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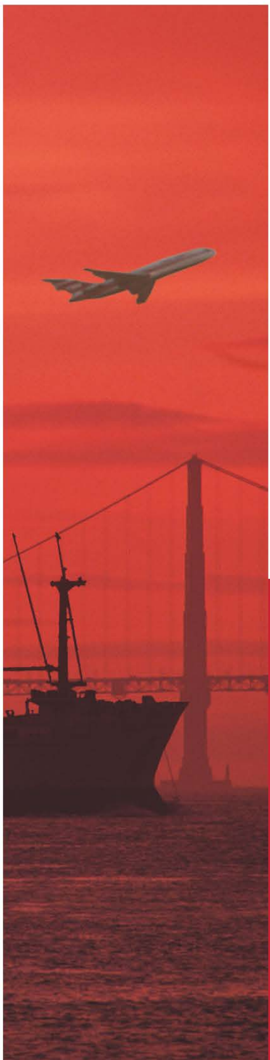

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# RESEARCH FOR TRAN COMMITTEE – SELF-PILOTED CARS: THE FUTURE OF ROAD TRANSPORT?

**Provisional version - STUDY**

EN

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DIRECTORATE-GENERAL FOR INTERNAL POLICIES

POLICY DEPARTMENT B: STRUCTURAL AND COHESION POLICIES

TRANSPORT AND TOURISM

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STUDY

Provisional version

This document was requested by the European Parliament's Committee on Transport and Tourism.

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TRANSPORT AND TOURISM

# RESEARCH FOR TRAN COMMITTEE – SELF-PILOTED CARS: THE FUTURE OF ROAD TRANSPORT?

## STUDY

## Provisional version

**Abstract**

The study provides an analysis of the development of automated vehicles inside and outside the EU, including both the technologies which are already on the market and those under testing and research. The EU is giving increasing attention to automated and connected vehicles as they could have huge impacts on road safety, travel behaviour and urban development. The study reports on state of the art key research projects and large scale testing in this area and discusses future pathways and potential impacts of increasing vehicle automation. It concludes with recommendations on aspects that should be considered when shaping policies to sustain the research and development, and bringing to market, of highly automated and connected vehicles.

IP/B/TRAN/FWC/2010-006/Lot1/C1/SC11 2016

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# CONTENTS

# LIST OF ABBREVIATIONS

| | |
|---|---|
| **AAMVA** | American Association of Motor Vehicle Administrators |
| **ABI** | Association of British Insurers |
| **ABS** | Anti-lock Braking Systems |
| **ACASS** | Accident Causation Analysis with Seven Steps |
| **ACC** | Adaptive Cruise Control |
| **ADAS** | Advanced Driver Assistance Systems |
| **AEB** | Autonomous Emergency Breaking |
| **AEBS** | Advanced Emergency Braking Systems |
| **AI** | Artificial Intelligence |
| **ARTS** | Automated Road Transport Systems |
| **CACC** | Cooperative Adaptive Cruise Control |
| **CCF** | Connected Car Forum |
| **CES** | Consumer Electronic Show |
| **CIS** | Center for Internet and Society |
| **C-ITS** | Cooperative Intelligent Transport Systems |
| **DAE** | Digital Agenda for Europe |
| **DARPA** | Defense Advanced Research Projects Agency |
| **DAVI** | Dutch Automated Vehicle Initiative |
| **DfT** | Department for Transport (UK) |
| **DSRC** | Dedicated Short-Range Communication |
| **EPoSS** | European Technology Platform on Smart Systems Integration |
| **EPSRC** | Engineering and Physical Sciences Research Council |
| **ERTRAC** | European Road Transport Research Advisory Council |
| **ESC** | Electronic Stability Control |

| | |
|---|---|
| **ESP** | Electronic Stability Program |
| **EU** | European Union |
| **FCA** | Fiat Chrysler Automobile |
| **FCW** | Forward Collision Warning |
| **FFI** | Fordonsstrategisk Forskning och Innovation (Strategic Vehicle Research and Innovation – Finland) |
| **FHWA** | Federal Highway Administration |
| **FIA** | Federation Internationale de l'Automobile |
| **GHG** | GreenHouse Gas |
| **GIS** | Geographic Information Systems |
| **GPS** | Global Positioning Systems |
| **IIHS** | Insurance Institute for Highway Safety |
| **ITF** | International Transport Forum |
| **ITS** | Intelligent Transportation System |
| **LCA** | Lane Change Assist |
| **LDW** | Lane Departure Warning |
| **LKA** | Lane Keeping Assist |
| **MIT** | Massachusetts Institute of Technology |
| **NHTSA** | National Highway Traffic Safety Administration |
| **OECD** | Organisation for Economic Co-operation and Development |
| **OICA** | International Organization of Motor Vehicle Manufacturer |
| **OTA** | Over The Air |
| **PA** | Park Assist |
| **PDC** | Park Distance Control |
| **PROUD** | Public Road Urban Driverless |
| **PRT** | Personal Rapid Transit |

| | |
|---|---|
| **R&D** | Research & Development |
| **SAE** | Society of Automotive Engineers |
| **SARTRE** | Safe Road Trains for the Environment |
| **SNACS** | SafetyNet Accident Causation System |
| **StVO** | Straßenverkehrsordnung (German Road Traffic Code) |
| **TCS** | Traction Control System |
| **TLN** | Transport en Logistiek Nederland |
| **TNO** | Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organisation for Applied Scientific Research) |
| **TTI** | Texas Transportation Institute |
| **UK** | United Kingdom |
| **UNECE** | United Nations Economic Commission for Europe |
| **US** | United States |
| **USDOT** | United States Department of Transportation |
| **UVEK** | Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation (Federal Department of Environment, Transport, Energy and Communications - Switzerland) |
| **VDA** | German Association of Automotive Industry |
| **V2I** | Vehicle-to-Infrastructure |
| **V2V** | Vehicle-to-Vehicle |
| **VMT** | Vehicle-Miles Travelled |
| **VRAIN** | Vehicular Risk Awareness Intelligence Network |
| **VTI** | Väg- och TransportforsknIngsinstitut (Swedish National Road and Transport Research Institute) |

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# EXECUTIVE SUMMARY

## Existing implementation

A variety of driving assistance systems of Level 0 (no automation), Level 1 (driver assistance) and a smaller number of Level 2 (part automation) technologies are currently available on the market, mainly implemented on passenger cars to support driving on motorways or for parking. Vehicle manufacturers are investing in R&D of more advanced automation systems up to Level 3 (conditional automation), which are expected to further improve the driving safety and comfort of private vehicles. Concurrently, research and testing of higher automated systems (level 4 – high automation and level 5 – full automation) is already underway. The concept of "self-driving vehicle" represents the pinnacle of vehicle automation, although, at the moment, the implementation of fully automated vehicles still requires a considerable amount of research and technological advancement.

In the EU a number of countries – namely the UK, Sweden, Germany, France and The Netherland - are taking significant steps to be at the forefront of research in this sector; in many cases actions in this area are led by vehicle manufacturers. Outside Europe, the United States is arguably the country where most has been done in the research and testing of automated vehicles, especially on the part of technology companies such as Google. In that regard, a remarkable difference can be retraced in the approaches adopted respectively by car manufacturers – which are generally taking an *evolutionary approach* in developing increasingly automated systems with a driver-centric approach – and technology companies – which are generally taking a *revolutionary approach* in testing self-driving vehicles whose diffusion would revolutionise the current mobility paradigm.

## Future pathways

Different stakeholders and experts have different views on the timescale for the diffusion of automated passenger vehicles in the market. However, a scenario is broadly shared according to which increasingly automated systems (level 2 to 4) are likely to be introduced in the short (next 5-10 years) and middle term (10-20 years), while full automation is expected to be feasible on a large scale in a farther time horizon (more than 20 years) as it requires more advanced technological systems, as well as greater modification to the current international and national regulatory frameworks and available infrastructure.

As for freight transport, truck platooning is expected to follow an incremental pathway consisting in the progressive reduction of the responsibilities of the drivers until full replacement would ultimately occur. Urban mobility and public transport is expected to follow a different pathway towards full automation – i.e. the *everything somewhere* approach, consisting in the development of highly automated vehicles initially bound to circulate in specific restricted environments and then gradually opening up to less protected circumstances.

## Potential impacts

Road safety is expected to significantly improve as automated vehicles should reduce accidents due to human errors. However, the effective safety performance of automated systems has yet to be demonstrated and several technical challenges still need to be addressed, and little evidence is available on the potential emergence of new risky situations. The extent to which automated systems could contribute to improve safety will also depend on their rate of market penetration – which is likely to be a relatively long process.

Automated vehicles are expected to improve mobility for young, elderly and disabled people. Also, they would allow for the possibility of undertaking tasks and activities other than driving – thus reducing the opportunity cost of the time spent in the vehicle and the labour cost by respectively increasing comfort and productivity while travelling. Moreover, vehicle automation and connection are expected to generate new jobs in the automotive, technology, telecommunication and freight transport industry. Increasing driving automation would also have an impact on professional drivers, which would be required to be trained to use the new technologies and might face a lower labour demand over the long term.

The likely net impact of automated vehicles on road congestion and emission levels is hard to establish. On the one hand, the diffusion of automated vehicles and traffic management optimisation systems is expected to determine a reduction in fuel consumption and a significant increase in infrastructure capacity, thus reducing emissions and congestion. Environmental benefits are also expected from automated systems regulating both acceleration and braking and route choice. On the other hand, an overall increase in private transport demand is likely to be spurred by the availability of the new automated transport technologies, therefore environmental gains could be counter balanced by increased demand for road transport.

### Conclusions

Automated cars are likely to sustain the shift towards a new mobility scenario where more sustainable transport solutions can replace the traditional car ownership/car usage paradigm. However, unfavourable scenarios could also occur – e.g. where the diffusion of automated vehicles would end in spurring private transport demand and the negative externalities related thereto. In that regard, European, national and local authorities should support and/or coordinate the development of automated transport systems to guide the development of connected and highly automated vehicles toward the goal of a reduction of road transport externalities.

Further research is needed to investigate full impacts of increased vehicle automation. A thorough assessment of the safety implications of automated systems should be conducted in order to estimate their likely effects on traffic accident frequency and severity, and identify potential risks from human behaviour. The findings from such assessments should, in turn, inform regulatory actions to mitigate the identified risks and accompany the introduction of this technology to guarantee that the overall effect of vehicle automation on road safety will be positive. Additional research is needed also in the field of environmental issues – e.g. to better quantify the potential for fuel consumption and emissions reductions.

The outcomes of research programmes should inform autonomous vehicle regulation to ensure safety standards are met and accompany technological developments preventing possible market failures. To date, there seems to be little coordination across the actions taken by different jurisdictions to allow for prototype testing on public roads. To some extent, different countries are competing to create the most favourable conditions for testing and attracting investment in this area. At present there is also little evidence of regulatory actions addressing the potential usage of autonomous vehicles on a large scale. Indeed this is a difficult task given the existing level of uncertainty on future pathways. Yet, amendments to existing international, European, and national regulations concerning both areas of vehicle operation/design and driver behaviour will be required in order to permit a wide implementation of a number of automated systems. A coordinated approach – which could be effectively led by UNECE - is recommended to tackle existing international and national rules that are creating barriers against the global market launch of automation Levels 3, 4 and 5 and, in some cases, also challenge the use of Level 2.

Accident liability is also an issue that needs to be addressed opportunely. Although we believe that existing legislative provisions on product liabilities can effectively guide the shift towards new insurance and liability agreements that will accompany increasing vehicle automation, actions would be needed to avoid incurring in too high litigation costs. While for current tests liability lies solely with manufactures, it is more difficult to say who will be liable when private automated vehicles are allowed to circulate on public infrastructure. Regulators would need to provide clear guidance to establish the boundaries of liability for the different levels of automation and allow for the identification of the responsible of the accident and limit litigation.

As for the potential impacts on the labour market, we believe that driving automation could deliver significant productivity gains to the freight and logistic sector, however monitoring would be needed to verify that this gains are passed to consumers through reduced product prices. Moreover, education and training will have a crucial role either to train professional drivers and to prepare the new generations to work in a more technological society where new professions might replace ones that might no longer be needed.

Finally, as higher levels of automation and vehicle connection come to the market, the role of software will also become increasingly important. It would be necessary that completely reliable and up-to-date software and IT infrastructure would be available. Requirements about data and data transmission standards, quality, security and content must also be established in order to guarantee data security and protection. When establishing such measures, particular attention must be paid to privacy concerns due to the fact that vehicle automation and connection require the use and analysis of an enormous amount of data.

# 1. INTRODUCTION

## 1.1. Preface

This study has been commissioned to look at the state of the art of automated vehicles inside and outside the EU, including both the technologies which are already on the market and those under testing and research. The study was also required to examine to investigate the potential impacts and regulatory implications and challenges arising from the diffusion of automated systems.

The study has been informed by a number of previous studies, desktop analysis and discussions with stakeholders, and provides a review of current developments in a subset of EU Member States and other countries. These countries were selected according to a number of criteria. Particular attention has been given to those countries which are at the forefront of the research and development on vehicle automation.

## 1.2. Study requirement

The purpose of the study was to provide the Members of the Committee on Transport and Tourism with a clear and comprehensive understanding of the technological developments, ongoing testing programs and legislative debate on automated vehicles. The Terms of Reference required:

- An overview of the technology and of the latest technological developments as well as an illustration of the different definitions and formal classification in use.
- A presentation of the current research, testing, and actual implementation of self-driving technology inside and outside the EU covering different application contexts and stakeholders involved, accompanied by an illustration of the regulatory regime in place to allow for the testing of this type of vehicles on the roads.
- An assessment of the technology currently available – with an indication of a potential timescale for penetration of fully automated system on the market.
- An assessment of the extent to which automated vehicles might contribute to road safety improvements on EU roads and to the reduction of other negative externalities (congestion and GHG emissions).
- Identification of other outcomes that could be generated by increasing recourse to driving automation such as potential implications on labour market, data protection, investments in transport infrastructure, driver liability and public acceptance – complemented by a review of the impact of other EU policies on the implementation of automated systems.

Finally this study provides conclusions setting out recommendations on the actions to take in order to support the achievement of the potential benefits of vehicle automation and mitigate the possible drawbacks.

## 1.3. Organisation of the research study

The remainder of this study is structured as follows:

- Chapter 2 presents the definitions and classification of automated systems which will be adopted throughout the entire report.

- Chapter 3 describes the state of the art of research, testing and implementation of automated systems, including key stakeholders and their goals; it also presents the existing regulatory framework enabling testing in different countries.
- Chapter 4 presents possible pathways of evolution of automated systems and illustrates potential impacts and implications of the diffusion of vehicle automation.
- Chapter 5 concludes by outlining key findings and recommendations.

# 2. AUTOMATED VEHICLES CLASSIFICATIONS

## 2.1. Introduction

This chapter presents an overview of the different automated systems currently available or under testing worldwide, focusing on their level of automation and on current state of the art.

## 2.2. Definitions

There is no full agreement on the definition of "automated", "autonomous", "self-driving" and "driverless" vehicles.

For this report we will identify "**automated vehicles**" as those that use on-board equipment to perform one or more driving tasks automatically and "**self-driving vehicles**" as those public or private vehicles designed to drive autonomously, without the control of a human driver. Based on this definition "self-driving vehicles" actually belong to the wider family of automated vehicles.

Another distinction found in the literature is based on the degree to which the automated vehicle is "**autonomous**", relying solely on its on-board equipment to collect information, take decisions and inform tasks, or "**connected**", i.e. in communication with other vehicles, personal devices (e.g. smart phones) or the surrounding traffic infrastructure to collect information and perform driving tasks.

Although connected and automated vehicles are two distinct concepts, they are firmly linked to one another. Technologies that can connect vehicles with other vehicles or infrastructure are already in use in non-automated vehicles – an example being the e-call device that can connect vehicles with emergency services in case of road accidents – yet, as further discussed in the rest of the report, they are a crucial element to driving the development of more advanced levels of vehicle automation both in passenger and freight transport.

This chapter presents an overview of both low and high automation systems; the rest of the study will focus primarily on the latter, as the most disruptive and challenging effects of automation will happen when vehicles with more advanced levels of automation are allowed to widely circulate on roads

## 2.3. Automated vehicle classifications

At present, a broad range of automated systems are already on the market, both on private (cars and trucks) and public vehicles (buses). In addition, many other advanced technologies are under research and being testing worldwide.

In order to facilitate the understanding of different automated technologies within the technical and policy domains, the Society of Automotive Engineers, **SAE International** [1], proposes a six level classification of road vehicles spanning from Level 0 – no automation to Level 6 – full automation. The classification considers a vehicle's capability to control its

[1] SAE International – On-Road Automated Vehicle Standards Committee, *Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems*, Information Report, January 2014

position, understand/ different environments and allow the driver to dedicate his/her attention to other activities during the journey.

Figure 1 reports the schematic representation of the levels of automation proposed by SAE international, complemented by the description of each category[2]. It is worth noticing the distinction between levels 0 to 2, under which the responsibility of monitoring the driver environment belongs to human drivers, and levels 3 to 5 including those automated systems capable – under certain conditions – of monitoring and responding to the external environment without the intervention of a human driver.

**Figure 1: SAE International's Levels of Automation**

| SAE level | Name | Narrative Definition | Execution of Steering and Acceleration/ Deceleration | *Monitoring* of Driving Environment | Fallback Performance of *Dynamic Driving Task* | System Capability *(Driving Modes)* |
|---|---|---|---|---|---|---|
| ***Human driver* monitors the driving environment** | | | | | | |
| 0 | No Automation | the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems | Human driver | Human driver | Human driver | n/a |
| 1 | Driver Assistance | the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task* | Human driver and system | Human driver | Human driver | Some driving modes |
| 2 | Partial Automation | the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task* | **System** | Human driver | Human driver | Some driving modes |
| ***Automated driving system* ("system") monitors the driving environment** | | | | | | |
| 3 | Conditional Automation | the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene* | System | **System** | Human driver | Some driving modes |
| 4 | High Automation | the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene* | System | System | **System** | Some driving modes |
| 5 | Full Automation | the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver* | System | System | System | **All driving modes** |



**Key definitions** in J3016 include (among others):

**Source:** SAE International

- Level 0 – No automation: the driver is responsible for monitoring the environment and performing all the dynamic driving tasks (longitudinal and lateral) on a sustained basis during the journey. Level 0 is defined as "no automation"; nevertheless, two sets of systems intervening without the input of the driver fall in this class, namely warning systems – e.g. Lane Change Assist, Park Distance Control, Lane Departure Warning and Front Collision Warning – and emergency systems – e.g. Anti-Lock System, Electronic Stability Control and Emergency Braking. Although the latter class includes systems that actually provide lateral and/or longitudinal control under specific situations (e.g. when breaking) these functions are still considered non-automated as they intervene for short and non-sustained periods.

