for C&A vehicles in their country are at an advantage compared to their counterparts, with a 'moderate' advantage being the most frequent opinion (~40%).</p>
Effectiveness of EU support measures	<p>KF_25. The growing media coverage dedicated to C&AD, as well as an increased number of research projects, has contributed to an increased level of public awareness. Nevertheless, public acceptance of C&AV is still an important issue. Aspects related to safety and security, whether vehicle or pedestrian related, are of significant concern to citizens. Liability and other moral issues are also of concern.</p> <p>KF_26. Many non-EU countries recognize the positive impact that C&AD can have on revolutionizing the automotive industry. Thus, they are investing significantly in new infrastructure to support research as well as reforming laws and regulations to support future commercialisation of vehicles. The EU is still working to equal this momentum. Harmonisation of regulations and public investment in specific infrastructure is needed. The Letter of Intent on the testing and large scale demonstration of C&AD is a good example of the EU's efforts in this area. An EU report from DG Internal Policies urges for further assessment on insurance and safety, and requests for governments to review and coordinate regulations on liability issues.</p> <p>KF_27. Additional funding from Europe, Member States and the private sector is identified as important for the development of C&AD. Currently, and through the EC's Horizon 2020 programme, a step forward has been taken in allocating public funding (while leveraging private funds) for research activities aiming at developing innovative solutions for C&AD. From the €80 billion budget of H2020, more than €160 million has been allocated to topics that address C&AD, namely €114 million focused on the Automated Road Transport (ART) call (for the 2016-2017 WP). Moreover, the Connecting Europe Facility (CEF) has reserved €24 billion for</p>

Sub-Task	Key findings (KF)
	<p>infrastructure-specific development, which is relevant to C&AD.</p> <p>KF_28. Europe has made strong efforts to foster C&AD technology through the establishment of various groups/ programmes: (1) the High Level Group on Automotive Industry 'GEAR 2030', created to ensure a co-ordinated approach and to address the challenges faced by the European automotive industry. (2) The Connected and automated driving (C-ITS) Platform, established as a cooperative framework, which includes national authorities, C-ITS stakeholders and the Commission, in view to develop a shared vision on the interoperable deployment of C-ITS in the EU. (3) The Strategic Transport Research and Innovation Agenda (STRIA), which is built on and integrates seven thematic transport research areas: electrification, alternative fuels, vehicle design and manufacturing, C&A transport, transport infrastructure, network and traffic management systems, and smart transport and mobility services. (4) Round Table on Connected and Automated Driving, which serves to discuss digital aspects of C&AD, such as network coverage, standards, interoperability, cyber-security, etc. It also focuses on identifying a proposal for a pan-European, large-scale project that will provide enabling connectivity.</p> <p><u>Supporting Evidence from Primary Information:</u></p> <p>Q3B.1: Of existing EU support initiatives, experts agree that facilitating testing of C&A vehicles (~75% <i>very important</i>), innovation and market creation support (~80% <i>very important</i>) and technology development required for deployment of C&A vehicles (~90% <i>very important</i>) are the most important items. Public awareness (~55% <i>important</i>) and reducing market barriers (~40% <i>important</i>) are other important items.</p> <p>Q3C.1: Experts agree that facilitating testing (e.g. infrastructure and regulatory actions) is the most important support action for the EU (~75% <i>very important</i>), followed by development and harmonisation of standards and regulations (~70% <i>very important</i>), facilitating deployment (~65% <i>very important</i>) and technical development (~55% <i>very important</i>).</p> <p>Q3C.2: Experts suggest that increased trials, testing, public demonstrations, campaigns and the alike can help achieve public awareness and acceptance.</p> <p>Q3C.4: Several experts believe that international cooperation in R&D can contribute to levelling the playing field for C&AD. This is possible because international cooperation can contribute with public access to data for testing and validation and sharing of R&D resources; it can lead to fewer replications of efforts and to the development of common rules.</p>

5.2 Policy recommendations

This section presents policy recommendations for the field of C&AD. These recommendations have been derived from the key findings identified in the study (Section 5.1). In consonance with the desired harmony for C&AD at the EU level, the proposed recommendations consider the preliminary conclusions of the Gear 2030 Working Group 2 as well as the priorities identified in Europe's ambitious Declaration of Amsterdam for cooperation in the field of connected and automated driving. It is expected that these recommendations be the basis of additional reflections by the relevant European authorities and organisations, Member States, the industry and all stakeholders.

Each recommendation includes an overall context, a thematic influence (there are four themes – Legislation; Infrastructure and Technology; Financing and R&D&I) and related key findings. A total of seven recommendations are proposed. These are:

Recommendation (R)	
R01	Establish a coherent funding strategy supporting the EU position in the global C&AD market.
R02	Establish a coherent national and European legal framework for C&AD.
R03	Develop a common European legislation on liability for manufacturers, drivers and third parties.
R04	Align and implement national and European initiatives for promoting C&AD awareness and acceptance.
R05	Simultaneously prioritise investments in connectivity technology between vehicles and infrastructure and improvements to road infrastructure.
R06	Foster additional and continuous European and international cooperation on all domains of C&AD.
R07	Strengthen industrial and technological cooperation between the EU ICT and vehicle manufacturing industries.

Description of the recommendations for C&AD

Recommendation 01

Establish a coherent funding strategy supporting the EU position in the global C&AD market.

Considering the strategic importance of the development of C&AD for the global competitiveness of the automotive industry, the EC and Member States have already moved forward with various programmes focused on C&AD. However, there is still a **gap in the support measures put in place in third-countries**. This is visible in the different levels of government involvement and support, which has been identified as a priority in many non-EU countries.

To ensure that appropriate funding is allocated to priority areas and projects, which can support the EU's position in the global C&AD market, a more **coherent funding strategy is recommended, focussing on a limited number of priorities**.

It is recommended that national and EU, and public and private priorities all be subject to funding through **flexible processes and with limited administrative implications**. Currently, funding is distributed under various structures and programmes, which ultimately increases complexity. While there is limited flexibility for change in the short-term, this strategy could be put in place in the next EU Multiannual Financial Framework (MFF) after 2020, which may coincide with a jump in automation levels and new opportunities.

Building on the considerations from a recent analysis [235], and considering the many relevant instruments presented in this study, the proposed EU funding strategy could include four elements: (1) Contractual Public Private Partnership (cPPP) for R&D projects, (2) ERA-NET co-fund or a EUREKA Cluster on cross-border activities for industrial deployment, (3) Large-scale deployment projects in the TEN-T corridors and (4) an Important Project of Common European Interest (IPCEI) with a long-termed vision for industrialization of C&AD. Considering the four aforementioned funding strategy elements, the recommended coherent C&AD funding strategy would focus on the following:

Horizon 2020: cPPP and ERA-NET co-fund for European R&D projects

Horizon 2020 is the EU's largest programme dedicated to R&D&I, with a budget of nearly €80 billion until 2020. Among the many specific innovation-oriented instruments within H2020, **contractual public-private partnerships (cPPP)** ³⁷ **are considered one of the most successful**. This type of instrument is particularly relevant because they **prioritise R&D topics in consultation with relevant stakeholders**, are capable of leveraging private money alongside public investments, and focus on delivering beneficial results to society.

Focusing on a C&AD cPPP would allow the implementation of a common programme on C&AD, based on a multi-annual roadmap developed by private partners. The roadmap would include demonstration activities which would favour a strong market uptake. The roadmap would necessarily outline the way forward and actions for the development and deployment of C&AV. Within this framework, a budget for a cPPP on C&AD could be fixed in relation to the one retained for the cPPP for the European Green Vehicles Initiative [227].

Funding could be distributed across various Innovation Actions (providing results closer to the market), Research and Innovation Actions and, in some scenarios, Coordination and Support Actions. The implementation of a cPPP is expected to **improve coordination efforts between the EC and industry representatives**, mainly because it encourages more specific objectives and a stronger research focus. It is considered that projects launched under the umbrella of the cPPP are better positioned to receive more funding because of their cross-thematic nature (although under the topic of C&AD). The cPPP could focus on, among other topics, Big Data, 5G, cybersecurity or IoT, among

Recommendation 01**Establish a coherent funding strategy supporting the EU position in the global C&AD market.**

others.

There are several factors that make a cPPP a valid instrument for C&AD, including the fact they are based on a long-term strategy, target topics of EU relevance, leverage private co-funding, establish a firm commitment from all parties involved, enable sustained partnerships and are extremely relevant to the industry and technology readiness levels. While a cPPP may take a year to set up (mainly because of industry participation, development of the roadmap and respective project topics), the success rate is positive [236]. Overall, a cPPP, reflecting public and private interests, would be a good opportunity to build a stronger EU C&AD sector.

Still within the boundaries of H2020, and aiming to strengthen collaboration among Member States, **an ERA-NET³⁶ co-fund is a relevant scheme to consider. This instrument supports public-private partnerships, including joint programming initiatives between Member States.** The instrument supports the preparation, design and implementation and coordination of joint activities. An ERA-NET co-fund allows collaboration in any part of the R&I cycle, but results closer to the market could be prioritised. One of the compulsory activities is the implementation of a co-funded joint call for proposals that can later finance trans-national research and/or innovation. Thus, an ERA-NET for C&AD focusing on transnational innovation could be an important complement to a cPPP.