[2] Adaptive – Automated Driving Applications and Technologies for Intelligent Vehicles, *System Classification and Glossary*, Deliverable D2.1, February 2015

- Level 1 – Driver Assistance: automated systems of Level 1 execute parts of the dynamic driving task (longitudinal or lateral control). The human driver is responsible for the remaining aspects of driving, including object and event detection and response, supervision of the automated dynamic driving task, execution of the dynamic driving tasks that are not automated and activation or deactivation of the assistance system[3]. Examples of Driver Assistance systems include adaptive cruise control (ACC), Parking Assist with automated steering and Lane Keeping Assist (LKA).
- Level 2 – Partial Automation: these systems execute parts of both the longitudinal (accelerating/breaking) and lateral (steering) control. The driver is responsible for monitoring and responding to the conditions of the driving environment and for supervising and activating/deactivating the automated systems. Under this automation level, the driver could be disengaged from physically operating the vehicle in certain circumstances (e.g. he/she can have his/her hands off the steering wheel). Nevertheless, he/she needs to monitor the driving environment at all times and be able to immediately take full control of the vehicle when necessary. Level 3 systems include advanced Park and Traffic Jam Assist systems.
- Level 3 – Conditional Automation: level 3 systems are able to perform all the aspects of one or more dynamic driving tasks and safety functions, including monitoring of the driving environment, under certain conditions (e.g. traffic jams on motorways). The driver is not required to constantly monitor the automated dynamic driving tasks while the Level 3 system is active, but needs to be able to take over control with appropriate reaction time when required. The system needs to alert the driver in advance if conditions require transition to driver control. Level 3 systems include Traffic Jam Chauffeur and Highway Chauffeur systems.
- Level 4 – High Automation: these systems perform all the aspects of the dynamic driving tasks under specific conditions in a similar way to level 3 systems. Nevertheless, systems under level 4 do not require a human driver to provide fallback?, as they are capable of initiating deactivation when design conditions are no longer met, fully deactivating only when the driver takes control or a minimal risk condition is achieved[4]. As a consequence, the driver might perform secondary actions, even those requiring a long reaction time, while the automated mode is active.
- Level 5 – Full Automation: level 5 systems are capable of performing all aspects of the dynamic driving tasks under all roadway and environmental conditions. Being designed to autonomously complete journeys without the need of a human driver, these are the only autonomous systems that can be properly named "self-driving vehicles" according to the definition provided at the beginning of the chapter.

The U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) provides a second definition of the levels of automation[5], which is commonly adopted when dealing with automated vehicles. This classification subdivides driving vehicles according to five levels (including Level 0 – No Automation).

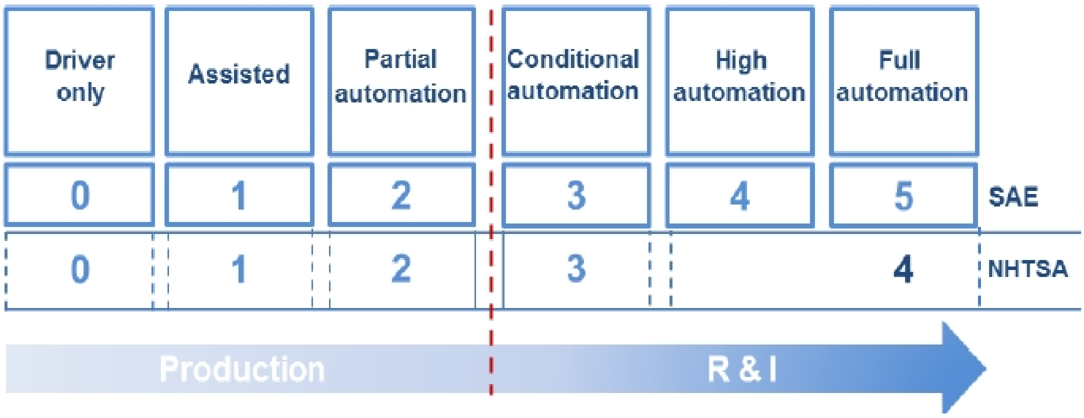
It is possible to find an analogy between the two definitions: the definitions of first four levels of the two classifications are very similar to each other although the name of the level might change (Level 0 – No Automation, Level 1 – Function-specific Automation, Level 2 –

[3] Idem, p. 39
[4] Idem, p. 43
[5] NHTSA, *U.S. Department of Transportation Releases Policy on Automated Vehicle Development – Provides guidance to states permitting testing of emerging vehicle technology*, Press Release, May 2013

Combined Function Automation, Level 3 – Limited Self-Driving Automation according to the NHTSA classification).

The main difference is that SAE International specifies a distinction between high and full level of automation, while NHTSA consider both classes as Level 4 – Full Self-Driving Automation. The following figure compares the two classifications.

**Figure 2: SAE International versus NHTSA automated vehicles classification**




**Source:** EPoSS, European Technology Platform on Smart Systems Integration[6] (2015)

Other classifications systems might be encountered when dealing with automated systems, such as those provided by the VDA (German Association of Automotive Industry) "Vehicle Automation" working group – including Audi, BMW, Bosch, Continental, Delphi, Daimler, Denso, Ford, Knorr Bremse, MAN, Opel (European branch of GM), Porsche, Valeo, Volkswagen and Wabco – and the BASt "Legal Consequences of an Increase of Vehicles Automation" working group, whose members are BASt, BMW, Bosch, Daimler, DLR, University of Berlin, University of Braunschweig and Volkswagen[7].

Despite using different slightly different definitions for the description of the automation levels – due to the differing targets of the association or working group providing the classification – the above mentioned classification systems are very similar each other. For this reason, in this study we present only the details of the SAE classification, as this is the system to which we refer throughout the document.

[6] The European Technology Platform on Smart Systems Integration (EPoSS) is an industry-driven policy initiative, defining R&D and innovation needs as well as policy requirements related to Smart Systems Integration and integrated Micro- and Nano-systems. EPoSS is contributing to EUROPE 2020, the EU's growth strategy for the 2010-2020 decade.

[7] Adaptive, *System Classification and Glossary, Deliverable D.2.1., February 2015*

## 2.4. Technology

### 2.4.1. Available technologies

#### Level 0 systems

From the beginning of the 1970s vehicle manufacturers, especially in the US, began installing systems that performed basic driving functions in their vehicles in order to enhance safety and comfort. General Motors, Ford and Chrysler were the first to develop their own prototypes of assisted driving systems.

These systems, which intervene beyond the human capability to act, taking control of the vehicles in emergency situations, are available on the market and belong to level 0 – no automation, according to the SAE classification.

They include the **Anti-lock Braking Systems (ABS),** namely closed-loop devices preventing wheel lock-up during braking and, as a result, maintaining vehicle stability and steering[8]; the **Traction Control System (TCS)** preventing wheels from spinning when starting off and accelerating[9]; and the **Electronic Stability Control (ESC)** applying braking power to individual wheels and/or reducing engine power in order to restore the vehicle's stability when detecting that skidding is imminent[10]. Unlike ABS and TCS, which only act longitudinally, ECS also improves the lateral dynamics of the vehicle, thus ensuring stable driving in all direction[11].

Other devices belonging to this category are **Advanced Emergency Braking Systems (AEBS)**, which automatically applies emergency braking if sensors monitoring the vehicle in front detect situations where the relative speed and distance between the two vehicles suggest that a collision is imminent[12].

A second set of assist systems belonging to level 0 – no automation are currently available on the market. These systems either help the driver perform specific operations such as parking or warn him/her if specific safety conditions are not occurring. Below follows the description of some of the most widespread devices belonging to this category.

- **PDC – Park Distance Control** supports parking manoeuvres by acoustically or optically warning the driver about the distance of the vehicle from the nearest obstacles.
- **LCA – Lane Change Assist** monitors the areas to the sides of the vehicle, including blind spot, and visually warns the driver who is about to change lane if a potentially hazardous situation is detected.
- **LDW – Lane Departure Warning** alerts the driver either visually, acoustically or by means of a vibration on the steering wheel when detecting that the vehicle starts to unintentionally drift off its lane while driving on motorways or major trunk roads.

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8 Royal Automobile Club of Victoria (RACV), *Effectiveness of ABS and Vehicle stability Control System*, Research Report, April 2004

9 Charlie Constant, *ESP: Electronic Stability Program*, from Car-engineer.com, 12/15/2012

10 Bosch Mobility Solutions, *Active Safety*, webpage

11 Charlie Constant, *ESP: Electronic Stability Program*

12 UNECE, *UNECE works on new standards to increase the safety of trucks and coaches*, Press Release, 12/05/2011

- **FCW – Forward Collision Warning** alerts the driver if its radar sensors detect the risk of an imminent collision with the vehicle in front. The warning may consist in a visual or acoustic signal as well in a jolt of the brakes.

### Level 1 systems

Since the 1990's a number of more advanced driving assistance systems, capable of executing parts of the dynamic driving task in place of the driver have been introduced to the market. Examples of these (level 1) systems include:

- **PA – Park Assist** supports parking by automatically steering the vehicle into a parking space thus leaving only the responsibility of accelerating and braking to the driver. PA measures the parking space, allocate the starting position and the perform the steering movements automatically.
- **LKA – Lane Keeping Assist** is an evolution of the Lane Departure Warning System, activating for speeds higher than a certain limit (usually around 60 km/h); LKA detects lane markings and takes corrective actions if the vehicle is about to leave its lane unintentionally. If the system is not capable to maintain the vehicle within its lane it warns the driver in the same ways of the LDW system.
- **ACC – Adaptive Cruise Control** is an intelligent cruise control device capable of automatically adapting the speed of the vehicle based on that of the vehicle ahead. The system monitors distance and speed of the vehicle in front and, in case this distance falls below a safety threshold, reduces the speed of the vehicle. When there is no traffic or the vehicle runs at a sufficient distance from the one ahead, the ACC system brings the speed to the target limit set by the user. If combined with an automatic gearbox the system is able to brake the vehicle to a complete standstill and takes the name of **ACC including stop-and-go function**.

An extension of the ACC system to trucks is **Co-operative ACC platooning** which is a level 1 automated system in research and testing phase where the following vehicle of the platoon adapts its speed to that of the vehicle ahead based on communication between the two trucks. This automated system controls acceleration and braking in such a way that the following truck runs at a short distance from the vehicle ahead.

### 2.4.2. Technologies under development

According to the European Automobile Manufacturers Association the European automobile industry invests €41.5 billion in Research and Development (R&D) annually, about 5% of its total industry turnover[13]. Although this amount is spent on a variety of research and test programs, it is undeniable that the development and implementation of advanced automated systems represents one of the main interests of vehicle manufacturers.

Being at the forefront of technological innovation is seen as an essential element to securing an important market share in the future of the automotive industry. The development of advanced, automated systems capable of improving driving comfort and safety is therefore a key target for vehicle manufacturers.

Whit this in mind, it is clear why more advanced systems, compared to those of level 0 and level 1, are currently under study and testing, with some already available on the market.

[13] European Automobile Manufacturers Association (ACEA), *Research and Innovation*, webpage

These devices are mainly classified as partial (level 2) and conditional (level 3) automation systems, with the latter having the ability to monitor driving tasks automatically.

### Level 2 and 3 systems

These devices should be considered an evolution of level 1 systems, as they are activated in the same specific situations (e.g. parking), but are capable of automatically executing both acceleration/braking and steering.

**Automated Parking Assistance** (level 2), capable of performing both steering and acceleration/deceleration to park the car, is already available on the market. The evolution of this system is the so called **Park Assist Level 2**, which is designed to automatically complete the entire parking manoeuvre, following remote activation by the driver, who can be located outside the vehicle. Nevertheless, monitoring the parking process, and interrupting the manoeuver if necessary, is still the responsibility of the driver.

**Traffic Jam Assist** is a level 2 system which might be considered as an extension of ACC with stop-and-go function, as it adds sideways movement function to the ability to adapt speed based on distance to the vehicle ahead.

**Traffic Jam and Highway Chauffeurs** are level 3 systems representing a further evolution of Traffic Jam Assist, as they are capable of performing lateral and longitudinal movements when driving on motorways. With Traffic Jam Chauffeurs, the vehicle is able to function autonomously on fast road (e.g. dual carriageways) at moderate speeds (e.g. speeds below 50 kph) in traffic jams. Highway Chauffeurs is a cruise control technology that allows the driver to delegate driving during long motorway journeys (although he/she must still be able to take action), which could help reducing fatigue on long trips. These technologies use automated steering to keep the vehicle on course, a high-precision GPS to find its route, and a range of sensors to allow the vehicle to change lanes to overtake or take a fork.

As for freight vehicles, level 2 and 3 are represented, for example, by truck platooning – which is an evolution of the co-operative ACC platooning system mentioned above. In this case two or more vehicles (a leader and a follower) cooperate is such a way that the leading vehicle is driven by a human driver, whereas the following one works under automated longitudinal and lateral manoeuvres directed by the leader on the basis of a the vehicle-to-vehicle communication system installed between the two. This technology still requires the presence of a driver in each truck, yet the driver sitting in the following vehicle can undertake other activities during the journey.

### Level 4 and 5 systems

The ultimate stage of vehicle automation consists in the realization of highly automated vehicles, which are not meant to support the driver, but to perform manoeuvres autonomously. Research in this area began in the 1980s, with the support of advances in Artificial Intelligence (AI) and the possibility of using Geographic Information Systems (GIS) and Global Positioning Systems (GPS).

During the 1990s the USA Defence Department promoted the development of self-driving vehicles for military purposes by financing projects across academia and automotive companies. As a result of the stimulus given by these studies, from the 2000s several automotive manufacturers, including General Motors, Mercedes Benz, Volkswagen, Audi, Nissan, Toyota and Volvo, started designing and testing their own models of self-driving cars.

As further illustrated in Chapter 3, a number of automotive and Information Technology companies such as Toyota, Volvo and Google are studying prototypes of self-driving vehicles that perform autonomously at all times. At the same time, truck manufacturers (Scania, Volvo) are investigating highly automated systems for their vehicles and a number of self-driving public transport system projects are also underway.

According to SAE classification these advanced systems correspond to high-level of automation (level 4) or full-level of automation (level 5), the former being completely independent only in certain driving modes, whereas the latter perform autonomously at all times.

Possible level 4 automation systems include highly automated parking such as the **Parking Garage Pilot**[14], performing all parking operations in a garage without the need for a human driver to monitor the process, which can be initiated remotely. Another level 4 system is the **Highway Pilot**, which is an evolution of Highway Chauffeurs, in that it performs all the driving operations on a motorway without the need for the driver to take control of the vehicle when the system is in its normal operation area. A further application of the Highway Pilot system might consist in the creation of ad-hoc convoys of vehicles (cars or trucks) connected through vehicle-to-vehicle communication (**Highway Pilot with ad-hoc platooning**).

**Fully automated cars and trucks** represent the final stage of private vehicle automation (level 5) as they would be able to perform all the driving tasks without any input from the passenger (who will therefore no longer be called driver).

With the exception of this last type of vehicle, all the above mentioned systems – whose complexity and automation level are expected to progressively increase over time – have been mainly developed for application in private transport vehicles (cars and trucks) running in extra-urban areas.

For urban environments, it is generally agreed that vehicles (cars, buses, rapid transit systems) will probably have highly automated (driverless) systems (level 4) implemented from the beginning and initially drive at low speed and/or in segregated infrastructures/dedicated spaces.

In the next chapter we provides examples of ongoing research and development on automated systems to draw evidence that will inform our assessment on the perspectives and potential implications of high and full automated vehicles in the EU.

[14] International Transport Forum (OECD/ITF), *Automated and Autonomous Driving – Regulation under uncertainty*, Corporate Partnership Board Report, Paris, 2015

**KEY FINDINGS**

- Automated vehicles and connected vehicles are two distinct concepts: automated vehicles rely on on-board equipment to collect information, take decisions and inform tasks; connected vehicles need a network to communicate with other vehicles, personal devices (e.g. smart phones) or the surrounding traffic infrastructure to collect information and perform driving tasks.
- "Self-driving" is just the ultimate achievement of vehicle automation and, at the moment, the implementation of fully automated vehicles, capable of driving regardless of the external conditions, still requires a considerable amount of research and technological advancement.
- At the moment, a variety of driving assistance systems of Level 0 (no automation) and Level 1 (driver assistance) and a smaller number of Level 2 (part automation) technologies are already on the market, mainly implemented on passenger cars to support driving on motorways or for parking. At the same time, vehicles manufacturers are investing in Research and Development of more advanced automation systems up to Level 3 (conditional automation) which are expected to further improve the driving safety and comfort of private vehicles: for example the Highway Chauffeur is expected to reduce driver's fatigue on long trips.
- Concurrently, research and testing of higher automated systems (level 4 – high automation and level 5 – full automation) is already underway. Tests and pilots in this area are being taken forward with contributions from a variety of organisations, including vehicle manufacturers, information technology companies and public authorities interested in the implementation of full self-driving technologies.

# 3. ONGOING RESEARCH, TESTING AND ACTUAL IMPLEMENTATION

## 3.1. Introduction

In this chapter we analyse state of the art research, testing and implementation of highly automated vehicles inside and outside the European Union, focusing on the following aspects:

- **Identification of stakeholders and goals** leading the research and development of highly automated vehicles;
- **Description of current projects and research programmes** concerning these technologies;
- **Analysis of the legislative framework** currently regulating testing activities at international and national level.

We have combined findings from desktop research together with interviews of stakeholders from public authorities, academia and the private sector (e.g. car manufacturers, technology companies, insurance companies, etc.) who are active in some of the countries more deeply involved in the development of advanced automated vehicles. These include eight EU Member States (Belgium, France, Germany, Italy, Netherlands, Spain, Sweden and United Kingdom), a member of the European Economic Area (Switzerland) and two OECD members (United States and Japan).

When relevant, to complement the analysis, we also collected relevant information and experience from other countries (e.g. China, Australia).

## 3.2. Stakeholders and goals

Assessing the motivations that different stakeholders have in investing in research and development of automated driving technologies is crucial to understanding what they are focussing their attention on and providing the highest contribution to.

Among the various stakeholders that are supporting innovation in this area, two different groups can be distinguished:

- **Traditional transportation stakeholders** that are already active in the automotive sector – such as those that manufacture, sell and repair vehicles (e.g. vehicle manufacturers, automotive industry suppliers, etc.); those that are responsible for transport policies or road vehicle roadworthiness and infrastructure safety (e.g. international organisations, national and local governments and public authorities in charge of these issues); those providing transport services (e.g. public transport operators); and those that provide services and facilities to the transport system, such as those that have a role in the management of risk and liability (e.g. insurance companies) or in the provision, transmission and storage of data (e.g. telecommunication companies).
- **Emerging and prospective transportation stakeholders** – such as technology companies that see potential for new areas of business to be exploited – as well as providers of new transport mobility services (e.g. car sharing and ride sharing) that can build on technological advancement in this area to further challenge the dominant private transport demand paradigm based on the pillar of private car ownership.

In many cases different stakeholders cooperate with each other to make progress; sometimes it is difficult even to assign them exclusively to one of the two categories. Nevertheless, we believe that this distinction between traditional and emerging stakeholders helps in understanding the factors driving research and development in vehicle automation, as well as the possible different scenarios and paradigms of exploiting these technologies in future years, which will be discussed in Chapter 4.

The following figure summarizes the major categories of stakeholders involved in automated vehicle deployment. For each class the figure points out the most relevant objectives and goals.

**Figure 3: Major categories of stakeholders involved in automated vehicle deployment**


This section provides an illustration of key motivations behind each of the involved stakeholders and illustrates some examples of the actions they have taken; more information on specific projects and programmes mentioned is reported in Section 3.3.

It is worth noting that the stakeholders and projects quoted below aim to provide an in depth assessment of the stakes in place and state of the art of technological development on automated vehicles. The information reported does not attempt to provide a comprehensive overview of all existent organisations or all actions taken or planned in this field.