A similar option to an ERA-NET, but outside the scope of H2020 and its funds, are **EUREKA-clusters.** A EUREKA-cluster would **increase EU competitiveness in C&AD by fostering innovation-driven entrepreneurship and productivity through technology.** One example of the role of EUREKA is the PROMETHEUS⁴⁰ project, which from 1986 to 1994 defined the state of the art on autonomous vehicles.

Connecting Europe Facility and TEN-T

The **Connecting Europe Facility (CEF)**³⁵ **instrument** supports trans-European networks and infrastructures in the sectors of transport, telecommunications and energy.

In the transport sector⁴¹, CEF focuses on implementing EU transport infrastructure policy (TEN-T policy⁴²). It aims at **supporting investments in building new transport infrastructure in the EU** or rehabilitating and upgrading the existing one. With more than €24 billion in funds, projects mostly focus on completing the TEN-T core network and respective corridors by 2030. Because of their relevant role in infrastructure (including digital infrastructure) a **CEF dedicated to C&AD could be an important instrument to help deploy C&AD** on important EU transport networks.

Specifically, and to complement the existing CEF for Transport, a **CEF dedicated to digital infrastructure is recommended**, thus supporting the installation of the necessary infrastructure to ensure seamless and safe and secure connectivity between vehicles. Another complementary instrument to consider is a **CEF specific city infrastructure**, which would include both traditional road structure adaptation and additional digital infrastructure.

IPCEI

Lastly, and as discussed in Section 4.3, an **IPCEI is an important instrument to consider for**

⁴⁰ PROMETHEUS. <http://www.eurekanetwork.org/project/id/45>

⁴¹ Connecting Europe Facility (CEF) for Transport. <https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport>

⁴² TEN-T policy. https://ec.europa.eu/transport/themes/infrastructure/ten-t-guidelines_en

Recommendation 01**Establish a coherent funding strategy supporting the EU position in the global C&AD market.**

C&AD, having already been recommended by the High Level Expert Group on Key Enabling Technologies. As discussed, an IPCEI is a state-aid instrument that can facilitate public funding, going beyond current EU or national funding in scope, objective and budget. The C&AD IPCEI could focus on large scale demonstrations, pre-deployment projects and pilot initiatives involving all relevant stakeholders. The IPCEI would also **prioritise projects that are closer to the market and near deployment stage**. The IPCEI could eventually be launched in parallel with the other aforementioned instruments (cPPP, ERA-NET and CEF).

A focus on these three vectors would contribute to a more coherent funding strategy, allowing funds to be dedicated to specific programmes/instruments. At the national level, funds and programmes for C&AD should be aligned with these aforementioned instruments, namely the ERA-NET or EUREKA, and more importantly, the IPCEI. This would also contribute to a stronger alignment of priorities and a reduction in duplication of results.

For this funding strategy, it is important that it focuses on some of the EU's priorities for C&AD, namely related to (1) deployment of C-ITS services, (2) security of vehicles and communications, (3) privacy and data protection, (4) development of a hybrid communication infrastructure, and (5) system interoperability. Other specific priorities may also include testing and validation of infrastructure, development of pilots for performance analysis and analysis of user acceptance; validation of C&A vehicles in different environments (e.g. terminals, harbours); and validation of vehicle performance in mixed traffic environments [237].

It should be emphasized that **EU funding and respective programmes should be made available under specific conditions that leverage additional private funding**. This is an important approach that can contribute to companies further investing in automated road transport, as it fosters additional cooperation between stakeholders that would commonly work on single aspects and topics, but can use this opportunity to cooperate in other sectors. Thus, EU funds should mainly target projects that encourage contributions of multiple stakeholders, cooperative processes and early involvement of users, but simultaneously leverage private investment.

Theme	Financing; R&D&I		
Main supporting key findings	<ul style="list-style-type: none"> • KF_03 • KF_04 • KF_05 	<ul style="list-style-type: none"> • KF_06 • KF_16 • KF_19 	<ul style="list-style-type: none"> • KF_20 • KF_21 • KF_26

Recommendation 02**Establish a coherent national and European legal framework for C&AD.**

Currently, Member States have different national rules, which can affect the development and deployment of the technologies behind C&AD. At the EU level, the preparatory work done within GEAR 2030 suggests there are no significant legislative barriers for C&AV up to level 3. **However, as C&AV become technologically more advanced and progressively reach automation level 5, concrete and coherent regulatory and legal changes are expected to be required.**

The EU requires a **harmonised framework on aspects related to both vehicles and drivers.** For vehicles, key aspects of the framework should include the conditions for testing, system operability, vehicle connectivity, vehicle certification/registration and speed limits. For drivers, key aspects include driving licenses and consent to the use of personal data. Relevant to both are traffic rules, liability and data security and privacy. Also, and considering the role they will play, a coherent legal framework related to mobility services is also recommended.

In alignment with the item on a Joint Agenda of the Declaration of Amsterdam, the EU should establish a **coherent** framework that should contribute to the removal of barriers, facilitate C&AV testing, and promote interoperability and legal consistency. This framework would also integrate the many aspects included within the Letter of Intent on testing and large scale demonstrations of C&AD, from March 2017 and signed by 29 European Countries.

Within this EU-wide framework, it is recommended to focus on the **development of specific ICT standards** that can facilitate all aspects of C&AD development and technological interoperability. For this objective, it is recommended to liaise with the European Telecommunications Standards Institute (ETSI), who already have concrete ideas for the transportation sector.

For example, the ETSI ITS Committee is working on achieving global standards for co-operative ITS, namely in vehicle-to-vehicle and vehicle-to-roadside communication. Among other applications, road safety is of particular importance. ETSI already collaborates with the EC, the industry and road infrastructure operators. It is important to maximise and extend this cooperation, and work to ensure that the developed standards are also capable of being adopted outside of the EU.

Another key item to address within the **EU legal framework is cybersecurity**, considered one of the biggest threats to C&AD. It is important to define the necessary regulations related to security and privacy and then define the mechanisms to ensure stakeholders adhere to these specific regulations. The European Union Agency For Network And Information Security (ENISA) has already compiled various good practices and recommendations that can serve as a basis for regulations within the recommended EU-wide legal framework. Again, it is important to note that as **C&AV reach higher levels of automation and become more connected, these may become increasingly targeted by cyber threats**. Thus, it is important that specifications and regulations address the entire scope of automation levels. Of the many confluent areas in C&AD, international cooperation (see *Recommendation 06*) amongst manufacturers and IT companies on cybersecurity is of high value. Independently of each manufacturer's work on vehicle characteristics and performance, the shared common goal is ensuring driver, passenger and pedestrian safety. **At the EU-level, one possibility to foster increased collaboration and ensure results are tailored to the actual needs of the market is through the C&AD cPPP (see Recommendation 01).**

For regulation on C&AV testing, it is relevant that a **common and harmonised evaluation methodology be designed** to ensure that all vehicles, whether small cars or large trucks, be evaluated and tested according to the same guidelines. The guidelines could focus on various aspects, including physical inspection, road performance, stress testing and analysis of system robustness (including against cyber-attacks). **These guidelines should be upheld by all vehicle**

Recommendation 02**Establish a coherent national and European legal framework for C&AD.****manufacturers to ensure that, at minimum, all vehicles meet the same levels of safety.**

This methodology could also be applied to ITS infrastructure and systems, which would need to meet specific measurement indicators [238]. To facilitate and harmonise national and EU-wide vehicle testing, it is recommended that the legal framework include possibilities for temporary ad-hoc testing permits which would be granted to manufactures pending approval of national authorities. These permits could be based on a multi-phase testing process (e.g. start within a closed circuit and then move to open-roads).

Regulation should also envisage specific rules related to the use of C&AD data taking into consideration the role of cities and their changing dynamics. The (big) data transmitted by C&AV would prove beneficial for cities. Through V2V and V2I interactions, C&AV will continuously broadcast data regarding their location, speed, route, and other data. This information provides cities' traffic management systems real-time data on traffic conditions.

This data will be far more detailed and accurate compared to data available today. This would allow continuous monitoring of traffic conditions and let traffic managers effectively solve traffic problems in an immediate manner, contributing to safer and more liveable cities. Therefore, cities are also interested parties regarding data generated from C&AV. However, how this data is used and how consent is requested must also be regulated.