#### 3.2.1. Traditional transportation stakeholder

##### *3.2.1.1. Public entities*

National and international public organisations are interested in research and development in automated vehicles as they see the potential to:

- Improve performance of the different transport systems (national, regional, local) by preventing accidents caused by human error; reducing transport congestion and negative environmental emissions by optimising traffic flows; providing accessibility to people currently unable to drive (e.g. elderly and disabled people) or to those that cannot afford to own a car; etc.

- Sustain economic development in their territories by attracting investors who are pursuing new business opportunities in this area and/or ensuring that existing companies (e.g. car manufacturers) can benefit from a legislative framework that facilitates their investment in these fields.

The **European Commission** and other European bodies have demonstrated their interest in vehicle automation by funding a variety of research and innovation projects relating to automated vehicles in the past decade. One of the main areas of interest of the European Commission was the development and implementation of driver assistance systems to improve driving safety in the EU: PreVent (2004-2008), Haveit (2008-2011), InteractIVe (2010-2013) and CityMobil (2005-2011) are some of the most important projects financed by the European Union in this field. The "European Roadmap – Smart Systems for Automated Driving", published by the European Technology Platform on Smart Systems Integration (EPoSS) in 2015, provides a comprehensive list of the EC funded projects[15].

In the **United States**, the National Highway Traffic Safety Administration (NHTSA) is currently engaged in research on automatic braking systems (dynamic brake support and crash imminent braking), including the development of test procedures and the assessment of the benefits of these technologies. The NHTSA is also working on Vehicle-to-Vehicle (V2V) communications technology and offers guidance to States that are looking to legislate self-driving vehicle testing.
Late in 2015 and early 2016 saw a few very promising policy developments in the US on a national level. The Obama Administration's proposed $98.1 billion budget prioritizes investment into autonomous vehicle technology, to "accelerate the integration of autonomous vehicles, low-carbon technologies, and intelligent transportation systems into our infrastructure." Additionally, US Secretary of Transportation Anthony Foxx announced at the 2016 Detroit Auto Show a proposed nearly $4 billion over 10 years to funding pilot projects that accelerate the development and deployment of safe self-driving cars. USDOT also committed to creating best practice guidelines and model state legislation within 6 months of the budget adoption. The NHTSA 2013 preliminary policy statement on AVs also will receive an update to reflect the reality of the feasible deployment of fully automated vehicles. This acknowledgement of the status of AV technology and reinforcement through funding commitments is significant in legitimizing autonomous vehicles.

The **UK** government is taking a proactive role in creating the environment in which autonomous vehicles can be tested by establishing a supportive, light-touch regulatory framework. Moreover, the government is providing direct support to the Research and

[15] European Technology Platform on Smart Systems Integration (EPoSS), *European Roadmap – Smart Systems for Automated Driving*, Berlin, April 2015

Development of these technologies through the establishment (July 2015) of a cross departmental group, named Centre for Connected and Autonomous Vehicles (CCAV), that will lead the innovative policy development for self-driving vehicle, provide a single contact point for stakeholder engagement, and deliver a programme of R&D activity worth up to £200m through the UK's innovation agency Innovate UK. This £200m funding has been announced within the Spring Budget 2015 (18/03/2015) and is made up by £100m from the UK Government, match funded by industry. The UK Government also supports several cross-sector programs – Autodrive, VENTURER and GATEway – which investigate the applications and implications of autonomous vehicle technologies, mainly in urban areas.

In September 2015, the **German** Federal Ministry of Transport and Digital Environment published its Strategy for Automated and Connected Driving[16], in which it sets out the potentials of autonomous driving as well as the strategy's objectives and specific action areas and measures. Moreover, The Federal Government initiated an Automated Driving Round Table where industry, academia and government come together to set out specific areas of action to support the introduction of automated driving in Germany, including:

- Infrastructure: roll-out of full broadband coverage with at least 50Mbit/s by 2018 and investigation of the requirements for intelligent roads in relation to automated and connected driving ('Digital Motorway Test Bed').
- Legislation: amendment of the Vienna Convention and relevant UN regulations and review current national legislation – particularly in terms of driver liability and training.
- Innovation: funding of research projects related to automated and connected driving that investigate human-machine interaction, functional validation, the social dimension, and transport infrastructure.
- Interconnectivity: provision of open-source traffic and infrastructure data through a data cloud and willingness to shift to digital radio and universal network coverage.
- Cyber security and data protection: greater use of anonymisation and pseudonymisation in data collection and processing and provision of comprehensive information to vehicle owners and drivers about what data is collected and by whom.

The **Swedish** government is supporting a national program to promote alliances between stakeholders. In particular, in 2009 Sweden established a partnership with automotive industry, named FFI (Strategic Vehicle Research and Innovation[17]), aiming at investigating innovative solutions for Climate & Environment and Safety. FFI involves R&D activities worth approximately €100m per year (half of this amount is government funding) including research on Automated Vehicles and Connected Transport Systems[18].The government is also supporting the "Drive Sweden" Strategic Innovation Program[19]– currently in launch phase and expected to start in early 2016 – which will study the development of autonomous vehicle technology in the country.

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[16] Federal Ministry of Transport and Digital Infrastructure, *Strategy for Automated and Connected Driving – Remain a lead provider, become a lead market, introduce regular operations*, Berlin, September 2015

[17] Vinnova, *Transportation,* webpage: http://www.vinnova.se/en/Our-acitivities/Search-for-programme/Transportation/

[18] Vinnova, *FFI - Strategic Vehicle Research and Innovation*, webpage: http://www.vinnova.se/en/FFI---Strategic-Vehicle-Research-and-Innovation/#

[19] Volvo Car Group Global Newsroom, *Volvo Car Group initiates world unique Swedish pilot project with self-driving cars on public roads*, Press Release, 02/12/2013

The **French** government is encouraging a new strategic alliance across the major French automotive companies in order to favour the development of autonomous cars in the country. In the industrial strategy "La Nouvelle France Industrielle" promoted by the Ministry of Economics and Finances in 2014, automated vehicles are mentioned as a key point for technology development in the country. The strategic national plan includes a detailed roadmap for self-driving cars, specifying future actions and the respective timescales[20].

Moreover, the Ministry of Sustainable Development is promoting a national program, SCOOP@F[21], that aims at developing Cooperative Intelligent Transport Systems (C-ITS) in France. About 2,000 kilometres of roads and highways are to be equipped to allow wireless communication with automated vehicles on road. Part 1 of the project (March 2014 – December 2105) dealt with the study and pre-deployment phase, while the infrastructure adaptation is expected to start during Part 2 of the project (January 2016 – December 2018).

The **Dutch** government aims at both maintaining a strong position in European automation and converting Rotterdam Port to one of the most logistically efficient ports worldwide with the support of autonomous supply lines. Dutch Automated Vehicle Initiative (DAVI) was launched in March 2013 and is currently the most relevant public-private platform, coordinating national strategies[22]. Amongst the major DAVI partners, the statutory research organization TNO stands out; this has the role of supervising and promoting testing activities.

Overall, the public sector has a crucial role and responsibility in enabling the development and market penetration of automated vehicles, as public authorities are responsible for both setting the conditions to undertake tests and authorising the use of automated vehicles on road infrastructure, provided that adequate safety standards are met. This point will be further explained in Section 3.6 where we discuss the regulatory framework.

#### *3.2.1.2. Vehicle manufacturers and automotive suppliers*

Automotive companies – and their suppliers – have a long track record of innovation in making vehicles more automated and they undoubtedly play a key role in research and development in this area, supporting most of the current on-going programs worldwide.
Their development is mainly characterised by an approach which builds on the existing paradigm of private car ownership and usage and focuses on drivers' needs. In this respect they are focusing their attention on developing sophisticated driver assistance technology, through an incremental approach, that will progressively lead the market to more sophisticated automation systems. This approach is dictated by the primary concern of being competitive in the market and investing in technologies that appeal to consumers.

The **UK** automotive industry is involved in the push towards autonomy. As part of this, the Society for Motor Manufacturers & Traders (SMMT) commissioned a study to establish the potential size of the connected and autonomous vehicles market[23]. One of the key drivers for the move towards a higher level of automation from the automotive industry's

20 Le Gouvernement de la Republique Française, *La Nouvelle France Industrielle – Présentation des feuilles de route des 34 plans de la nouvelle France industrielle*, Dossier de presentation, September 2014

21 French Ministry of Ecology, Sustainable Development and Energy, Direction générale des Infrastructures, des Transports et de la Mer, *SCOOP@F – Test deployment project of cooperative intelligent transport systems*, Press Release, May 2014

22 DAVI website, *http://davi.connekt.nl/partnership/*

23 KPMG and SMMT, *Connected and Autonomous Vehicles – The UK Economic Opportunity*, KPMG LLP, March 2015

perspective is to provide features that enhance the safety and enjoyment of vehicles for their customers.

**German** manufacturers are promoting self-driving vehicles and are currently undertaking tests. Audi, BMW and Mercedes Benz are all active in this sector, leading experiments worldwide, as shown in Table 1. The significant interest of German manufacturers in vehicle automation is also testified by the recent acquisition of Here – the digital mapping and location-service division of Nokia – by Audi, BMW and Daimler for €2.8 Billion[24]. This acquisition is an interesting example of synergy between manufacturers and tech companies where the traditional stakeholder incorporate the new one in order to take advantage of its greater skills and experience in a specific area of automated driving. Another example of collaboration between companies coming from the automotive and technology sectors is the partnership between car manufacturers including BMW and the Chinese search engine and technology company Baidu for the development of increasingly automated systems of driver assistance[25]. Interestingly, Baidu's approach is different from Google's one, as the latter is competing rather than collaborating with vehicle manufacturers by developing its own model of self-driving car, as explained in Section 3.3.1.

Volvo Car Group and Scania are some of the most important stakeholders in the autonomous vehicle market in **Sweden**. Both of them have been very active in this area, looking at automation for private and freight transport vehicles and taking the lead in EU-wide research programmes. Since 2009, Volvo Car Corporation has been involved in the SARTRE project, an European program focused on the development of vehicle platoons[26], while Scania is a key partner of the European program COMPANION, the SARTRE successor[27]. Both the SARTRE and the COMPANION project were funded by the European Commission under the Framework 7 programme and involved companies from other EU Countries as UK, Germany and Spain. Volvo Car Group is also currently promoting the "Drive Me – Self-driving cars for sustainable mobility"[28] programme mentioned above.

Renault and Peugeot Citroën PSA are the **French** automotive companies most involved in self-driving. At the beginning of October 2015, Peugeot Citroën presented its future plans for automated cars during the 22nd ITS World Congress. The company is developing an automated system relying on Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication technology, in collaboration with the SCOOP@F program[29]. Renault is developing a new model of automated car: NEXT TWO. Prototypes have already been tested for short routes and even public demonstrations occurred last year[30]. Both Peugeot Citroën and Renault claimed that they will introduce their models on the market by 2020.

Valeo, a French automotive technology supplier, presented automated car models in 2015, while EasyMile, a joint venture signed between the French automotive company Ligier and

[24] Chris Bryant, *VW, BMW, and Daimler agree €2.8bn deal for Nokia Here digital maps*, Financial Times, 03/08/2015
[25] The Guardian, *China's Baidu could beat Google to self-driving car with BMW*, 10/06/2015
[26] Safe Road Trains for the Environment (SARTRE), *First demonstration of SARTRE vehicle platooning*, Press Release, 17/01/2011
[27] Scania Group Newsroom, *Scania lines up for platooning trials*, Press Release, 04/04/2012
[28] Volvo Car Group Global Newsroom, *Volvo Car Group initiates world unique Swedish pilot project with self-driving cars on public roads*, Press Release, 02/12/2013
[29] PSA Peugeot Citroën – Innovation by PSA, *Enabled automatic E-call & B-call*, Presentation at the ITS World Congress, Bordeaux (France), October 2015
[30] Danielle Muoio, *4 self-driving French cars successfully made a 360-mile trip with no test driver*, Business Insider UK – Tech News, 05/10/2015

robotics company Robosoft[31], which led to the design of an autonomous vehicle for use in pedestrian and protected zones (e.g. hospitals and university campuses).

In **Japan**, manufacturers are planning to release their first automated vehicles on the market by the 2020 Tokyo Olympic Games. Toyota, Nissan and Honda have already carried out tests on public roads.

Some long-standing **US** automakers appear to be in a period of transition away from traditional values of the automobile industry, towards new models of mobility. This movement away from traditional values and business models seems to have come about through competition and collaboration with the tech industry's rapid advancement in vehicle autonomy. Where initial ambitions for automaker's self-driving technology seemed to lie in a gradual building on driver assistance approach, US automakers seem to be making moves to partner with the tech industry to create fully autonomous vehicles, and show an awareness for and interest in shared self-driving car business models. The competition and fast pace at which autonomous technology is advancing are forcing companies to innovate and re-evaluate business models. As the CEO of GM Mary Barra says of automakers, "we are disrupting ourselves."

Other US companies such as Delphi and Tesla continue to approach automation as a gradual process and focus on developing vehicles with high level of automation, and the transition between human and system driver.

#### *3.2.1.3. Telecommunications companies*

Telecommunications companies see potential for new business opportunities in exploiting increasing communication needs among vehicles and between vehicles and infrastructure.

**Swiss** telecommunications company Swisscom is promoting self-driving car trials on Zurich roads. The company is investigating the role that communications will play in an automated transportation world. The first Swisscom test occurred in May 2015 in collaborations with UVEK (the Federal Department of Environment, Transport, Energy and Communications) and Germany's Autonomos Labs. The demonstration involved a VW Passat model, which Autonomos Labs has equipped with sensors and software[32].

The **Spanish** automotive provider Applus IDIADA launched the VRAIN project (Vehicular Risk Awareness Intelligence Network), in collaboration with the telecommunications company Cellnex Telecom, to allow information transmissions between vehicles. The program aims at investigating Vehicle-To-Vehicle (V2V) and Vehicle-To-Infrastructure (V2I) communication in order to avoid car accidents. At the moment the VRAIN project is at a pilot phase. In Terragona, IDIADA created a test zone where the system can be studied without legal barriers. The project is testing vehicles driving at speeds of up to 250 km/h in this protected area, where car movements are monitored and supervised[33]. These devices are planned to potentially be installed on any production car.

#### *3.2.1.4. Insurance companies*

A number of insurance companies are actively participating in research activities to understand the impacts of higher levels of autonomy on the insurance industry. They are

[31] EasyMile website, *http://easymile.com/mobility-solution/*
[32] Swisscom, *Swisscom reveals the first driverless car on Swiss roads*, Press Release, Berne, 12/05/2015

interested in understanding the impact that different automated systems can have on accident frequency and severity – as this would affect motor insurance risks and premiums – as well as investigating other risks that might arise from a deeper penetration of automated vehicle technologies along with the liability regime that will be established to accompany their market penetration.

In the **UK** AXA is involved the Venturer and UK Autodrive projects, RSA Insurance Group is participating in the GATEWay project, while Lloyds is currently interested in assessing the risks associated with autonomous features.

Zurich Insurance Group is involved in several research programs worldwide, including CitiMobil, where it provides insurance assistance for tests being carried out in European cities. The **Swiss** company is mainly interested in understanding frequency and severity of accidents in automated vehicles – with particular focusing on medium levels of automation as they see full automation as a far reaching target to achieve for mass transport.

#### *3.2.1.5. Academia*

Academia plays an important role in the research and development of automated systems as universities develop innovative prototypes as well as cooperating with automotive companies around application of the technologies. Academia lies between the traditional and emerging stakeholders, as it is working both with car manufacturers and other emerging stakeholders of the technology and telecommunication sectors as discussed below. Both are important players in this market

At the moment, universities from different countries are cooperating in cross-sectorial programs with public and private stakeholders in the development and application of automated mobility systems.

In the **UK** academia is researching a range of topics associated with connected and autonomous vehicles. Some institutions are investigating the development of autonomous control systems (e.g. University of Oxford's Mobile Robotics Group, University of Bristol), others are researching the human machine interaction (e.g. University of Cambridge, University of Southampton), whilst yet others are investigating software validation issues (e.g. Sheffield University).

In **Italy**, the Vislab laboratory – a company born as a research spin-off of the University of Parma, and recently (July 2015) merged with the Californian hardware company Ambarella – launched an innovative program on autonomous vehicles in 2009 that led to the development of a self-driving car that has already been publically demonstrated. Vislab technology has also been applied to military vehicles and factory/mine working machines[34]. In 2010, Vislab undertook an intercontinental demonstration (The Vislab Intercontinental Autonomous Challenge – VIAC) in which a convoy of four self-driving vehicles ran from Parma to Shanghai along a 16,000 kilometre route. In March 2014, Visilab presented its new prototype DEEVA, a highly innovative solution for autonomous driving design. DEEVA integrates more than twenty cameras and four laser scanners on a sedan with open rooftop, showing that Visilab's driverless technology can be installed on any vehicle with no change in the external vehicle look and in its aesthetics.

[33] Cellnex, *Cellnex Telecom colabora con Applus IDIADA en el desarrollo de un Sistema de Comunicación Inteligente entre vehículos para una gestión segura y eficiente de la conducción*, Press Release, 10/06/2015

[34] VisiLab website, *http://vislab.it/*

Moreover, La Sapienza University in Rome has been involved, since 2001, in several European research programs on full-automated vehicles performing in urban context. In particular, La Sapienza participated in CityMobil and is currently taking part in its successor CityMobil2 by supporting demonstrations across Europe.

In **Germany**, the Technical University of Brunswick, as part of the Stadtpilot research project, has been developing a self-driving vehicle based on a conventional Volkswagen Passat since 2008. In October 2010, the automated car, named 'Leonie', drove autonomously in the city traffic of Brunswick under authorisation by Federal State of Lower Saxony. In late 2011, the car named 'MadeinGermany' completed a fully automated 40km run through the city centre of Berlin without any incidents[35]. Since 2012, a research group of the University of Ulm has been developing a fully automated vehicle based on a Mercedes Benz limousine[36]. In early 2014, their vehicle ran its first trials on the public roads network in the city of Ulm.

A research team at Alicante University (**Spain**) is developing a system allowing automated pilot on common cars. This device is designed to be installed on any production car[37]. The researchers are currently testing an adapted golf cart inside the University campus. At the beginning, the technology was studied for freight movements inside factories while, in a second phase, researchers understood its potential for application in cars.

In the **United States**, universities are contributing significantly to the development of autonomous vehicle technology. The 2004, 2005, and 2007 DARPA Challenges[38] created an opportunity for these academic institutions to invest competitively into the development of this technology. Carnegie Mellon University, Stanford, Virginia Tech, MIT, University of Pennsylvania and Cornell all took part in these competitions. Following the challenges, members of the university teams that participated in the competition were recruited to join private companies such as Google to work on developing the current self-driving prototypes. Moreover, Uber has partnered with two academic institutions, the College of Optical Sciences at University of Arizona[39], to develop mapping technology, and CMU Robotics Lab[40]. The University of Michigan opened Mcity[41] in July 2015, a 32 acre test site for connected and autonomous vehicles that simulates complex environments that pose challenges to this technology. Michigan is partnering with a wide range of stakeholders who will use this site to test pilot technology.

The **Singapore**-MIT-Alliance for Research and Technology produced a notable case study[42] for a Shared Self-Driving Car program for Singapore.