Theme	Legislation; Infrastructure and Technology		
Main supporting key findings	<ul style="list-style-type: none"> • KF_01 • KF_02 • KF_07 	<ul style="list-style-type: none"> • KF_09 • KF_11 • KF_12 	<ul style="list-style-type: none"> • KF_21 • KF_24 • KF_28

Recommendation 03**Develop a common European legislation on liability for manufacturers, drivers and third parties.**

Liability is one of the key issues affecting both the development and deployment of C&A vehicles. Although the existing legislation is sufficient for current automation levels, **it is important to already discuss and define clear directives regarding liability at the five levels of automation, with special emphasis at full automation (level 5).**

The circumstances for the collection and usage of data for the assessment of responsibilities should also be defined. In this case, standardisation of data should also be considered to ensure that data is stored and can be read equally across vehicle brand. Liability for C&AD must consider two key issues: (1) liability transfer and (2) data on liability. [239]

Liability transfer

It can still be unclear **who is liable for issues or misconduct with C&AV in various possible scenarios**: the driver, the manufacturer or other parties (data/vehicle owner, software developer, network operator, telematics service provider). Liability itself cannot be fully addressed unless other issues are first considered (e.g. traffic rules, the process for the certification/approval of vehicles, driver education or road user behaviour.) Liability can be structured according to the five levels of automation: between partial to highly automated vehicles on the one hand (up to level 4) and fully automated on the other (level 5).

The simplified approach is that for fully automated vehicles (level 5), liability shifts from the owner/driver to the manufacturer, mainly because the accident results from vehicle technology failure. However, even with fully autonomous vehicles, the owner/driver must assume responsibilities for the safe driving of the vehicle (e.g. using the vehicle according to manufacturer operating instructions, keeping the vehicle in good state, etc.). Also, in specific situations, the transfer of liability may not be in the public interest, as it may affect compensation to third party victims.

There are additional considerations related to the transfer of liability between parties: (1) a shift in decision making: from drivers to manufacturers or the software/ algorithm; (2) vulnerability to third-party shortcomings: highly automated/ autonomous vehicles will also be connected vehicles, which will expose them to third-party actions, such as security/ performance controls; (3) decrease in driver engagement: users will rely fully on the vehicle's technology and operate it with less caution than intended.

There are five approaches for the management of liability transfer: (1) treat autonomous vehicles and human drivers equally; (2) strict liability of the owner/keeper of the vehicle, be it automated/autonomous or not – due to the vehicle's operational risks; (3) find an agreement on liability claim resolution across the relevant industries; (4) let compliance with performance standards pre-empt further liability; and (5) introduce a government fund/instrument for new emerging risks.

Data on liability

The process of **how incidents are investigated to determine how they happened is also important**. This is also linked to the area of connectivity/data and the wider issue of access to in-vehicle data. It will be necessary for the different parties involved (e.g. authorities, manufacturers, insurers, etc.) to be able to access vehicle data to determine the circumstances surrounding an incident, any possible defect/ fault in the system, etc. The format in which data is collected and stored (relevant to standardisation) and the conditions under which data can be accessed should also be considered.

Recommendation 03**Develop a common European legislation on liability for manufacturers, drivers and third parties.****Moving forward**

The current legal framework remits to the Motor Insurance Directive (MID) and the Product Liability Directive (PLD), but both fall short of the needs that will emerge with higher levels of automation. The MID primarily ensures victims of road traffic accidents are adequately protected throughout the EU; the PLD harmonises liability rules at EU level by imposing strict liability on producers of defective products that cause death, personal injury or damage to property and, by ensuring this protection, to facilitate the free movement of persons throughout the EU. However, it is possible to consider these directives as a basis.

For example, the PLD harmonises liability rules at the EU level. It imposes liability on producers of defective products that cause death, personal injury or damage to property. In this case, producers are required to compensate injured parties for the damage caused, with injured parties having to prove the causal link between the damage and defect. The MID works well in the interest of road users, delegating complex legal actions to insurers and other stakeholders, and also providing compensation for consumers (victims of road traffic accidents). The MID ensures swift compensation to victims, even where an autonomous vehicle is involved.

Related to both liability transfer and data is the **impact of cybersecurity**. It is recognised that cybersecurity is a major threat to C&AD. Considering the different interconnected components of C&AV, a **breach in vehicle security can jeopardise the safety of the vehicle**, its passengers and pedestrians. In scenarios where cybersecurity issues are relevant, it is also important to know who becomes liable. This is the case for scenarios where attacks are directly on the vehicle or on the data related to the vehicle or the driver.

A step forward is thus needed to make use of available and relevant directives and develop a common European legislation on liability for manufacturers, drivers and third parties. While this may not be possible for the short-term, and although the available legislation can manage current status of automation and respective systems, liability will continue to be a concern as vehicles increasingly become more automated and become mainstream.

Theme	Legislation		
Main supporting key findings	<ul style="list-style-type: none"> • KF_01 • KF_02 • KF_07 	<ul style="list-style-type: none"> • KF_08 • KF_09 • KF_21 	<ul style="list-style-type: none"> • KF_25 • KF_26

Recommendation 04**Align and implement national and European initiatives for promoting C&AD awareness and acceptance.**

Public awareness and acceptance are important elements for the success of C&AD. While the public is increasingly becoming aware of C&AV and the technology behind their operation, mainly boosted by their ever-growing presence in specialized and non-specialized media, **public acceptance of C&AV is still a challenge of its own for reasons mainly linked to safety and security.** Public intervention could **focus on promoting awareness and acceptance,** while at the same time **fostering interest and demand.**

At the EU level, and as part of the proposed coherent funding strategy, it is recommended that specific topics within an H2020 call be launched for projects that have some impact on increasing public acceptance. In the form of a research or coordination and support action, these topics could be considered as part of the aforementioned cPPP, and would have to include demonstration activities to increase public acceptance and a strong market uptake.

There is a range of potential action types to support public awareness and acceptance. One example would be the presented C&AD City Challenge, inspired on the success of the USDOT Smart City Challenge. Project holders would be required to show how emerging transportation data, technologies, and applications could be integrated within their city to address existing transportation challenges. They would also be required to show how collaboration would be established with other national and competing cities. It is expected that the results of the awarded projects foster significant interest in all aspects of C&AD.

At the national level, vehicle dealers/ manufacturers should organise different events that allow the demonstration of these vehicles. This includes, for example, the organisation of roadshows where vehicles and the necessary demonstration infrastructure is taken from city to city to show the public how the vehicles work.

To engage users in these events requires a creative approach. A feasible option would be to align these demonstration activities with popular national and international auto/ motor shows. Many vehicles shows are hosted in the EU, some annual or biennial (e.g. Frankfurt Motor Show, International Geneva Motor Show, and Paris Auto Show). Considering the influx of people (and their specific interest in vehicles) at these events, they would be key opportunities to promote both the public's awareness, but also to spark a greater interest and possible demand.

It is vital for the C&AD deployment strategy that these **demonstration activities show the full potential of C&A vehicles and that they are worthy of citizens' confidence.** First-hand experience with the vehicles will contribute to users' confidence in the safety of the technology. Along the lines of initiatives favouring the purchasing of green vehicles, Member States could envisage specific measures to promote the deployment of C&AD vehicles. C&AD can notably offer a competitive advantage for entities/ organisations involved in the transport sector and are thus a target group that should be addressed, especially for future mobility services.

Theme	R&D&I; Financing	
Main supporting key findings	<ul style="list-style-type: none"> • KF_01 • KF_03 	<ul style="list-style-type: none"> • KF_19 • KF_25

Recommendation 05

Simultaneously prioritise investments in connectivity technology between vehicles and infrastructure and improvements to road infrastructure.

Maximising the impact of C&AV requires a simultaneous prioritisation of investments in connectivity technology and improvements to road infrastructure.

Connectivity can increase the effectiveness of automated systems and improve road safety and traffic efficiency by improving awareness and communication with the surrounding environment. While connectivity may not be essential for autonomous vehicles before 2020, the suggested forward looking approach calls for increased investments in connectivity between vehicles and infrastructure. By investing in connectivity technology at infrastructure level, autonomous driving can be improved through the provision of additional sensory resources as well as positive information redundancy. This will contribute to a more detailed environment perception and prediction, as well as a coordinated resolution of the vehicle's complex decisions.

Connectivity technology can be grouped under two types: (1) vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and vehicle-to-pedestrian/ other road users (V2P) connectivity. These are based on standardised protocols and data sets in a licence-exempt regulatory framework and do not require a mobile network or subscription. (2) Vehicle-to-network (V2N) connectivity is delivered over commercial mobile networks (3G, 4G or 5G) and bands. The deployment of both types of technologies would be beneficial for the deployment of C&AV and thus efforts in this direction should be continued.

Increased connectivity and the emergence of vehicle-to-everything (V2X) communication requires significant attention to cybersecurity threats. Fragmented and disharmonised security solutions can constrain interoperability and put the safety of end-users at risk. Thus, a mix of technologies can contribute to a more stable and constant V2V and V2I communication. This can also attenuate eventual threats with hacking communication channels. This is also a step forward in favour of public acceptance of C&AV, as users may feel a greater level of safety.

In addition to communication, **traditional road infrastructure (e.g. roads, bridges, traffic signals and lamp posts) must also adapt to C&AD and the emergence of a new type of vehicle**. The responsible local and national bodies must assess the extent to which existing infrastructure has to be replaced or renewed through maintenance and improvements. While current infrastructure may be sufficient for the current level of automation (as suggested by ERTRAC), once C&AV reach higher levels of automation, revisions and improvements to infrastructure performance (e.g. visibility, state of repair, etc.) regarding traffic signs, signals and road markings must be considered.