### 3.2.2. Emerging and prospective stakeholders

The huge technological progress of the last decade has had disruptive impacts on many industries, including media and telecommunication. Transport itself has been deeply affected by the birth and success of companies who took advantage of the opportunities

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35 Autonomous-Labs website, *http://autonomos-labs.com/history/*

36 Ulm University website, *https://www.uni-ulm.de/index.php?id=53474*

37 Coches autónomos, *Un dispositivo permitirá circular sin conductor a los vehículos tradicionales*, 30/09/2014

38 Defense Advanced Research Projects Agency (DARPA) website, *http://www.darpa.mil/*

39 NBC News, *Uber Working With University of Arizona to Create Self-Driving Cars*, 25/08/2015

40 UBER Newsroom, *Uber and Carnegie Mellon University: A Deeper Partnership*, Press Release, 09/09/2015

41 University of Michigan – Mobility Transformation Center, *Mcity Test Facility,* webpage, *http://www.mtc.umich.edu/test-facility*

42 Spieser K., Treleaven K., Zhang R., Frazzoli E., Morton D., Pavone M., *Toward a Systematic Approach to the Design and Evaluation of Automated Mobility-on-Demand Systems – A Case Study in Singapore*, in Meyer G., Beiker S. (editors), Road Vehicle Automation – Lecture Notes in Mobility, Springer, 2014

offered by technology and enhanced communication systems to create new mobility services, such as transport networking (e.g. Uber) and car sharing providers, to challenge traditional transport services (e.g. taxi, car rental) and even the concept of car ownership.

This tendency is expected to continue in the future as technology companies or start-ups with a technology vocation see vehicle automation as an opportunity to increase their market share or entry (if they aren't already in it) to the transport market.

#### *3.2.2.1. Technology companies*

Technology has revolutionized many industries. Nevertheless, the automotive industry hasn't dramatically changed its business model or major players in the last 10 years. Those stakeholders (technology companies) that have already revolutionised communications, etc. (Google, Apple, etc.) are now willing to enter in the automotive industry. They are primarily active in the US where the automotive sector currently employs 1.7 million people, provides $500 billion in annual turnover and accounts for approximately 3% of US GDP, but they have the ambition to lead a world-wide revolution in this market.

Indeed what distinguishes their action is the development of a new mobility paradigm where people should no longer need to be car drivers, but rather be passengers of an automated mobility service that will drive them where they need. As such, they are not focusing on actions that would progressively help people to drive better, safer and more relaxed – which is the automotive industry approach – but are looking for solutions that completely relieve people from driving activities, allowing them to spend their time on other activities while taking a ride in a self-driving car. As a consequence, these companies are generally focused on developing fully autonomous cars, with little interest in developing market-ready driver assistance technology.

In doing this, some are pursuing alliances with automakers or automotive producers, while others are interested in designing their own model of self-driving vehicles. This is very similar to what happened with smartphones and other technological devices where the Apple approach of putting internally developed, innovative products on the market differs from the Android one of establishing partnerships and commercial agreements with players already present on the market.

Key stakeholders active in this area are Google – that in the US is designing its own models of self-driving car – and, likely, Apple, which seems to be developing its driverless automated electric car ("Project Titan"). Further details on these projects are reported in section 3.3.1.2.

In Europe, the **Hungarian** computing company Adasworks is currently developing an innovative operating system allowing automated pilot on common cars. The main idea of the project is to integrate the hundreds of chips that are currently installed in cars (for air conditioning, cruise control and other devices) into a single, high performance virtual chip. This innovative chip is expected to control several automated tasks at the same time. The system will be installed on different kind of vehicles and operate on unmodified roads. The company has so far only undertaken tests in protected and limited situations.

While the major technology companies (e.g. Google) are working on the development of software and solutions that could be installed across a variety of vehicles – although targeting private vehicles – other companies are working on market niches such as the taxi service. This is the case of the **Japanese** company Robot Taxi – a joint venture between mobile-internet firm DeNA and vehicle-technology developer ZMP – and the **Australian** autonomous mobility company Zoox.

It is worth noting that the new paradigm launched by these technological companies would also create significant synergies and market opportunities for telecommunication companies as connectivity among vehicles and between vehicles and infrastructure is a crucial aspect of their plans.

#### *3.2.2.2. Transport networking and car sharing companies*

Innovative providers of transport solutions, such as car sharing companies and car clubs or platforms to provide ride sharing services, are interested in automated and connected vehicles as they see the potential to increase their productivity thanks to cost reduction deriving from the removal of driver costs - which allows them to be more competitive on the road passenger market – and improved system efficiency that can derive by new ICT applications.

For example, Uber recently entered in a strategic partnership with the Carnegie Mellon University to do research in the areas of mapping, vehicle safety and autonomy technology in order to develop driverless cars. This partnership was followed up by $5.5 million of support from the tech rideshare company.

## 3.3. Projects and application contexts

In this section we present a number of projects and research programs relating to automated vehicles. This is not meant to be an exhaustive list of all the tests undertaken worldwide – as this is not the scope of the study. Instead we aim to provide a picture of cutting edge research and testing activities in the EU and in some foreign countries.

To provide guidance on the assessment of what is being testing in this innovative area, we have grouped projects by type of vehicle – private cars, freight vehicles, public transport and urban mobility vehicles – as each of these application contexts present peculiarities in terms of technology, stakeholders and future pathways of development.

### 3.3.1. Cars

Discussing private cars, which are where research is more active at the moment, we have provided examples of the incremental approach to automation led by car manufacturers, as discussed above – hereafter called the "evolutionary approach" – and cases that belong to the new mobility paradigm proposed by technology companies – the "revolutionary approach". The first approach is traditionally followed by car manufacturers and suppliers, though there are cases where the automotive industry is moving towards the second approach, as shown below. Cars are probably the most studied and developed transport application of automated systems worldwide.

#### *3.3.1.1. Evolutionary approach*

Car manufacturers are interested in developing increasingly automated assistance systems to improve driving safety and comfort. Key examples are reported in Table 1.

Most of the examples quoted below – with few exceptions - focus on the introduction of higher level of automation on selected infrastructure (e.g. highways, dedicated routes, etc.).

This can be partially explained by fact that automotive industries are interested in investing in technologies that can pass safety and roadworthiness tests in the short/medium term to be able to sell them on the market and respond to their customer's needs – such as the need of reducing effort and fatigue while driving for long trips.

A remarkable exception – that is, a research project following the revolutionary approach carried out by a car manufacturer – is the Drive Me project, supported by Volvo, that looks at full automation of vehicles required to interact with other non-automated vehicles in different contexts, as further illustrated below in the section dedicated to urban mobility.

**Table 1: Examples of application of automated vehicles in private cars under the evolutionary approach**

| PROJECT/STAKEHOLDER | DESCRIPTION |
| --- | --- |
| Tesla | In October 2015, Tesla Motors released an over the air (OTA) software update for all Tesla Model S[43] vehicles purchased after September 2014, allowing for semi-autonomous driving in suitable conditions. Essentially an extension of Level 1 Driver Assistance – this system combines automated cruise control, collision warning systems, automatic steering and automated lane changing by using radar, cameras, GPS and ultrasonic sensors to operate. The current system is still in beta mode and a number of issues are still to be solved, such as excessive speeds of the pilot mode, abrupt turns and reliability in rainy conditions. Also in early 2016, Consumer Report flagged a safety flaw with Tesla's "Summon" feature, which allows users to operate the vehicle remotely at low speeds for tasks like parking or navigating tight spaces. The original application of pressing a button to begin movement and pressing again to stop raised concerns over the possibility of the remote being dropped and the moving vehicle being out of operator control. In response to the report finding, Tesla updated the feature to operate as a "dead-man's switch" to require continual button pressure by the operator. The safety flaw, however quickly amended, raises concerns about the ability of autonomous vehicle producers to put products that pose a safety hazard on the market. |

[43] Ron Amadeo, *Driving (or kind of not driving) a Tesla Model S with Autopilot*, ArsTechnica.com, 15/10/2015

| PROJECT/STAKEHOLDER | DESCRIPTION |
|---|---|
| Valeo | In March 2015 Valeo presented its model of automated car in collaboration with the engine and security company Safran[44] at the National Army Museum in Paris. The trial reproduced a route in urban area. The vehicle performed at low speeds (down to 20km/h) facing up with pedestrians and fixed obstacles[45]. This model could be classified as a semi-autonomous vehicle whose main capability consists of reacting in stop&go situations without human intervention.<br><br>In October 2015 , the company showed its innovative model of adaptive cruise control system Cruise4U on Bordeaux's A630 highway declaring that it would be available at an affordable sale by a couple of years[46]. This device, which is designed to be installed on any production car, allows automatic driver mode in traffic jams and queues and in homogeneous flows (highways), and is capable to reach speed up to 210 km/h on a straight lane and 130 km/h on a common highway. This system is not supposed to perform as a full automated vehicle but only aims at supporting the driver. |
| Peugeot Citroën | Peugeot Citroën developed an automated model designed to drive autonomously on highways and main extra-urban roads. This model is capable of recognising traffic signs and moderate speed due to flow conditions[47]. In October 2015, Peugeot Citroën tested four autonomous cars along a 280 kilometre route from Paris to Bordeaux. The vehicles started performing in automated mode after entering on the principal road[48] although, during the trial, the driver stayed at the wheel at all times to conform to legal requirements. |
| Renault | The Renault automated car prototype, named NEXT TWO, is designed to be able to perform autonomously when the vehicle is circulating on protected roads (without pedestrians and cyclists) and at low speeds (not exceeding 30 km/h). The optimal application of Renault automated pilot would therefore be traffic jams on highways. Prototypes have already been tested for short routes. The model could connect to Wi-Fi, 3G and 4G network and is equipped with an autonomous parking system[49]. |

[44] Safran Group website, http://www.safran-group.com/
[45] Peter Sayer, *French self-driving car goes for a spin around Paris monument*, PCWorld.com, 27/03/2015
[46] Valeo, *Valeo unveils its autonomous vehicle at ITS Bordeaux 2015*, Press Release, Paris, 10/05/2015
[47] PSA Peugeot Citroën, *A PSA prototype car travels from Paris to Bordeaux in autonomous mode*, Paris, 02/10/2015
[48] Danielle Muoio, *4 self-driving French cars successfully made a 360-mile trip with no test driver*, Business Insider UK – Tech News, 05/10/2015
[49] Groupe Renault, *NEXT TWO: the autonomous car made in Renault*, Press Release, 24/01/2014

| PROJECT/STAKEHOLDER | DESCRIPTION |
|---|---|
| Jaguar Land Rover | Jaguar Land Rover has announced that they (alongside the Engineering and Physical Services Research Council) will be investing £11m in a research programme[50] to identify and resolve some of the key technical issues associated with autonomous and driverless vehicles. |
| Audi | In 2009, Audi was the first car manufacturer to test a fully automated vehicle in a desert in Utah, United States, reaching a speed record for automated driving of about 210 km/h. In 2010, the vehicle developed by Audi participated in the Pikes Peak Challenge (an annual automobile and motorcycle hill climb set of races in Colorado, USA) completing the 20km long climb with 156 bends in around 27 minutes. In 2013, Audi was the first car manufacturer to be granted a special permit from the Nevada Department of Motor Vehicles to test autonomous vehicles[51]. |
| Mercedes-Benz | Mercedes-Benz already offers partially automated driving in its most recent E- and S-Class models thanks to the DISTRONIC PLUS systems which is capable of mainly autonomous steering in stop-and-go situations[52]. Moreover, in August 2013, a Mercedes-Benz prototype drove the 100km route between the cities of Mannheim and Pforzheim in fully autonomous mode. |
| AdaptIVe | AdaptIVe[53] is a research project co-funded by the European Commission as part of the Seventh Framework Program (€ 14.3 million out of the total € 25 million budget) aimed at improving automated systems' safety and efficiency, by dynamically adapting the level of automation to the situation and conditions of the driver. AdaptIVe studies automated systems – ranging from Level 1 to Level 4 of the SAE classification – mainly applied to passenger cars (six demonstrations) although also heavy vehicles will be investigated (one demonstration). The project, which started in 2014 and will run until 2017, is led by the Volkswagen Group Research and includes a total of 29 partners from 8 countries (France, Germany, Greece, Italy, Spain, Sweden, The Netherlands, United Kingdom). |

[50] Engineering and Physical Sciences Research Council (EPSRC), *Jaguar Land Rover and EPSRC announce £11 million autonomous vehicle research programme*, Press Release, 09/10/2015

[51] Audi, *History of piloted driving*, webpage, *http://www.audi.com/com/brand/en/vorsprung_durch_technik/content/2014/10/history-piloted-driving.html*

[52] Mercedes-Benz, *Autonomous long-distance drive*, webpage, *https://www.mercedes-benz.com/en/mercedes-benz/innovation/autonomous-long-distance-drive/*

[53] Adaptive website, *https://www.adaptive-ip.eu/index.php/objectives.html*

| PROJECT/STAKEHOLDER | DESCRIPTION |
|---|---|
| Toyota | In Japan, Toyota is developing a modified Lexus GS called Highway Teammate, using on-board technology to evaluate traffic conditions and drive autonomously on highways. Tests have been performed on Tokyo's Shuto Expressways, including entering and leaving the highway, maintaining and changing lane and regulating speed and distance with respect to other vehicles[54]. |
| GM | In early 2016, GM is testing a small fleet of self-driving hybrid Chevrolet Volts on their Michigan campus. The current fleet of five cars could increase up to 30 in the future. GM in a joint venture with Chinese auto manufacturer SAIC has released a concept for Chevrolet-FNR, a fully autonomous electric vehicle. The company projects these vehicles to be available on the mass market by 2030[55]. The company is working to improve sensor technology to operate in heavy fog and icy conditions, and develop precise mapping to guide cars. GM works with Mobileye, a provider of visual processing chips and software that detect potential collisions with pedestrians, vehicles or other obstacles, and process road markings, signs and traffic lights. This technology already powers existing features in some GM vehicles such as lane departure warnings, and the company is considering using its camera data to create highly detailed and constantly updated road maps that are continually self-updating. This use of sensors could potentially allow AVs to be aware of their own location within 10 cm compared to other current GPS systems whose margin of error is measured in meters[56]. Beyond developing its autonomous vehicle technologies, GM has taken actions to establish itself in the car sharing economy. GM acquired staff and access to a 14 year old patent for ride-hailing technology from Sidecar, an early and less successful competitor of Uber and Lyft, started up a car sharing service called Maven that currently operates in one city with the intentions of expanding to others, and most notably, entered into a partnership with Lyft in early 2016 to "create a national network of self-driving cars"[57] |

[54] Toyota Global Newsroom, *New Toyota Test Vehicle Paves the Way for Commercialization of Automated Highway Driving Technologies*, Press Release, 06/10/2015

[55] GM-Chevrolet Media, *Chevrolet-FNR and All-New Chevrolet Malibu Make Global Debut at Shanghai GM Gala Night*, 19/04/2015

[56] GM Corporate Newsroom, *GM Exploring Mobileye Advanced Mapping With OnStar Data*, 05/01/2016

[57] Bloomber Business, *General Motors Salvages Ride-Hailing Company Sidecar for Parts*, 19/01/2016

| PROJECT/STAKEHOLDER | DESCRIPTION |
|---|---|
| Ford | Ford currently has a fleet of 10 self-driving cars with the intention of adding an additional 20 in the near term, with plans to run testing in Michigan, Arizona and public roads in California. Ford is hoping to offer a fully autonomous vehicle within 5 years. In 2015, the company established a Silicon Valley research lab to help forge partnerships with tech startups and big companies. In early 2016 there have been unconfirmed reports of a partnership between Ford and Google, the announcement of which was expected but not delivered at the International Consumer Electronics Show (CES)[58].The automaker and tech giant have existing connections, including the revolutionary approach to autonomous technology rather than a gradual, driver assistance approach, a former long-term Ford employee heading Google's self-driving car project and former Ford chief executive on Google's board. Google has the most advanced autonomous vehicle to date, with a fleet of 57 and millions of miles logged, while Ford has the experience and resources for large scale automobile manufacturing.. At the date of issuing of this report, information available does not allow us to confirm any ongoing joint initiative in this respect. |
| Delphi | In 2015, the Delphi Drive project drove a highly automated vehicle nearly 3,400 miles from San Francisco to New York, 99% of which was done autonomously. Delphi team took an Audi SQ5 and retrofitted it with Delphi technologies to make the car highly automated. As a technology supplier, Delphi's approach is to produce the technologies to sell to automakers interested in producing autonomous vehicles, operating as supplier rather than an self-driving car producer. In March 2015, Delphi's automated vehicle completed the longest automated drive in North America – traveling from San Francisco to New York in autonomous mode 99% of the time[59]. At CES 2016, Delphi introduced a user interface focusing on facilitating transitions between autonomous and human driving, a feature while not essential, important to acclimatising users to autonomous driving by providing the user with reassurance through an indication of what the car is seeing, thinking and planning. Delphi's focus on user integration is especially important for high level yet not full levels of automation. |

[58] The annual Consumer Electronics Show or CES in Las Vegas is traditionally the place where the electronics giants have unveiled the latest consumer technology innovations for the coming year. CES 2016 ran officially from January 6 to January 9 in Las Vegas, US

[59] Delphi Press Releases, *Delphi Successfully Completes First Coast-to-Coast Automated Drive*, 02/04/2015

### 3.3.1.2. *Revolutionary approach*

As discussed above, technology companies are mainly focussing on full automated vehicles capable of running without a driver.

The **Google Driverless Car**[60]/[61] is arguably the most known and debated project concerning full automation worldwide and is a clear example of a prototype built from the ground up to be a driverless vehicle, as it neither includes a steering wheel nor pedals – thus completely removing the occupant from the operator role. Also the design is autonomous driving oriented, with even the vehicle shape being rounded to optimize the capability of the sensors.

In the US, it is not only large companies driving the discussion on AVs. Startups, like Faraday Future are also taking a role in imagining the applications of self-driving cars. Faraday, a company of just over 400 people, is looking at a user-driven approach to future vehicle design. The company presented its concept automated car – the FFZERO1 Concept – at CES 2016 and talks about vehicle intelligence not only being outwardly directed towards its surroundings, but capable of learning its users and making decisions based on passenger desires. The company has gained interest from poaching significant numbers of talent from other companies in the field and being very well funded.

In early 2016, two important partnerships are emerging between automakers and tech companies. GM entered into a partnership with Lyft with the goal of creating a national network of shared self-driving cars. GM invested $500 million in the tech company, taking a seat on the board of directors. This shift towards a shared, mobility service rather than a private ownership model is a big step for auto manufacturers. The second, rumoured but unconfirmed partnership between Ford and Google follows a similar pattern. While unconfirmed, the partnership would most likely be non-exclusive, so further partnerships between tech and automakers are probable.

Early in 2016, Uber is experimenting with using smartphones to monitor quality of driving. Uber is testing using GPS, accelerometers and gyrometers in smartphones to attempt to flag dangerous driving. The use of widespread a widespread technology as smartphones could have implications for collecting data that informs the development of autonomous vehicle technology.