To guarantee the smooth mass deployment of C&AD in the future, there is also a **need to complement traditional road infrastructure with digital infrastructure**. This is crucial in order to achieve the connected aspect of C&AV with the road and its surroundings. Digital infrastructure would also address the need of cooperation from the vehicles and infrastructure operators to collect, update and correct eventual changes made on the physical infrastructure.

Digital infrastructure should also be able to provide accurate map data, provide knowledge along the road, enable digital driving patterns, allowing automated functions on roads (particularly being able to manage lanes) as well as be able to notify the vehicle regarding specific situations that may require human attention or intervention.

This development and implementation of digital infrastructure would require a significant amount of investment. Building on the existing Connecting Europe Facility (CEF) for Transport, it is recommended to reinforce the efforts being made on the development of digital infrastructure for C&AD. This is recommended to ensure that complementary initiatives not only address C&AV specifically, but also the necessary (digital) infrastructure to see them through.

Recommendation 05**Simultaneously prioritise investments in connectivity technology between vehicles and infrastructure and improvements to road infrastructure.**

Other instruments such as an IPCEI can also be considered in the field of digital infrastructures. A possible IPCEI notified by several Member States could focus on the implementation of cross-border infrastructure projects involving the development of continuous corridors across multiple countries, allowing for vehicles to drive in a near to uninterrupted manner. The EU already has nine core network corridors which could be the basis for one or more IPCEI to improve and adapt the existing infrastructure to facilitate the deployment of C&AD. Not only could this be of value to EU citizens, but it would also bring advantages to the logistic (e.g. better implementation of platooning) and transport sectors. As required by the IPCEI, a large-scale cross-border infrastructure project would involve extensive cooperation and collaboration between Member States, the EC and many other public and private authorities and organisations.

Theme	Infrastructure and Technology; Financing; R&D&I		
Main supporting key findings	<ul style="list-style-type: none"> • KF_01 • KF_09 • KF_13 	<ul style="list-style-type: none"> • KF_15 • KF_17 • KF_18 	<ul style="list-style-type: none"> • KF_23 • KF_26

Recommendation 06**Foster additional and continuous European and international collaboration and cooperation on all domains of C&AD.**

Europe's competitiveness in C&AD requires additional collaboration and cooperation at the EU level as well as with other key international players. This is an essential step as C&AV markets are developing at a global scale. A first step for the EU is upholding the terms within the Declaration of Amsterdam, which focuses on 'Cooperation in the field of C&AD', and targets Member States, the European Commission and the Industry. Furthermore, it must consider the recent agreements included within the Letter of Intent on the testing and large scale demonstrations of C&AD, signed by European countries in March 2017.

At the EU level, cooperation is vital between Member States based on a common vision for C&AD. **National strategies, programmes and projects could focus on this vision and work together rather than separately to avoid duplication of efforts and reduce existing fragmentation.**

Bringing together various EU stakeholders along the C&AV value chain could notably be achieved through the **establishment of a dedicated EU Centre of Excellence (CoE) on C&AD.** Several Member States already have C&AD related centres, such as the Centre for Connected and Autonomous Vehicles (CCAV) in the UK, VisLab in Italy, or VEDECOM in France. An EU CoE in this sector would help strengthen EU's position, covering and contributing to various different areas in the C&AD value chain.

The CoE could act as key point of contact for the EU industry, academia working on C&AV, and other stakeholders. The CoE would be directly funded through the EC as well as its Member States. The CoE should also create synergies with the aforementioned centres, as well as others across the EU. Furthermore, in view of fostering additional international cooperation, the CoE should also connect with international centres of reference, and work together on common projects of global interest. The CoE should also act as a platform to support and advise the EU with its various C&AD policy challenges, related to standardisation, testing or others. The CoE should also encourage discussions and knowledge-gaining (e.g. acquisition of specific skills) around C&AD through the organisation of events, including policy and professional workshops, dedicated seminars and large conferences, which could also run in parallel with other EU events. It is considered that an EU CoE on C&AD could in the long-term play an important role in the EU's competitiveness in the sector.

Member States should also aim to establish additional international cooperation with other regions, namely the USA and Japan, to work towards a **global framework and international standards for C&AV.** This may be a particular challenge, namely in terms of communication, as the EU may favour one communication standard and the USA, for example, may prioritise another. Within the EU, the industry should collaborate on **developing technology following common standards which allow for interoperability** across the different C&AD domains. The industry, with national and EU support, should continue to participate in large-scale projects that explore the advantages of C&AD, thus increasing public awareness and acceptance.