**Table 2: Examples of application of automated vehicles in private cars under the revolutionary approach**

| PROJECT/STAKEHOLDER | DESCRIPTION |
|---|---|
| Google | Google started working on self-driving in 2009, initially focusing on data collection and mapping through tests undertaken with Toyota Prius on freeways in California. In 2012, Google began working with the Lexus RX450h and focus shifted to testing on city streets. The first real build of the Google driverless car is dated December 2014 with speed capped at 25 mph and a simple design on the |

[60] Google Official Blog, *What we're driving at*, Press Release, 09/10/2010
[61] Claire Cain Miller, Nick Bilton, *Google's Lab of Wildest Dreams*, The New York Times, 13/11/2011

| PROJECT/STAKEHOLDER | DESCRIPTION |
|---|---|
| | inside accommodating two passengers. The software builds experience with all driving done, so the more driving that is done in any of the vehicles the smarter and more experienced all of the cars become.<br>Since 2009, Google's self-driving car has logged 1,210,676 autonomous miles, 911,252 manual miles, and is averaging 10,000 to 15,000 autonomous miles per week on public streets (data updated to September 2015). Google vehicles have experienced 14 accidents in six years of driving and around 1.9 million miles of test, all of which have been attributed to human error[62]/[63].<br>As of market launch, Google has not released any official statements about the timing planned to introduce their automated vehicle prototype on the market. |
| Apple | Rumour has it that Apple is developing its own model of electric autonomous car, named Project Titan[64]. It seems that the IT company is going to test their vehicles in the abandoned GoMentum Station in the San Francisco Bay area – which is currently closed to the public – to keep their plans secret. |
| Robot taxi | In Japan, at the beginning of 2016, Robot Taxi will test a fully automated taxi service on 50 residents of the Kanagawa prefecture. The selected people will book the taxi via mobile phone and the self-driving vehicle will drive them to selected shopping centres. The project will also study characteristics and behaviours of the users of the self-driving service[65]. |
| Zoox | The innovative autonomous taxi "L4" – designed by the Australian company Zoox – could be defined as fourth level of automation according to NHTSA classification. The vehicle is not equipped with steering wheel and pedals and is designed to drive in either directions due to its shape without front or rear. Zoox is planning to install four independent motors and automated equipment at each corner of the vehicle to enable future models performing in whichever direction. Zoox declared they will be |

[62] The Guardian, *Crash involving self-driving Google car injures three employees*, 17/07/2015
[63] Matt Richtel, Conor Dougherty, *Google's Driverless Cars Run Into Problem: Cars With Drivers*, The New York Times, 01/09/2015
[64] The Guardian, *Documents confirm Apple is building self-driving car*, 14/08/2015
[65] Kazuaki Nagata, *Robot Taxi plans to have Fujisawa residents test driverless car for supermarket rides*, The Japan Times, 01/10/2015

| PROJECT/STAKEHOLDER | DESCRIPTION |
|---|---|
| | ready to test their models on public roads by 2019 with the aim to run a taxi service in cities with favourable weather conditions such as Las Vegas in 2020. |
| Vislab | In Italy, Vislab is focusing on automated cars performing in mixed traffic situations such as urban contexts. In 2013, the company experimented with automated driving in urban environments. The project – called PROUD (Public Road Urban Driverless) – involved an automated car travelling in downtown Parma from the University Campus to the city centre. Vislab is currently developing its new model of autonomous car: DEEVA. This vehicle is equipped with 4 laser scanners and more than 20 cameras, allowing the complete detection of external obstacles all around the vehicle. Utilizing a Sedan model with open rooftop, the research team wants to demonstrate that the technology could be applied to any kind of vehicle[66]. |

### 3.3.2. Freight vehicles

The most studied application of automated systems in road freight transport is truck platooning due to its potential to reduce fuel consumption and emissions – by decreasing the distances between successive vehicles – as well as the cost of the driver who would be substituted by the automated pilot. Details of key projects tested are reported below. Several programs are conducted also by other truck companies in addition to those mentioned in the table, such as Mercedes-Benz, Volvo and Daimler (Freightliner).

Initiatives are been taken also at the policy level towards platooning implementation Europe-wide. One example is the European Truck Platooning Challenge organized by The Netherlands Government in April 2016[67].

**Table 3: Examples of application of automation in freight transport vehicles**

| PROJECT/STAKEHOLDER | DESCRIPTION |
|---|---|
| EcoTwins | In March 2015, the truck manufacturing company DAF Trucks NV and Netherlands Organisation for Applied Scientific Research (TNO) gave a demonstration of truck platooning (EcoTwins) on the N270 national road near Helmond, Netherlands. The demonstration consisted of a convoy of two trucks driving on a short distance with the second vehicle able to accelerate, brake |

66 VisiLab website, *http://vislab.it/*
67 www.eutruckplatooning.com

| PROJECT/STAKEHOLDER | DESCRIPTION |
|---|---|
| | and steer autonomously thanks to Cooperative Adaptive Cruise Control (CACC) systems[68]. In the near future EconTwins should undertake tests in the Rotterdam harbour area, as both the Port of Rotterdam Authority and the Transport en Logistiek Nederland (TLN) trade organisation are involved in the project. In 2016, the Netherlands will initiate a European Truck Platooning Challenge aimed at encouraging truck manufacturers, logistics service providers, research institutes and governments to partner and share their knowledge and experience about truck platooning[69]. |
| COMPANION | The 2013-2016 European research project COMPANION[70], which was preceded by the 2009-2012 SARTRE project , is studying the application of platooning in daily transport operations in order to reduce greenhouse gas emissions of heavy vehicles. The objective is to create dynamic platoons by merging vehicles that share parts of their route and to suggest regulations to allow trucks to run at shorter distances in the EU. The budget of COMPANION is € 5.4 million, of which € 3.4 million are funded by the 7th Framework Program. The project is led by SCANIA and also involves participants from Germany (Volkswagen Group Research and Oldenburger Institut für Informatik), Sweden (Stockholm's Royal Institute of Technology) Spain (IDIADA Automotive Technology and Transportes Cerezuela) and Netherlands (Science & Technology).<br>As part of this project, Scania tested truck platoons along the 520-kilometre route between the Swedish cities of Södertälje and Helsingborg. These tests, supported by Swedish National Road and Transport Research Institute (VTI), took place on two-lane motorways and adopted only Adaptive Cruise Control systems, controlling the speed of the following vehicle based on the speed of the vehicle ahead. The gap between the trucks varied from 2 to 3 seconds and the company is willing reduce it during next tests. |

[68] DAF, *DAF and TNO demonstrate 'EcoTwin'*, Press Release, Eindhoven, 27/03/2015
[69] European Truck Platooning Challenge 2016
[70] Companion Project website, *http://www.companion-project.eu/*

### 3.3.3. Urban mobility and public transport

A number of projects, generally involving a large number of stakeholders coming from different sectors of expertise, are currently underway to develop automated transport systems in urban and mixed-use areas. Some of them focus on public transport solutions; others – such as many of those supported by the UK government - are looking at a wider range of technical options and implications of interactions between different types of vehicles and road users, setting the base for future research in this area.

Indeed prototypes of highly automated transport systems performing at low speed in protected environments (hospitals, airports, universities, etc.) already exist and the main challenge is to progressively operate these vehicles at higher speeds in less protected areas.

**Table 4: Examples of application of automation on urban mobility and in public transport vehicles**

| PROJECT/STAKEHOLDER | DESCRIPTION |
|---|---|
| CityMobil | The CityMobil[71] project was a research, development and demonstration project addressing the integration of automated transport systems in urban areas. The project ran between May 2006 and December 2011 and involved stakeholders of public sector and academia coming from a number of EU Member States. The total budget was € 40 million and the project was co-funded by the sixth framework programme of the European Commission. The programme involved three large-scale implementations of automated driving in Heathrow Airport, Castellón and Rome, five showcases in European cities and a 3-month demonstration in La Rochelle (France). Future perspectives, technological challenges and operational issues related to vehicle automation were investigated within the study[72] |
| CityMobil2 | The CityMobil successor, named CityMobil2, is a project co-funded by the EU Seventh Framework Programme, focusing on the implementation of driverless transport systems (mainly small buses) in areas of low or dispersed demand to complement main public transport networks. The programme, which started in September 2012 and will run until 2016, involves 45 partners coming from public authorities (mainly cities), systems suppliers, academia and networking organisations[73]. The project will test driverless automated road transport systems (ARTS) through three large-scale and four small-scale demonstrations as well as three shorter showcases. Demonstrations already took place in La Rochelle, Lausanne (EPFL), Helsinki and Bordeaux – where four self-driving shuttles operated from C Tram Palais des Congres station to the Convention Center during the ITS world congress.<br>EasyMile is providing driverless vehicles for CityMobil2 |

[71] CityMobil Project website, http://www.citymobil-project.eu/
[72] CityMobil Project, *Advanced Transport for the Urban Environment*, Brochure, November 2011
[73] CityMobil2 Project website, http://www.citymobil2.eu/en/About-CityMobil2/Overview/

| PROJECT/STAKEHOLDER | DESCRIPTION |
|---|---|
| | demonstrations. Their EZ10 model is a driverless shuttle with a capacity of 10 passengers and a maximum speed of 25 km/h capable to detect obstacles and move autonomously thanks to its sensors and cameras. The model allows also for V2V and V2I communication[74]. The EZ10 Model is also involved in Wepod, a Dutch project promoted by the province of Gelderland to connect the Wageningen University campus to the city of Ede by means of self-driving buses. The innovative aspect of this project relies in the possibility for its users to book a seat and specify their origin and destination via app. First public demonstrations of this driverless system are expected to take place in 2016. |
| PostBus | The bus company PostBus Switzerland Ltd will test the ARMA electric self-driving shuttles in Sion over the next two years. Shuttles – running at a maximum speed of 20 km/h and capable of carrying a maximum of 9 people – will be controlled and managed by software developed by the Swiss company BestMile. In the initial phase (December 2015 – spring 2016) the vehicles will be tested in a private area; subsequently – and upon approval of relevant authorities – shuttles will be operated also in public areas. Two shuttles are expected to be able to transport people in the centre of Sion in spring 2016.[75] |
| LUTZ Pathfinder project | The LUTZ Pathfinder project[76], involving Transport Systems Catapult, RDM Group and Oxford University's Mobile Robotics Group is exploring the use of autonomous vehicles (pods) in shared space environments. The objective of the project, which began in 2014 and is scheduled to run until 2017, is to develop pods that can be run on pavements and test them in Milton Keynes (Buckinghamshire) to observe the interaction with other users (pedestrians, cyclists etc.). A range of systems and technologies are being used for the project, including a bespoke vehicle that is designed to function in the shared space and pedestrianized environment, and an array of sensors (LIDAR, RADAR, ultrasonic, weather sensors, stereo cameras and wide-angle cameras). |

[74] EasyMile website, http://easymile.com/mobility-solution/
[75] PostBus, *Autonomous shuttles run for the first time*, Press Release, 17/12/2015
[76] Catapult Transport Systems, *Driverless Pods,* webpage, https://ts.catapult.org.uk/pods

| PROJECT/STAKEHOLDER | DESCRIPTION |
|---|---|
| Autodrive | Autodrive[77] is a project jointly funded by industry and the UK government that will test autonomous vehicle technologies in Coventry and Milton Keynes. This was one of the three projects selected in 2014 by Innovate UK to introduce driverless cars to UK roads (the other two being VENTURER and GATEway described below). The Autodrive project, which is led by Arup and involves a variety of stakeholders from public sector, private sector and academia, runs from 2015 and is expected to conclude in 2018. The aims of the activity are to validate autonomous vehicle technologies by exploring their application in a number of environments (on road trials, plus a commercial scale service for low speed autonomous vehicles in a shared space). Additionally, the project is keen to explore the long term benefits and application of autonomous vehicles to the urban environment by identifying mobility services at a variety of scales. The project will explore a range of autonomous vehicle types and technologies ranging from pods designed for low speed, shared space use, to on-road vehicles offered by some of the world's leading automotive manufacturers (Ford, Tata, Jaguar Land Rover). |
| VENTURER | VENTURER[78] is a project funded by UK government and industry that will trial autonomous vehicles in Bristol and South Gloucestershire. The consortium is led by Atkins and involves a number of partners again coming from a different sectors. Venturer will run from 2015 to 2018 and will seek to understand and enhance user acceptability, insurability and related legal aspects for autonomous vehicles such that they can operate in busy urban settings. The programme will test autonomous vehicles on public and private roads, explore the legal and insurance issues, explore car-to-car communications, and use buses as vehicle probes for data collection purposes. |
| GATEway | GATEway[79] is a programme jointly funded by government and industry which began in 2015 and will run until 2017. The project is being led by TRL and involves a number of consortia partners from private sector and academia. The project plans to demonstrate that automated transport systems can safely and efficiently operate in a range of environments (e.g. urban transit, automated valet parking, urban delivery). The consortium also seeks to understand the wider social, technical and legal issues associated with |

[77] ARUP, *'UK Autodrive' consortium wins competition to develop driverless cars*, Press Release, 03/12/2014

[78] ATKINS, *VENTURER consortium - autonomous vehicles*, webpage, http://www.atkinsglobal.com/en-gb/projects/venturer-driverless-cars

[79] TRL, *Greenwich's digital credentials driven home after TRL-led consortium wins £8m trial to pilot futuristic automated vehicles*, Press Release, 03/12/2014

| PROJECT/STAKEHOLDER | DESCRIPTION |
|---|---|
| | the developments. The project will be exploring systems dealing with remote vehicle operation, autonomous control, simulation, traffic management, and vehicle-to-infrastructure (V2I) communications, as well as specialist vehicles. |
| NEXT | The NEXT[80] project seeks to create an automated transport system run by autonomous pods to operate as an intermediate solution between a taxi service and public transport. The vehicles will have a capacity for six people and perform with electric traction. The pods are supposed to pick up passengers at home, travel together in "road trains" and then disconnect to reach their final destinations. The project is still in research phase but it is expected to be completed in approximately five years. |
| Drive Me | The Volvo Car Group is currently leading the most innovative project around autonomous cars in Sweden: "Drive Me – Self-driving cars for sustainable mobility"[81]. The project has the ambitious purpose of introducing vehicles with high levels of automation in a real urban context, interacting with other non-automated cars and facing real traffic situations. The DRIVE ME pilot will start in 2017 and take place in Gothenburg. The project will involve 100 self-driving cars using approximately 50 kilometres of selected roads. The vehicles in the project are defined as Highly Autonomous Cars according to the official classification. |

## 3.4. Legislative framework for testing and place into market

In discussing the legislative framework for automated vehicles a clear distinction needs to be made between large scale testing – where single countries can usually define the context also in derogation to international traffic rules – and place into market of increasingly automated vehicles – which is affected by a number of EU, international and national provisions on road safety, vehicle legislation, driver behaviour, liability, etc.

This Section illustrates first the key legislative provisions on vehicle legislation and driver liability that are of interest for the place into market of automated vehicles and concludes by reporting examples of the state of the art of national legislative frameworks on road tests of this type of vehicles. Issues concerning legislation on motor vehicle insurance, product liability or data protection and security – which too are of relevance for the circulation of automated and connected vehicles on public roads, will be dealt with as part of the discussion of the main implications of the spread of automated vehicles, discussed in Chapter 4 this report.

[80] Next – The Future of Transportation website, http://www.next-future-mobility.com/

[81] Volvo Car Group Global Newsroom, *Volvo Car Group initiates world unique Swedish pilot project with self-driving cars on public roads*, Press Release, 02/12/2013

Further details on the international and European regulatory framework can be found in a recent publication from the European Parliamentary Research Service – EPSR on Automated Vehicles in the EU[82].

### 3.4.1. Technical aspects: vehicle legislation

At the EU level, Directive 2007/46/EC regulates how new vehicles should operate and be designed. The purpose of this Directive is to set up a fully harmonised EU-wide framework for the approval of motor vehicles, thus creating an internal market within the European Community and ensuring a high level of road safety, health protection, environmental protection, energy efficiency and protection against unauthorised use. However, the more detailed technical provisions are mainly contained within UNECE (WP 29) and can be found in the UNECE regulations to which the EU legislation refers.

At national level there is a degree of scope for guaranteeing alternative national requirements and permitting exceptions for test operations. Indeed, as discussed in detail in Section 3.4.3, at present different countries have introduced measures to ease tests on their roads or have clarified the regulatory context to allow for tests. However, neither in the EU nor in the US is there any coordination between the legislation produced by different governments. While this issue might be of lower relevance at the testing and experimental phase, it could pose some challenges for future development, as vehicles and technologies will need to fulfil international, harmonised requirements to be launched on the market.

A number of initiatives are under development to support a harmonised approach by amending international regulations and preventing fragmentation. In the most noteworthy of these, put in place by UNECE, the World Forum for the Harmonization of Vehicle Regulations (WP 29)[83] is assessing proposals covering semi-automated driving functions (autopilot systems to be used in traffic jams, self-parking functions and highway autopilots), which will ultimately pave the way for more highly automated vehicles. An example of the challenges faced is given by the ongoing work to amend UN R79 on steering equipment[84] that at present only allows automatically commanded steering functions up to 10 kph, while beyond 10 kph only 'corrective steering function' is allowed. As such, some Level 2, 3, 4 and 5 systems are not allowed with current requirements and an amendment is needed to accompany the development of automated systems. Discussions are ongoing at UNECE also to examine UN R13 on braking systems, which does cater for "Automatically Commanded Braking", but may require some examination to confirm its suitability. UNECE work in this area is fundamental to prevent that legislative barriers limit the introduction in the market also of lower level of automations which are ready to be deployed in the short term, as well as to pave the way for the place into market of higher level of automation.

Among the points to be addressed there is also a need to reconsider the approach used so far to regulate vehicle systems, an issue recently raised in a report issued by the Swedish Transport Authority[85]. Traditionally, regulating vehicles has been based on demonstrating

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[82] European Parliament, *Automated vehicles in the EU*, Briefing, January 2016

[83] The World Forum for Harmonization of Vehicle Regulations (WP 29) is a permanent working party in the institutional framework of the UNECE Inland Transport Committee, that works as a global forum allowing discussion on motor vehicle regulations. WP 29 it's open to member countries of the United Nations and regional economic integration organizations, as well as – in a consultative capacity – to governmental and non-governmental organizations.

[84] The UN Regulation No, 79 (*Uniform provisions concerning the approval of vehicles with regard to steering equipment*) was issued in 1988 to establish uniform provisions for the layout and performance of steering systems fitted to vehicles used on the road.

[85] Swedish Transport Agency – Road and Rail Department – Traffic and Infrastructure unit, *Autonomous driving – Pilot study*, Report, August 2014

that vehicles meet established requirement levels for each separate system. Essentially, this involves clearly defined limits and testing methodologies, which can be used by any testing organisation. For the complex safety-critical systems required for autonomous driving, the approach needs to consider not only how different systems are managed individually, but also and more importantly, how they interact with one another. There are currently no requirements that guarantee the safety of a vehicle's self-driving functions. The report suggests that regulation will be needed to ensure an adequate level of road safety for vehicles of level 3, or above, so as not to delay the launch to market.

This could be taken in place as part of an update of either the EU type of approval standards (Directive 2007/46/EC on vehicle approval), discussed above, and of the EU Roadworthiness Directive (Directive 2014/45/EU) – which provides a basis for checking that vehicles throughout the EU are in a roadworthy condition and meet the same safety standards as when they were first registered. The European Commission seems to be considering action in this area as the need to intervene on both these Directives to cover new technologies and vehicle capabilities and accompany mass production of highly automated vehicles in the EU has been recently pointed out also by the discussion paper on Highly Automated vehicles recently presented as part of the GEAR 2030 initiative[86].

### 3.4.2. Behavioural aspects: driver liability

*Legislative framework*

One of the central issues regarding autonomous vehicles is that concerning the responsibility of the driver. In most Member States, the driver behaviour is covered by traffic rules, civil and criminal law, in particular for ensuring road safety. The current law is based on the assumption that when a vehicle is used on the roads there is a natural person on board (the driver), which is considered responsible for the safe operation of the vehicle whilst on public roads. Automation technology is intended to partially or completely replace the driver – therefore, a new regulatory framework will be determined, where the requirements for car automation systems overlap with the rules for driver behaviour. Close coordination is therefore needed between the work on the two areas of road traffic legislation which until now were kept separate – rules concerning the vehicle and the driver. The traffic rules of Member States will need to be updated to take into account the use of highly automated vehicles on the roads.

At the international level, there are two framework agreements with implications for automated driving currently in force: the 1949 Geneva Convention on Road Traffic and the 1968 Vienna Convention on Road Traffic.

The Geneva Convention[87] is an international agreement, accepted by 95 states (Switzerland signed but did not ratify it), that established uniform rules to promote road safety internationally. The treaty requires that: i) every vehicle or combination of vehicles proceeding as a unit shall have a driver; and ii) drivers shall at all times be able to control their vehicles.
The Vienna Convention[88] of Road Traffic is an international treaty establishing standard traffic rules, which was signed in Vienna in 1968 and has been ratified in 73 countries to

[86] European Commission – *Roadmap on Highly Automated vehicles* – GEAR 2030 Discussion Paper, January 2016

[87] United Nations, *Convention on Road Traffic*, Geneva, 19/09/1949, in United Nations, Treaty Series, vol. 125, p. 3

[88] United Nations Economic Commission for Europe (UNECE), *Convention on Road Traffic*, Amendment 1, Vienna, 08/11/1968

date. All EU Member States are signatories of the Vienna Convention except for the UK and Spain – non-EU signatories include Mexico, Chile, Brazil and Russia, although not the United States, Japan and China. One of the fundamental principles of this treaty is laid down in Article 8 which requires that every vehicle – or combination of vehicles – have a driver, who must, at all times, be able to control his 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 (par. 6) was added to Article 8 requiring the driver to minimise activities other than driving; additionally, domestic legislations were required to forbid the use of hand-held phones on motor vehicles and mopeds in motion.

In 2014 the UN Working Party on Road Traffic Safety (WP.1) proposed amendments to Article 8 and Article 39 of the 1968 Vienna Convention, aimed at ensuring that safety rules do not hamper the advancement of new technologies aimed at improving road safety[89]. According to the amendment, 'systems which influence the way vehicles are driven', as well as other systems which can be overridden or switched off by the driver, are deemed to be in accordance with Article 8 of the Vienna Convention. The amendment adopted by the UN on 23 September 2015, will enter into force on 23 March 2016 and it is expected to facilitate the place into market of higher levels of automation once technology will be ready to be produced on a larger scale. The amendment was submitted by the governments of Germany, Italy, France, Germany, Belgium and Austria, showing the extent to which the new technology is important for Europe.[90]

**Box 1: 2015 amendment to 1968 Vienna convention**

A new paragraph (par. 5bis) has been inserted into Article 8: "Vehicle systems which influence the way vehicles are driven shall be deemed to be in conformity with paragraph 5 of this Article and with paragraph 1 of Article 13, when they are in conformity with the conditions of construction, fitting and utilization according to international legal instruments concerning wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles. Vehicle systems which influence the way vehicles are driven and are not in conformity with the aforementioned conditions of construction, fitting and utilization, shall be deemed to be in conformity with paragraph 5 of this Article and with paragraph 1 of Article 13, when such systems can be overridden or switched off by the driver."

*Emerging issues*

As underlined by the European Parliament Research Service (EPRS) in its Briefing on Automated vehicles in the EU (2016), the amended convention still demands that every vehicle have a driver – i.e. the driver may be able to take the hands off the wheel, but must be ready at all times to take over the driving functions, and can override the system and switch it on and off. In this sense, whilst systems with conditional automation (i.e. automated vehicles up to level 3,) could be operated in accordance with the Convention, systems with high or full automation (i.e. level 4 and level 5 systems) are mostly still incompatible with the Vienna Convention – even as amended in 2015 – because a driver may not be required in these systems, depending on the use case. Therefore, a further amendment process would be necessary to permit fully driverless vehicles.

[89] United Nations Economic Commission for Europe (UNECE) – Inland Transport Committee – Working Party on Road Traffic Safety, *Report of the sixty-eighth session of the Working Party on Road Traffic Safety*, Geneva, 24-26/03/2014

[90] Safe Car News, *UN amends Vienna Convention on Road Traffic to allow driverless cars*, 21/05/2014

In parallel to the activities on the 1968 Vienna Convention, the Working Party on Road Traffic Safety decided to align the text of the 1949 Geneva Convention on Road Traffic with the agreed text of the amendment to Article 8 of the Vienna convention[91].

An additional critical point is the fact that national traffic laws can also contain legislative specifications that prevent the adoption of level of automation higher than level 2 on their roads, thus creating an additional barrier to the development of these technologies. On the other hand, though, there are countries that have not ratified either of the two international conventions mentioned above and can therefore act with more autonomy in setting the regulatory framework.

In light of the difficulties that even level 3 of automation could face in some countries, and with different regulatory systems emerging worldwide, a number of stakeholders – including FIA[92] - are calling for further action in this area and for the exploration of synergies between provisions dealing with behavioural aspects (e.g. UNECE WP1[93]) and those to do with regulation and technological aspects (e.g. UNECE WP29[94]).

### 3.4.3. Examples of national legislative frameworks on road tests of automated vehicles

Different approaches have been adopted at national level worldwide to allow testing of highly automated vehicles. While some countries grant authorisation on a case by case basis, others are focused more on modifying national laws to facilitate vehicle testing in their territory.

In the **US[95]/[96]/[97]**, the states of California, Florida and Nevada and the District of Columbia, have passed laws allowing and setting the conditions for the testing of automated and highly autonomous vehicles. Eleven states are considering legislation addressing the testing of these vehicles and an equal number of states have failed to pass bills allowing the on-road testing of autonomous vehicles. All four states that have passed autonomous vehicle legislation allow non-testing use of those vehicles, though in the case of Michigan, the driver must be a representative of the manufacturer. In California, Nevada and Florida, vehicles must meet Federal Motor Vehicle Safety Standards[98]. California, Nevada and the District of Columba require autonomous vehicles to have an easy to trigger auto-drive disengage switch and an alert system for system failures. Both California and Nevada require vehicles to store sensor data from 30 seconds before a collision. Nevada restricts testing to specific geographic contexts and California reserves the right to do so. Neither Florida nor the

[91] UNECE, Informal document WP.29-167-04
[92] http://www.fia.com/news/77th-session-unece-inland-transport-committee
[93] The Working Party on Road Traffic Safety (WP.1) was established in 1988 as an intergovernmental body. WP.1 is the only permanent body in the United Nations system that focuses on improving road safety and guaranteeing legal instruments aimed at harmonizing traffic rules.
[94] See for example: Federation Internationale de l'Automobile (FIA), *Autonomous driving*, 2015
[95] International Transport Forum (OECD/ITF), *Automated and Autonomous Driving – Regulation under uncertainty*, Corporate Partnership Board Report, Paris, 2015
[96] American Association of Motor Vehicle Administrators (AAMVA) – Autonomous Vehicles Information Sharing Group, *Analysis of Laws Enacted in Jurisdictions (An Introduction to AAMVA AV Law Comparisons)*, Executive Summary, October 2014
[97] The Center for Internet and Society (CIS), *Automated Driving: Legislative and Regulatory Action*, webpage, http://cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action
[98] The National Traffic and Motor Vehicle Safety Act (1966) was enacted to empower the federal government to set and administer new safety standards for motor vehicles and road traffic safety. The Act created the National Highway Safety Bureau (now National Highway Traffic Safety Administration, NHTSA) which has a legislative mandate to issue Federal Motor Vehicle Safety Standards (FMVSS) and Regulations to which manufacturers of motor vehicle and equipment items must conform and certify compliance. The first standard to become effective was issued in 1967 and other FMVSS have been issued subsequently.

District of Columbia impose geographic restrictions. Nevada only issues registration permits explicitly for testing, whereas Michigan only issues registration certificates to manufacturers.

US Secretary of Transportation, Anthony Foxx, announced as part of President Obama's FY17 Budget Proposal a 2016 update to the 2013 NHTSA Preliminary Statement of Policy Concerning Automated Vehicles. In this respect, though, one significant development in this US regulatory contest comes from a NHTSA letter to Google[99] on the interpretation of 'driver'. On 04/02/2016, the NHTSA responded to a request from Google to interpret several provisions in the Federal Motor Vehicle Safety Standards as they apply to Google's described design for automated vehicles Google is developing and testing. The NHTSA affirmed that the driverless computer Google created to pilot its self-driving cars can be considered, under federal law, a 'driver'. NHTSA explained that it will interpret 'driver' as the self-driving system instead on any of the vehicle's occupants. The NHTSA further agreed that 'driver' for Google's autonomous vehicle would not be a 'driver' in the sense that vehicles for the last over 100 years have had drivers. This legitimization of artificial intelligence as an alternative to a human driver in the application of the Federal Law is a significant victory for autonomous vehicle producers and future users. The affirmation of this technology's ability by the NHTSA can significantly streamline the process of deployment, though still much needs to be done before these vehicles can safely be put on the market. In this respect, the NHTSA letter also indicates clearly the need for companies like Google to develop a method of standards and certification for self-driving systems, pointing out that 'the next question is whether and how Google could certify that the (self-driving system) meets a standard developed and designed to apply to a vehicle with a human driver'.

Although the progress made at federal level, still there are significant legal questions surrounding autonomous vehicles in the US States. The California Department of Motor Vehicles (CA DMV) recently proposed regulations for all autonomous vehicles to have manual controls with the ability for a human driver to regain control in emergency situations. The regulation would be a huge setback for AVs developers who aim to remove the human driver from the equation entirely. Google argues that the danger in the proposed auto safety features is that human occupants could be tempted to override the self-driving system's decisions, reintroducing the danger from human error that is responsible for 93% of incidents in the US.

In Europe, as the **UK** never ratified the Vienna Convention, their legislative framework does not require major legal 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. 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 summary report titled the "Pathway to Driverless Cars"[100]. The 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 summer 2017. The Department for Transport (DfT) has published

99 NHTSA, Response to Google Letter of 12 November 2015, February 2016.
Available at:
http://isearch.nhtsa.gov/files/Google%20--%20compiled%20response%20to%2012%20Nov%20%2015%20interp%20request%20--%204%20Feb%2016%20final.htm

100 Department for Transport, *The Pathway to Driverless Cars – Summary Report and action plan*, London, 2015

a non-statutory Code of Practice[101] that organisations testing autonomous vehicles in the UK are expected to follow. This provides guidelines and recommendations for measures that should be taken to maintain safety during testing. Moreover, in July 2015 the UK government launched a £20 million competitive fund for collaborative research and development into driverless vehicles.

In **Sweden**, the Vienna Convention and the Swedish Road Traffic Ordinance[102] coexist and Swedish authorities have incorporated several regulations from the Convention into the national legislation. At the moment, the Ordinance considers the presence of a driver inside the vehicle, capable of intervening at all times, to be compulsory, as someone has to be legally responsible at all times. 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. According to the Ordinance local authorities and municipalities are both 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. Swedish transport regulations allow authorities to make rapid decisions for specific and innovative purposes, such as self-driving tests (e.g. Drive Me program).

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 collaborate with other United Nations states to modify the current international legislation. 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. 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 allowing higher regulatory flexibility compared to rest of the country, was also granted a special permission to start testing Robot Taxi from March 2016[103].

**France** also signed the Vienna Convention. However, in October 2014, the French National Assembly authorised automated vehicles for testing purposes[104]. 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 automation in the country. Official standards to regulate tests are expected to be operative by 2020[105]. 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[106].

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[101] Department for Transport, *The Pathway to Driverless Cars: A Code of Practice for testing – Moving Britain Ahead*, London, 2015

[102] Swedish Transport Agency, *Autonomous driving – Pilot study*, Report, August 2014

[103] Kazuaki Nagata, *Robot Taxi plans to have Fujisawa residents test driverless car for supermarket rides*, The Japan Times, 01/10/2015

[104] Elena Roditi, *Voitures autonomes: les initiatives du législateur français*, Alain Bensoussan Avocats online, 04/11/2014

[105] Nil Sanyas, *Voitures sans pilote: des premiers tests sur les routes françaises dès 2015*, NextInpact.com, 08/07/2014

[106] Danielle Muoio, *4 self-driving French cars successfully made a 360-mile trip with no test driver*, Business Insider UK – Tech News, 05/10/2015

**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. Therefore tests of highly automated vehicles on public roads are allowed only under the monitoring of a driver who has full legal responsibly for the safe operation of the vehicle[107]. Meanwhile, the "Automated Driving" Round Table, launched by German Federal Ministry of Transport and Digital Infrastructure, announced in 2015 that a roadmap on the development of the legal framework to be published shortly[108].

**Belgian** legislation allows prototypes to be tested on roads under the responsibility of car manufacturers, subject to permissions from regional authorities (as owners of the infrastructure) and the federal administration, which has to approve the technology installed on the vehicle. Since Belgium ratified the Vienna Convention, permissions are given under the condition that a driver must be present in the vehicle and ready to intervene. As soon as the Vienna Convention article concerning self-driving vehicles is amended, on-road testing of driverless systems could begin.

The **Netherlands** signed the Vienna Convention; nevertheless the country aims to build a regulatory framework allowing automated vehicles to be tested in its territory. In 2015 the Council of Ministers approved an amendment to the national regulations authorising the national road traffic agency to grant exemption for large-scale testing of self-driving cars and trucks on public roads[109].

**KEY FINDINGS**

- Automated vehicles projects are currently underway in several countries worldwide. A number of European countries, including UK, Germany, France, Sweden and Netherlands are taking significant steps to be at the forefront of research in this sector. Other OECD countries such as US and Japan host technology companies (Google, Uber, Robot Taxi) which are undertaking significant investments in the research and testing of vehicle automation.

- The government is arguably the stakeholder leading automated driving research in the **UK**, taking steps to revise the regulatory framework in order to facilitate automated technology testing in the country; additionally, it is funding several research projects with the objective of positioning UK as centre of excellence for testing and development of vehicle automation and ensuring the UK automotive industry's vitality in the short, medium and long terms.

- The governments of **France**, **Germany** and **Sweden** are also actively involved in the development of vehicle automation in their respective countries. Nevertheless, in these countries the research is mainly driven by the automotive industries. In France, Peugeot Citroën and Renault – together with the automotive suppliers Valeo – are developing advanced automated systems for passenger cars. In Germany, Volkswagen, Mercedes Benz, BMW and Audi are testing advance driving assistance

[107] International Transport Forum (OECD/ITF), *Automated and Autonomous Driving – Regulation under uncertainty*, Corporate Partnership Board Report, Paris, 2015
[108] Maxime Flament (ERTICO), *Sub-WG on Legal and Regulatory issues*, iMobility Forum WG Automation in Road Transport, Presentation, 17/09/2015
[109] *Netherlands to test AVs on public roads*, Traffic Technology Today.com, 06/02/2015

systems capable of automatically performing a number of driving tasks under specific conditions. In Sweden, the Volvo Car Group is studying advanced applications of driving automation in an urban context (Drive Me project) whereas Scania, which has already tested truck platoons in Sweden – is now taking part in the European COMPANION project.

- Truck platooning is also one of the most studied applications of vehicle automation in the **Netherlands**, where both public and private stakeholders have shown interest in its potential to reduce the cost of freight distribution; in 2016, the Netherlands will initiate the European Truck Platooning Challenge. They will also host the WE pod project, which will test small, self-driving buses on the route between the Wageningen University campus and the city of Ede.

- Outside Europe, the **United States** is arguably the country where most has been done in the research and testing of automated vehicles. Technology companies such as Google, Apple and Uber are leading the way in a similar way as automotive companies are doing in France, Germany and Sweden.

- One relevant finding is that while car manufacturers are mostly developing increasingly automated systems with a driver-centric approach (evolutionary approach), technology companies are generally testing self-driving vehicles whose diffusion would revolutionise the current mobility paradigm (revolutionary approach). However, some exceptions exist with technology companies such as Baidu or Here partnering with German manufacturers for the development of automated and driver assistance systems.

- International and national **legislative provisions** set the technical conditions needed to be fulfilled to allow vehicle circulation on public roads and defining the liability of drivers. In the EU, Directive 2007/46/EC regulates how new vehicles should operate and be designed. However, more detailed technical provisions are mainly contained within UNECE (WP.29) and can be found in the UNECE regulations to which the EU legislation refers.

- Two **international conventions** largely determine driver liability and behaviour although there are differences in the way countries apply them – some have not ratified them or, in contrast, have implemented more stringent rules. Also the existing national frameworks adopted to regulate the testing of highly automated vehicles vary from country to country.

- Within existing rules, barriers exist against the global market launch of automation Level 3, 4 and 5 and, in some cases, national provisions could also challenge the use of Level 2.

- Some stakeholders have called for further action to set a legislative framework that could support the development of these technologies at international level, looking jointly at provisions dealing with behavioural aspects (such as UNECE WP1) and with regulation and technological aspects (such as UNECE WP29) .

# 4. WHERE AUTOMATED CARS CAN BRING THE MOST BENEFITS

## 4.1. Introduction

In this chapter we will discuss the main implications of the spread of automated vehicles based on their different levels of automation and paths of development.

We present a high-level analysis of possible scenarios for the market penetration of automated vehicles in the short-medium-long term, complemented by an illustration of potential impacts generated by the expansion of automated vehicles. In the long run, the scenarios we discuss envisage solutions where higher levels of automation come hand in hand with deeper levels of connectivity and communication between vehicles and between vehicles and infrastructure.

As further discussed below, the scale and likelihood of estimated impacts is strictly dependent on the degree of dissemination of automated and connected vehicles in future years as well as on the extent to which their introduction will be accompanied by a move towards a model of sharing and connected mobility as well as clean vehicle technologies.

This chapter has been informed by existing evidence and assessments collected to date from other studies and relevant stakeholders. We recognise though that this is an area that requires ongoing research as technologies quickly evolve and come to market.

## 4.2. Future pathways

In this section we present the potential future automation pathways for passenger vehicles, freight transport and urban mobility and public transport. These pathways combine the results and views from International and European public organisations including the OECD International Transport Forum (ITF), the European Road Transport Research Advisory Council (ERTRAC) and the European Technology Platform on Smart Systems Integration (EPoSS); moreover, we have also taken into account views from other public and private stakeholders such as the Netherlands Organisation for Applied Scientific Research (TNO) – particularly informative for freight transport – and industry players (vehicles producers and their suppliers) in order to inform a comprehensive analysis.

Different stakeholders and experts have different views on the timescale for placement and growth of automated vehicle in the global market. We have based our assessment on our understanding of the current state of technological development. However, beyond established pathways, there are many uncertainties which could influence deployment timelines and potentially block their actual implementation and/or diffusion.

These challenges encompass further technological advancements and a timely review of relevant regulations allowing for the safe and legal implementation of automated systems, as well as data security, liability and privacy concerns which will in turn determine public acceptance of these technologies – and, consequently, their widespread diffusion.

### 4.2.1. Passenger vehicles

As already anticipated in Chapter 3, the development of automated passenger vehicles over the next few decades is expected to be driven by two different approaches: evolutionary and revolutionary.