Despite possible cooperation challenges, the USA and China are two countries that can contribute to the EU's competitiveness in the sector. One of the areas that this cooperation can focus on is **artificial intelligence**, which is essential to C&AV. To be competitive in C&AD, the EU (and specifically vehicle manufacturers) should cooperate with third countries to acquire the necessary knowledge base.

Furthermore, cooperation may have a more **immediate effect if countries with a greater economic potential are involved**, including those of the G7 (the majority represented in this study). As discussed, the G7 has already recognised that work is needed to establish a harmonised regulatory framework, enabling safe deployment of (key enabling) technologies across the countries. They have also agreed that sustained collaboration should focus on, for example: coordinating

Recommendation 06**Foster additional and continuous European and international collaboration and cooperation on all domains of C&AD.**

research and cross-cutting triple-helix collaboration (relevant to R01); promoting international standardisation within an international regulatory framework (relevant to R02); ensuring data protection and cybersecurity (relevant to R02 and R05); and setting the legal and regulatory framework to allow for testing of highly automated vehicles (relevant to R01 and R02); among others.

Engaging in collaboration and cooperation is vital to **achieve the objective of full deployment of CA&V and their multiple benefits**. Through increased collaboration, better results are achieved in shorter periods of time. Once these results are achieved, there is the indirect benefit on the national economy and productivity.

Theme	Legislation; Infrastructure and Technology; Financing and R&D&I			
Main supporting key findings	<ul style="list-style-type: none"> • KF_01 • KF_03 • KF_04 • KF_07 	<ul style="list-style-type: none"> • KF_10 • KF_16 • KF_18 	<ul style="list-style-type: none"> • KF_19 • KF_20 • KF_23 	<ul style="list-style-type: none"> • KF_24 • KF_25 • KF_26

Recommendation 07**Strengthen industrial and technological cooperation between the EU ICT and vehicle manufacturing industries**

As vehicles transition to connected and/or automated vehicles, the incorporation of more advanced ICT-based technology becomes increasingly important to ensure the **safe operation of the vehicle and the safety of the driver, passenger and pedestrians**. Artificial intelligence, for example, is vital for C&AV, and is an area where both the USA and China are very competitive. Outside of the EU, the impact of ICT service/ technology providers (especially in the USA) and their capacity and potential involvement in C&AD is significant. This is not the case for the EU.

There is an opportunity to **increase the role of ICT companies in the sector and to strengthen industrial and technological cooperation** between the EU ICT and vehicle manufacturing industries, creating synergetic benefits. This should be complemented by an additional effort from the EU to support the development of skills in various IT areas (e.g. artificial intelligence, deep learning, big data analytics, and high definition mapping), areas that are essential to for C&AD and the EU's competitiveness. **This is part of the vision of the Digital Single Market strategy**, which is also reflected in C&AD: to maximise digital innovation in products, processes (e.g. manufacturing of vehicles) and business models (e.g. new C&AD mobility services).

Through an even more extensive involvement of ICT companies, the increased digitisation of the vehicle manufacturing industry will not only have a direct impact on the vehicles developed, but also increase the competitiveness of the EU C&AD sector. This cooperation would not only produce results in the vehicles, but can also impact how C&AV are designed and developed. Specifically, increased technological cooperation can lead to improved digital production processes, including the use of the Internet of Things, improved robotics, and big data.

In this process, the **involvement of ICT start-ups and SMEs would be welcomed**. However, and understanding the risk involved for both vehicle manufactures and ICT providers, complementary funding mechanisms to enable a greater interest in cooperation and minimize risks are recommendable. Mechanisms such as the SME Instrument (with Phase 2 funding levels, up to €2.5 million) or the I4MS initiative, which promotes manufacturing through the adoption of ICT technologies are two examples that can be replicated for this purpose.

Complementarily, and as outlined in the Digital Single Market strategy, the **involvement of the ICT sector and manufacturing industries can also be established through a C&AD public private partnerships** (as discussed in Recommendation 01), which would contribute to new digital industrial strategies applicable to C&AD. An IPCEI would also be a possible solution for additional ICT sector involvement in C&AD. This cooperation is also relevant in view of **increasing the EU's competitiveness in terms of developing patents related to C&AD**, an area in which the EU is behind its main competitors.

Another aspect to reflect on, and which has been considered in the USA, is the implementation of taxation incentives to boost ICT investments in C&AD. These incentives may be a positive way for organisations to invest in early-stage companies that are interested in working on C&AD.

Theme	Infrastructure and Technology; Financing; R&D&I	
Main supporting key findings	<ul style="list-style-type: none"> • KF_05 • KF_15 	<ul style="list-style-type: none"> • KF_17 • KF_23

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