Car manufacturers generally follow the driver-centric evolutionary approach, aimed at improving the driving experience by progressively increasing the level of vehicle automation (from driving assistance to partial and high automation) and expanding the application context (e.g. from free flow condition to all the driving situations on a motorway) of automated systems.

Transport network (such as Uber) and technology companies (such as Google) have moved directly to studying and testing fully automated vehicles: revolutionary approach – showing no interest for intermediate levels of automation – as their objective is to convert the driver into a passenger that can do other things while travelling. These companies expect to gain from selling IT and communication software and services both to the transport industry and road users.

Being pursued by different stakeholders with different objectives, the two approaches are expected to run in parallel. The evolutionary approach will probably lead to the implementation of increasingly automated systems (level 2 to 4) in the short (next 5-10 years) and middle term (10-20 years); the revolutionary approach is expected to be feasible on a large scale in a farther time horizon (more than 20 years) as full automation requires more advanced technological systems, as well as greater modification to the current international and national regulatory frameworks – though use restricted to specific circumstances could occur earlier.

#### Short term

In the next few years we expect that automated systems, already legal and available on the market, will increase their penetration. These systems, mainly belonging to Level 0 and Level 1 of the SAE's classification, include:

- Level 0: Park Distance Control (PDC), Lane Change Assist (LCA), Lane Departure Warning (LDW), Forward Collision Warning (FCW);
- Level 1: Park Assist (PA), Lane Keeping Assist (LKA), Adaptive Cruise Control (ACC);
- Level 2: Park Assist of Level 2 – capable of controlling both steering and acceleration/deceleration.

As already mentioned in Chapter 3, level 2 systems – able to control parts of both longitudinal and lateral driving functions, under driver monitoring, will require the amendment of the UN Regulation No.79 in order to be applied in situations other than parking (see section 3.4.1). These Level 2 systems should be available on highways due to the lack of intersections and interactions with users others than motor vehicles, initially in the form of **Traffic Jam Assist**, capable of performing both steering and acceleration/deceleration for low speeds with higher speeds to follow. We expect it will be a number of years before these level 2 technologies reach large scale diffusion after the amendment of UN R79.

### Medium term

Level 3 systems are expected to be the next implementation, in the form of **Traffic Jam and Highway Chauffeurs**, which represent an evolution of level 2 – being able to execute both longitudinal and lateral control under certain conditions without the need of constant monitoring of the driver. Again, application of these Level 3 systems will be probably limited to motorways or motorway-like infrastructures.

Highly automated level 4 parking systems, allowing for automated parking without the need of driver monitoring (known as **Valet Parking**, **Garage Parking Pilot** or **Remote Parking Pilot**), might be available in the medium term, at least in some protected situations[110]. Nevertheless, the implementation of these systems requires further amendments to the existing regulations. Therefore regulatory obstacles may delay the actual implementation of automated parking systems even after they are technically feasible.

Traffic Jam and Highway Chauffeurs are expected to evolve into the level 4 system named **Highway Pilot**, which should be capable of automatically performing all driving operations on a motorway, without the need for the driver to monitor the system or provide fallback performance.

### Long term

Due to the technological complexity of interactions between different road users and higher safety and public acceptance concerns, the application of Level 4 systems in suburban and urban areas is expected to take place in a more distant horizon. Moreover, it is not yet clear who will be the first to implement Level 4 vehicles capable of running safely in mixed-use areas. These systems might come from an evolution of the **Highway Pilot** developed by vehicle manufacturers, or technology/transport networking companies could pre-empt them, implementing Level 4 systems before putting fully automated cars on the market.

**Full automated vehicles** (Level 5) capable of driving themselves from origin to destination, without needing a driver, and with limited adaption of existing physical road infrastructure, represent the most advanced, complex and, as such, furthest away application of vehicle automation. Technology and transport networking companies are expected to reach implementation first. Nevertheless, vehicle manufacturers might be forced to follow or even beat them.

However, it must be pointed out that this level of automation comes hand in hand with high levels of connection across vehicles and between vehicle and other transport network infrastructure, which poses questions that still have to be answered on the features that such connected system should have, as well as on its costs and the parties that would be responsible.

## 4.2.2. Freight vehicles

As already mentioned in this document platooning represents the most investigated application of heavy vehicle automation and connection, due to its potential for optimising the logistic supply chain by reducing fuel consumption and labour cost. It is important to underline that the automated systems presented for cars might be applied also to heavy vehicles. However, as the timescale of implementation of these systems have already been

[110] E.g. the Valeo's parking assistance system Park4U® that allows drivers to leave a car at the entrance of an outside or underground car park and let the car find a space and park by itself, by activating the remote automated parking system on their smartphones.

discussed above and in light of the higher interest that freight transport and public stakeholders are showing in platooning, here we will focus our attention on this second application.

Truck platooning is expected to follow an incremental pathway consisting in the progressive reduction of the responsibilities of the driver/s of the following vehicle/s until full replacement occurs. When full automation is available, it will be possible to create platoons of self-driving trucks, leading to significant reductions in the cost of labour within the logistic supply chain.

### Short term

Initially, truck platooning will involve the presence of a driver in every vehicle of the platoon (**guarded platoons** according to the TNO[111]): such drivers will be responsible for monitoring the platoon and take control of the vehicle in case of complex traffic situations (e.g. roundabouts). As such, guarded platoons might be considered as Level 2 systems according to the SAE's classifications. Initial applications of these systems are expected to be scheduled by transport planners as it happens today for conventional freight transport (**scheduled platooning**).

Large-scale testing of these platoons will need to be conducted over the next few years in order to verify safety and measure the benefits of these systems, as well as gain public acceptance and understanding of what training truck drivers will require in order to be able to safely manage platooning.

### Medium term

In the medium term and upon amendment of relevant legislations – including the European regulation regarding driving time and rest periods (Regulation (EC) 561/2006) and the digital tachograph one (Regulation (EEC) 3821/85) – it is expected that Level 3 truck platooning will be implemented. This means that the driver/s of the following vehicle/s will not be required to monitor the platoon, but will have the opportunity to rest or perform non-driving tasks. The presence of a driver in the following vehicle/s will facilitate last mile operations including docking, loading and unloading.

Moreover, once market penetration of both guarded and non-guarded (for the following vehicle/s) platooning has taken off, on-the-fly platooning might become possible. This means that trucks, having parts of their trips in common, will be able to dynamically connect to each other through the use of Platooning Service Providers, who will manage and control platoon formation and disengagement.

### Long Term

In the long term and upon amendment inter alia of international and/or national regulations requiring the presence of a driver inside the vehicle, single driver platoons could be implemented, with significant reductions in labour costs. These systems will require one or more drivers (in case of platoons of more than two trucks) to take control of the vehicles for last mile operations.

The last step of truck automation consists of platooning fully automated trucks, which will not require the presence of any drivers.

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[111] Janssen R. et al., *Truck Platooning – Driving the Future of Transportation*, TNO Mobility and Logistics, Report, February 2015

As pointed out above for highly automated cars, similarly in the case of medium and long term truck platooning solutions, these would rely on highly connected technological systems.

### 4.2.3. Urban mobility and public transport

Urban mobility and public transport – or "urban environment systems", according to the nomenclature used in the ERTRAC and ITF reports – will arguably follow a different pathway towards full automation compared to those of cars and trucks. Indeed, while private vehicles and freight transport are likely to see the development and implementation of increasingly automated and connected systems, urban environment systems are expected to follow the so called "everything somewhere" approach (as defined by ITF). This pathway consists of the development of highly automated vehicles whose application is initially limited to specific environments (e.g. airports, campuses, exhibition centres, etc.) and then gradually opens up to less protected circumstances.

This dissimilar approach is mainly caused by the different aims of the stakeholders in urban systems (e.g. cities) compared to the private entities leading the development of automated cars and trucks. Local entities in charge of transport planning are interested in these systems to help improve transport accessibility and lead to environmental benefits. For example, self-driving vehicles could be used to provide transport services in dispersed areas feeding the existing public transport network, or in selected sections of urban areas, while connected driverless taxi services have the potential to improve accessibility and reduce car ownership, need for of parking and emissions, etc. Applications in this area aim to be clean, shared and safe, combining automation with advanced IT solutions and data connections and relying on the use of electric vehicles.

#### Short term

Fully automated vehicles capable of driving without needing a driver already exists in private sites (e.g. NAVYA ARMA). These are electric vehicles running at low speeds (maximum 45km/h), with capacities of generally 10-15 passengers. In the short term we expect increased implementation of these vehicles in industrial sites, airports, recreation parks, hospitals, resort complexes and convention centres.

At the same time, a number of projects involving such systems, as well as smaller driverless vehicles, will be developed over the next 3-5 years. Applications will range from dispersed demand areas to shared space environments in order to improve vehicle connection and management, better understand the interaction of these systems with other road users and the potentials/criticalities associated with such technologies. In parallel, it will be important to address the safety, security and legal implications/barriers preventing the implementation of such technologies on public roads. These aspects will be crucial for the next phases of development of such systems.

#### Medium term

Once national and, where relevant, international, regulations are amended to allow for the circulation of driverless transport systems, at least in selected areas/roads, it is expected that the first implementations of urban transport systems on public roads will commence. These might initially involve small automated passenger vehicles (including shuttles) for last mile solutions, operating at low speeds in specific areas and dedicated infrastructure. Alternative implementations might consist of automated buses for mass transport running in segregated lanes, which would include a driver only for driving out of their automated application area, and fully automated podcars (Personal Rapid Transit, PRT) with limited capacity (4-6 people) involving automated guideway transit (AGT), i.e. driving on their own exclusive infrastructure[112].

The main advantage of such applications would be the avoidance of interactions with other road users, along with the low speeds at which these systems will be initially operated. These characteristics should limit both the complexity of the technology needed to implement automated systems and safety and security issues.

After these systems have proved safe and delivered benefits in accessibility, cost-effectiveness and emission reductions, it is likely that applications in less protected environments will follow. Dedicated infrastructures for collective vehicles and shuttles might be replaced with adapted infrastructure; similarly, segregated bus lanes and exclusive PRT infrastructure might be substituted or complemented by dedicated bus lanes and supporting infrastructure, with all systems capable of running at higher speeds.

Although a number of uncertainties surround these urban transport systems, current research projects suggest that first applications will involve shuttles and small buses running in low demand areas, due to the lower interactions and therefore reduced complexity of such environments.

### Long term

Long term applications in urban areas encompass driverless systems capable of driving on shared infrastructure within mixed-use areas. These systems are generally expected to complement traditional public transport, rather than fully replace it, and to be based on strong V2V and V2I connection in order to allow for efficient vehicle coordination and cooperation.
Such fully automated systems – arguably in the form of small vehicles or shuttles – might provide on-demand and door-to-door services and interact with larger mass transit systems so as to improve accessibility to public transport and allow for the elimination of large buses riding empty in low demand areas. Urban transport systems incorporating full automated vehicles would require a central management system to collect and process data from vehicles and infrastructure (e.g. parking) and to coordinate vehicles in order to meet the demand, provide efficient transfer between different transit systems and manage empty vehicles. Traffic signal coordination and vehicle platooning might also be coordinated by the management system in order to optimise traffic flows and road capacity.

Such a scenario of urban mobility automation and connection represents the most complex application of vehicle automation as it would require significant technological advancements in vehicle automation and connection as well as cyber-security, extensive review of regulations concerning inter alia road safety, data privacy and security, plus significant public acceptance and market penetration.

## 4.3. Potential impacts of automated vehicles

Increasing vehicle automation is expected to yield significant impacts on a number of transport related aspects, such as road safety, traffic congestion, vehicle emissions, infrastructure requirements and spatial planning; a number of these effects are strictly

[112] ERTRAC, *Automated Driving Roadmap*, Brussels, July 2015

dependent though on the extent to which vehicle automation is accompanied by increasingly V2V and V2I communication.

Additionally, a number of challenges will have to be faced related to the peculiarities of automation, ranging from privacy and data protection, liability issues, ethics, public acceptance and socio-economic implications.

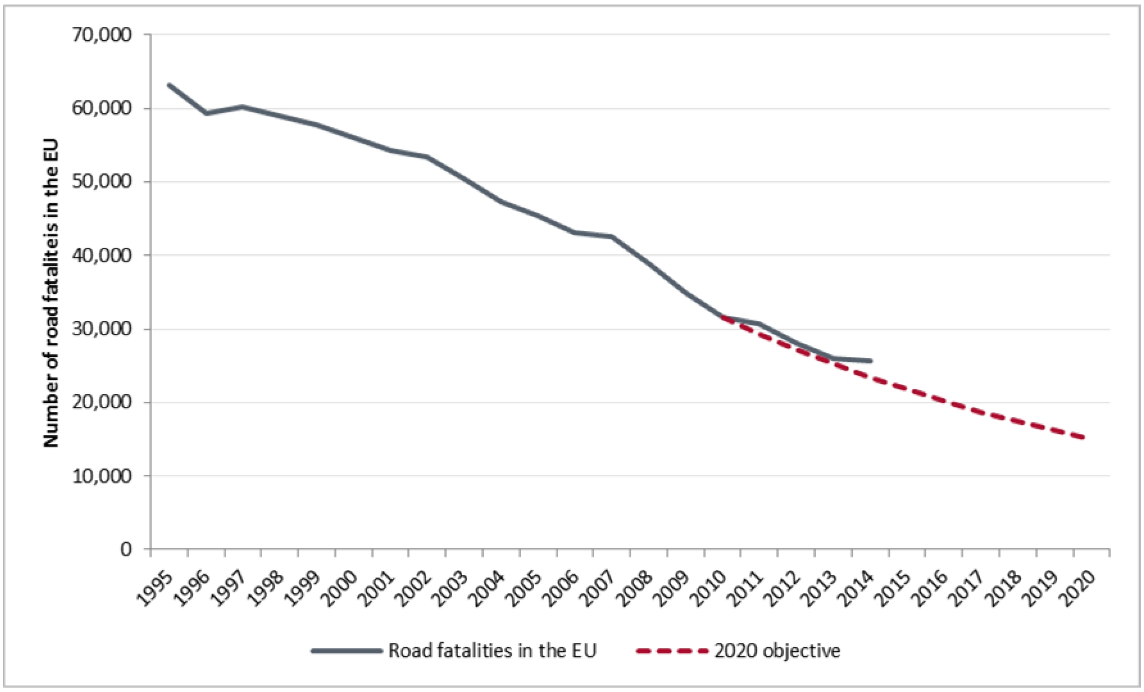
### 4.3.1. Road safety

#### *4.3.1.1. The current situation*

Road safety is monitored at the EU level through the collection of statistics on road accidents, fatalities and injuries on EU roads. A common data collection process has been set up across EU MSs and standardized statistics are published in the CARE database[113] – a Community database on road accidents resulting in death or injury, which provides the basis for the assessment presented in this section.

Figure 4 below shows the change in the number of road fatalities between 1995 and 2014 along with the target set by EU policy be achieved by 2020 – that is halving the number of road fatalities that occurred in the EU in 2010[114] . Road fatalities fell substantially over the period, considered as a whole, decreasing at an average annual rate of -4.6%. A significant step change occurred between 2007 and 2010 – over this period road fatalities fell by about 8.7% per annum.

**Figure 4: Road fatalities in the EU since 1995**




**Source**: Steer Davies Gleave elaboration on European Commission data (2015)

[113] European Commission, *Mobility and Transport – Road safety*, webpage, http://ec.europa.eu/transport/road_safety/index_en.htm

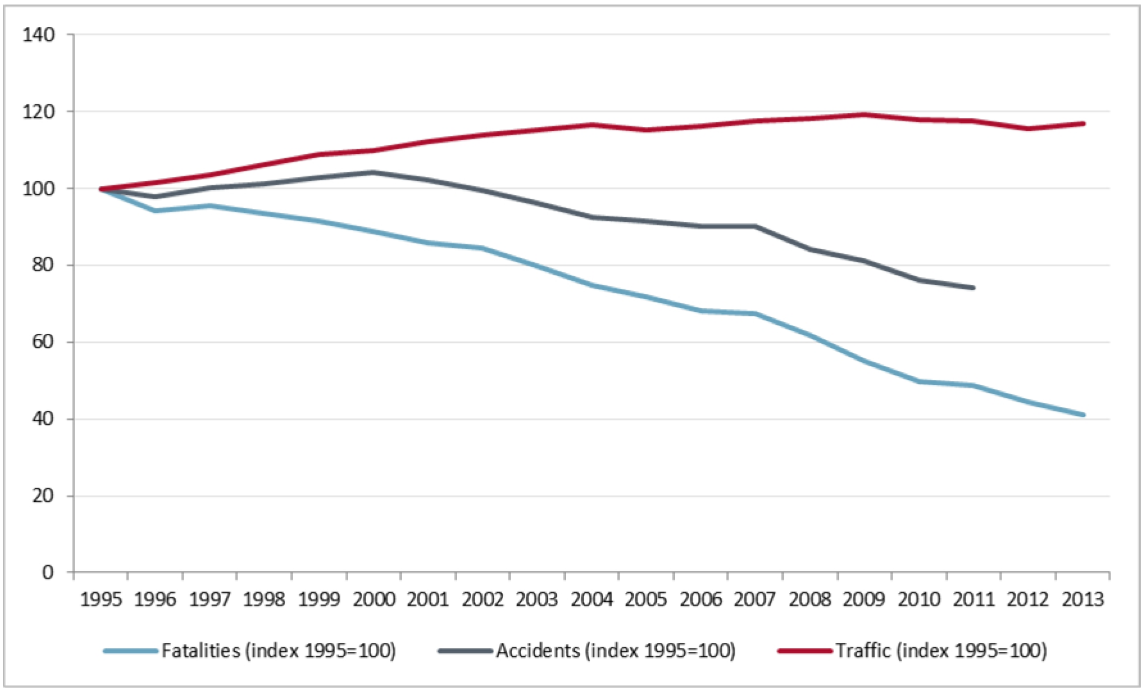
[114] For the 2020 target please see: European Commission, *Towards a European road safety area: policy orientations on road safety 2011-2020*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2010) 389 final, Brussels, 20/07/2010

Road fatalities in the EU have been decreasing despite the general growth in road passenger transport: between 1995 and 2013 road transport demand (measured in passenger-km) grew by an average of 1.0% per annum across the EU.

As can be seen in Figure 5, total passenger-kms, road fatalities and injury accidents experienced different trends:

- Between 1995 and 2000 total passenger-kms increased rapidly (+1.9% per annum on average), while the total number of fatalities decreased by -2.4% per annum and the number of injury accidents increased marginally.
- Between 2000 and 2007 road fatalities and injury accidents decreased at a higher pace (respectively -3.9% and -2.0%), while total passenger-kms continued to increase (+1.0% per annum on average).
- After 2007 the rate of reduction in the number of fatalities and injury accidents accelerated (-7.9% per annum on average between 2007 and 2013 with respect to fatalities, and -4.8% per annum between 2007 and 2011 with respect to accidents). We underline, however, that this result is likely to be partially explained by the stabilisation and slight decrease of road transport volumes that occurred in these years.

**Figure 5: Number of fatalities, number of injury accidents and million passenger-km in the EU, 1995-2013 (1995 = 100)**




**Source**: Steer Davies Gleave calculations based on UN Economic Commission for Europe and EC data

Looking at the different types of road users, in 2013 car users accounted for the highest share of fatalities (46%), with drivers representing more than two thirds of car fatalities, the remainder being attributed to passengers. Pedestrians accounted for about 22% of road deaths, followed by motorcyclists (18%), cyclists (8%) and heavy vehicles (6%). Pedestrians prove to be the most exposed in urban areas where they represent 40% of all fatalities, as well as being those with the highest risk death when involved in an accident. Between 2005 and 2013 the number of fatalities has fallen at a steady rate for cars (-49% over the period), as well as for heavy vehicles (-47%), motorcycles (-37%), cyclists (-34%) and pedestrians (-33%).

Overall, the number of road fatalities per billion passenger-kms has decreased in the EU from 13.9 in 1995 to 4.9 in 2013. The number of injury accidents per billion passenger-km has decreased from 286 to 180 over the same period. However, in 2014 unsatisfactory outcomes were recorded in the EU – fatalities decreased by 0,6% (compared with the decrease of 6,7% necessary to reach the target for 2020) and the number of seriously injured grew by almost 3%.

A similar trend in road fatalities and injuries has been recorded over the same period in the US. According to the US Bureau of Transportation Statistics, crashes per million vehicle-miles travelled (VMT) have decreased at an annual average rate of 2.1% between 1990 and 2012, while roadway injuries have fallen at a faster rate of 2.9%. US fatalities fell from 50.6 to 11.4 per billion VMT travelled between 1960 and 2012.

There are several reasons underlying the significant improvements achieved in road safety, among which:

- Improvements in the infrastructure network, through the adoption of safe design principles, road management and road-driver interaction;
- Improvements in traffic law enforcement, through the introduction of effective measures to influence the drivers' behaviour (e.g. to limit speeding);
- Improvements in the quality of vehicles, e.g. the introduction of measure to significantly increase the level of crashworthiness and user protection.

#### *4.3.1.2. The contribute of Intelligent Transport Systems to road safety*

As already pointed out in a 2014 EP study on Event data recording[115], technical devices and Intelligent Transportation Systems (ITS) applications have played an increasing role in supporting the execution of EU road safety policy. From 2001 to 2010 the EU adopted several ITS solutions to support road safety, for example:

- Regulation (EC) No 68/2009, adaptation of Regulation (EEC) No 3821/85 concerning the use of recording equipment for professional drivers in road transport (the digital tachograph);
- Directive 2002/85/EC – modification of the Council Directive 92/6/EEC – regarding the installation and utilisation of speed limitation devices for specific categories of motor vehicles;
- Recommendation COM(2003) 2657, on the development of location-enhanced emergency call services ;
- Regulation (EC) No 661/2009 regarding the introduction of an advanced emergency braking system as a pre-requisite for new vehicles in certain four-wheel passenger and goods categories (i.e. lorries and buses). In February 2015 Regulation (EC) No 661/2009 has been supplemented and amended through the Commission Regulation (EU) 2015/66.

ITS safety solutions are commonly known as "eSafety"; this includes all vehicle-based intelligent safety systems that improve road safety via crash avoidance, injury reduction and post-crash assistance. For example, seat belt reminders, electronic stability control,

[115] Steer Davies Gleave, *Technical Development and Implementation of Event Data Recording in the Road Safety Policy*, commissioned by the European Parliament's Committee on Transport and Tourism, 2014

Intelligent Speed Adaptation, event and journey data recorders and alcohol interlocks for repeat offenders and fleet drivers [116].

ITS can provide support in a number of areas, such as:

- Notifying drivers of road conditions, traffic congestion, and vehicle status in real time, leading to improvements in driving behaviour;
- Enforcing traffic laws through better monitoring and control of driver behaviour;
- Enabling emergency help after an accident; and
- Providing data for accident investigation to determine causes and assist the instigation of mitigating actions.

While the safety effects of some of these systems are palpable, e.g. anti-lock braking systems (ABS) in cars, in other cases there is no clear evidence of safety benefits.

In the UK, Thatcham (The UK Motor Insurance Repair Research Centre) states that individual Advanced Driver Assistance Systems (ADAS) features are making significant contributions to reducing the number and severity of accidents. One example is Autonomous Emergency Breaking (AEB) which has been equipped in mainstream vehicles since 2008 (and will be mandatory for new cars from 2020 onwards). Based on data from Volvo's vehicles equipped with AEB, Thatcham estimate that the presence of AEB led to a reduction in third party crashes and injuries by at least 15% and 18% respectively[117]

In the US, modern, frontal airbags were introduced in 1984, anti-lock brakes in 1985, electronic stability control in 1995, side airbags in 1998 and forward collision warning in 2000[118] This gradual adoption of safety technology has been shown to contribute to the improvement of road safety.

#### *4.3.1.3. Potentials for further improvement*

Despite this progress, there is still a long way to go to reaching satisfactory safety standards for automobiles. The potential for improving road safety through vehicle automation appears evident when looking at the causes behind road accidents.

Over the last ten years, the EU has made efforts to enhance its understanding of the circumstances leading to fatal accidents through conducting two studies under the SafetyNet research framework[119]:

- The Fatal Accident Database Development and Analysis (Work Package 5.1)[120], provides useful information on key accident drivers including type of road, vehicle specification, driver characteristics, weather and lighting conditions. It showed inter alia that in 41% of the fatalities the accident type was described as a 'Driving Accident' with no turn-off or intersection involved. However, the data collected did not allow a more detailed analysis of the causes behind each accident.

[116] For further information on eSafety, please consult the dedicated webpage on the European Commission's web portal (http://ec.europa.eu/transport/road_safety/specialist/knowledge/esave/)

[117] Miller A., Avery M., *Autonomous Emergency Braking, the next seat belt?*, Thatcham Research

[118] Insurance Institute for Highway Safety, *New Estimates of Benefits of Crash Avoidance Features on Passenger Vehicles*, Status Report, Vol. 45, No. 5, May 2010

[119] SafetyNet, *SafetyNet Final Activity Report*, January 2009

[120] The Fatal Accident Database Development and Analysis investigated 1,298 fatal accidents over a period of 4.5 years, in Germany, Finland, France, Italy, the Netherlands, Sweden and the UK, mainly from factual police reports of fatal accidents

- In-depth accident causation database and analysis report (Work Package 5.2), which provided an in-depth analysis of accident causation. The analysis of the causes showed that "Timing" was the most common critical event analysed with the SNACS (SafetyNet Accident Causation System) method, accounting for 61.9% of cases analysed. Using the ACASS (Accident Causation Analysis with Seven Steps) method, **92% of the accidents were caused by human factors** rather than vehicle or environment/infrastructure.

Similarly, in the **US over 90% of the 5.5 million** annual crashes reported in the ENO study have been primarily attributed **to human factors** and more than 40% of fatal crashes involve one or more of alcohol, distraction, drug and fatigue[121].

ITS e-safety solutions and devices that come along with higher vehicle automation can certainly play a role in tackling this situation. In this regard, the Association of British Insurers (ABI) expect that the introduction of connected and autonomous vehicles would save over 2,500 lives and prevent more than 25,000 serious accidents in the UK by 2030[122]. Indeed stakeholder consultation revealed that insurance companies believe that the penetration of automated vehicles will significantly reduce the risks of accident and will lead to a reduction in drivers' insurance premiums linked to this risk, though other risks might need to be addressed as further discussed below.

This point is supported by a study carried on by the Massachusetts Institute of Technology (MIT) that evaluates the feasibility of introducing a system of shared self-driving cars: the study points out that this technology can respond to dangerous situations on average one thousand times faster than humans[123]. Automated vehicles are therefore recognised as having the potential to not only severely decrease the frequency of these incidences, but also to make them a rare occurrence.

#### *4.3.1.4. Challenges*

If further vehicle automation could, in theory, prevent all the road accidents caused by human error, it must also be pointed out that effective safety of automated systems has yet to be demonstrated. Technical challenges include the ability of highly automated systems to perform under poor weather or visibility conditions and correctly recognise obstacles and understand infrastructure elements. At present ongoing tests on fully automated vehicles show also that systems need to be further tested and processed to make sure these vehicles are able to safely interact with other road users[124].
Other challenges regarding the way autonomous vehicles would react in a mixed use environment. Technology would need to adapt to the progressive recourse to vehicle automation in the circulating fleet: for example existing solutions for Highway Chauffeurs are settled to work in an environment where other vehicles are mainly driven by human drivers; different solutions – i.e. Cooperative Highway Chauffeurs – would need to be adopted once a substantial amount of the fleet is equipped with vehicle automation devices to make sure they maximize benefits on safety and congestion. Moreover, at present, it is difficult to find evidence about the potential risks involved in switching between automated and manual control. Therefore it will be important to investigate effective and transparent

[121] ENO Center for Transportation, P*reparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations*, Paper, 2010
[122] Department for Transport, *The pathway to driverless cars: a detailed review of regulations for automated vehicle technologies*, London, February 2015
[123] Spieser K. et al., *Toward a Systematic Approach to the Design and Evaluation of Automated Mobility-on-Demand Systems – A Case Study in Singapore*, 2014
[124] Phys.org, *Google releases more details on self-driving car accidents*, 05/06/2015

ways to verify automated vehicles safety, both before and during their implementation on public roads.

Furthermore, even when highly automated systems have proven their safety, they will need to be competitive with respect to traditional vehicles in order to achieve the expected effectiveness. Slow market penetration is a significant hindrance to the progress of new safety technologies. A 2012 study by the Insurance Institute for Highway Safety (IIHS) looked at the adoption of collision warning systems and estimated that at the current rate of adoption it could take up to 50 years for this technology to penetrate 95% of all fleet[125]. The same study found that if all vehicles had forward collision warning, lane departure warning, side view assist, and adaptive headlights, nearly a third of all crashes could be prevented.

Due to the above, what is most likely to occur is that road accidents will progressively decrease in line with the increasing automated systems available on the market and with their growing proportion in the total running fleet. However, at the moment it is hard to forecast the degree and speed at which this will be achieved as many existing technologies are still at a test stage.

### 4.3.2. Congestion

While stakeholders generally agree about the potential positive effects of vehicles automation on road safety, the impact of the diffusion of increasingly automated and connected driving systems on road congestion is far more debated; vehicle automation and connection is indeed expected to affect both road capacity and traffic, with an uncertain net effect on congestion.

#### *4.3.2.1. Increasing capacity of the existing network*

Increasing vehicle automation and communication are expected to allow vehicles to make a more efficient use of the existing road infrastructure, with a consequent increase of the effective network capacity given the same amount of traffic.

Highly automated and connected vehicles will be capable of driving more accurately than humans by being able to intake and process real-time data surrounding them in much larger quantities with much shorter reaction times than humans. One impact of this will be the possibility for highway traffic to speed up through coordinated and efficient driving, with less space between cars and fewer incidences of both unnecessary braking and accidents which contribute to congestion.

The achievement of this potential increase of capacity will largely depend on the implementation of vehicle-to vehicle and vehicle-to-infrastructure communication, which will allow for more efficient route choice and shorter headways between vehicles both in rural areas (increased highway capacity) and at signals (improved intersection capacity). Research indicates that vehicle platooning could yield up to a 500% increase of hourly capacity per lane[126]. However, to achieve the greatest benefits in terms of increased capacity a significant penetration of automated and connected vehicles will need to be achieved. As an example, actual lane capacities have been estimated to increase by around

[125] Insurance Institute for Highway Safety, N*ew Estimates of Benefits of Crash Avoidance Features on Passenger Vehicles*, Status Report, Vol. 45, No. 5, May 2010

[126] Anderson, J. M. et al., *Autonomous Vehicle Technology – A Guide for Policymakers*, RAND Corporation, Santa Monica (USA), 2014

1%, 21% and 80% in case of adoption of cooperative adaptive cruise control (CACC) systems on 10%, 50% and 90% of total running vehicles[127].

A more short-term effect of vehicle automation on the increase of network capacity is associated to the reduction of delays caused by traffic incidents – such as disabled vehicles, vehicles collisions, etc. – which account for about 25% of total congestion delays, according to the US Federal Highway Administration (FHWA)[128]. As already mentioned, automated vehicles are expected to improve road safety with a likely reduction of road accidents (which represent a major share of traffic incidents), in turn resulting in an increase of effective network capacity.

As a result of these factors, if the volume of vehicles driving at a given time remains constant, congestion is expected to significantly reduce thanks to the increased capacity effect due to technologies that improve connections between vehicles and between vehicle and infrastructure. Thus far, the effect of vehicle automation and connection is widely agreed upon. The uncertainty comes in the form of the unknown effect that more capacity and increased convenience of travelling by car will have on the aggregate demand for car travel.

#### *4.3.2.2. Impact on total traffic*

Some experts point to the Increased Highway Widening Conundrum. This refers to the negligible impact highway widening has – in cases had – on reducing congestion. The theory in these cases is that by increasing highway capacity, congestion will be reduced. What happens in practice, is that the decrease in congestion makes it more convenient for those who usually would not drive to do so, thus the additional capacity become saturated very soon after the increase. Reduced congestion from automated vehicles could also fall victim to this effect, especially as driving becomes less demanding for the rider; commuters may experience an increased tolerance for commuting for longer amounts of time and further distances.

Vehicle automation could lead to an increase of road traffic also in light of the possible reduction of several travel cost components associated with the use of private vehicles. These include the reduction of the opportunity cost of the time spent in the vehicle – as the user can replace driving with other activities – as well as lower fuel costs, due to the more efficient driving allowed by vehicle automation. Additionally, parking cost might be expected to decrease as self-driving vehicles could drive to less expensive parks after dropping off the user. Finally, insurance premium might decrease as well due to the expected lower frequency of car accidents.

Moreover, self-driving would allow the use of cars to people that currently cannot drive (e.g. disabled and elderly persons) arguably leading to an increase of car traffic overall.

Self-driving might also increase the competitiveness of taxi and transport networking services such as Uber by eliminating the cost associated with the driver. This might in turn reduce total road traffic as car-sharing services have proven to lead to a decrease of vehicle-mile travelled (VMT) in the U.S.[129]; on the other hand, the lower cost of networking

[127] ENO Center for Transportation, *Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations*, Paper, 2010

[128] Anderson, J. M. et al., *Autonomous Vehicle Technology – A Guide for Policymakers*, RAND, 2014

[129] Anderson, J. M. et al., *Autonomous Vehicle Technology – A Guide for Policymakers*, RAND, 2014

and taxi systems might lead people previously using alternative travel modes (e.g. transit) to switch to these car services with a possible VMT increase.

Due to all the above, the overall effect of vehicle automation on total traffic is difficult to predict although arguments for an ultimate increase of private vehicle traffic (expressed as total travelled distance) arguably overcome those in favour of a reduction. On this point, much will depend on how the extent of the penetration of automated vehicles will lead to a shift towards a paradigm of shared mobility in place of the paradigm of private mobility which currently dominates our transport behaviour choices.

#### *4.3.2.3. Net effect on congestion*

Congestion refers to the situation where traffic attempting to use a transport network equals or exceeds network's capacity. This results in significant reductions of travelling speeds and consequent delays for network users, leading to negative externalities in terms of social and environmental cost.

As discussed above, advanced automated systems are expected to increase network's capacity by allowing vehicles to make a more efficient use of the road network and reducing delays associated to traffic accidents.

However, many argues that self-driving is likely to increase road traffic as more people will be able to travel by car (e.g. elderly, young people, disable) and current drivers will experience a reduction in travelling costs. This might be mitigated by the recourse to sharing mobility solutions (e.g. car sharing), but a major step change in people travelling behaviour is probably required for this to compensate for increased traffic volumes.

Due to these contrasting effects it is hard to establish what will be the net effect of driving automation on road congestion.

#### *4.3.2.4. External cost of congestion*

Regardless of the uncertainty about the net effect of vehicle automation on traffic congestion, it is undeniable that self-driving would reduce the opportunity cost of travel time – and as, such, the social cost of congestion – by allowing vehicle users to dedicate to other activities while travelling.

Congestion in the EU costs nearly € 100 billion per year, about 1 % of the EU's GDP. A 2012 study on self-driving cars by KPMG and CAR (Center for Automotive Research) estimates that approximately 80% of US workers lose around 50 minutes per working day to driving to and from work[130]. This amount refers only to commuting, thus excluding all the trips with a purpose other than work. The Texas A&M Transportation Institute (TTI) estimated that in 2011 traffic congestion resulted in around 5.5 billion total hours of excess travel delay in the US[131].

The social cost of road congestion is usually computed by multiplying the time spent travelling by road users by their 'opportunity costs', which is referred in literature as value of time: this represents the cost borne by road users and society for being stuck in traffic rather than doing other more productive or entertaining things. Such a cost could be significantly reduced by highly automated vehicles as people could undertake other activities while driving, such as writing emails, working or watching movies.

[130] KPMG and SMMT, *Connected and Autonomous Vehicles – The UK Economic Opportunity*, KPMG LLP, March 2015

Indeed the possibility to make use of driving time for other productive or enjoyable tasks appears as one of the key motivations that could also lead users to purchase automated vehicles and support the market penetration of these technologies.

### 4.3.3. Emissions

Road transport is the second biggest source of greenhouse gas emissions in the EU, after power generation. According to the Commission it contributes about one-quarter of the EU's total emissions of carbon dioxide ($CO_2$), with passenger cars representing around 12% alone[132].

Road transport emissions have been rising rapidly over the last 20 years; the only exception was the period 2008 to 2010 when $CO_2$ emissions by transport activity reduced due to the economic slowdown, although over the period 1990 to 2010 road transport emissions increased by 22.6%.

The 2011 Transport White Paper sets the ambitious goal of reducing transport climate emissions by 60% in 2050 as compared to 1990 levels. Strong actions will be needed to reach this target, as recent emissions figures indicate that this would require a 67% reduction from 2012 levels.

#### *4.3.3.1. Efficient driving*

Automated driving is expected to contribute to improve fuel economy and, consequently, vehicle emissions through optimised traffic throughput. Through connected vehicle communication, and smart vehicles, space between vehicles can decrease, acceleration and deceleration can be optimised, and peak speeds decreased, while effective speed increases[133] – improving fuel economy and shortening trip time.

Past research and testing provided clear evidence about the reduction of fuel consumption by using truck platoons on highways, with the following vehicles achieving a fuel reduction of 8-13% and the leading one a fuel reduction of 2-8% according to the SARTRE project (predecessor of the COMPANION project described in the previous chapter)[134].
This fuel reduction would lead to significant environmental benefits considering an average $CO_2$ emission of 2.6 km per litre of diesel[135].

#### *4.3.3.2. Lighter vehicles*

Another possible positive consequence of vehicle automation on emissions derives from the already described advances in road safety, which should allow the production of much lighter cars in the long run. Existing regulations require cars to follow certain weights as a measure to improve safety for occupants; with lower accidents rate driven by technology, this measure may not be necessary. Although the way towards lighter cars is hindered by the fact that the introduction of automated vehicles will occur progressively, with pre-existing, heavy, human-driven cars remaining on the road for a long time, which may pose a safety threat to those who opt for lighter autonomous vehicles.

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131 Anderson, J. M. et al., *Autonomous Vehicle Technology – A Guide for Policymakers*, RAND, 2014
132 European Commission, *Climate Action – Reducing CO2 emissions from passenger cars*, webpage, *http://ec.europa.eu/clima/policies/transport/vehicles/cars/index_en.htm*
133 Folsom T. C., *Energy and Autonomous Urban Land Vehicles, Technology and Society Magazine*, Vol. 31, No. 2, 2012
134 Janssen R. et al., *Truck Platooning – Driving the Future of Transportation*, TNO Mobility and Logistics, Report, February 2015
135 Idem

#### 4.3.3.3. Type of fuel

The autonomous vehicle poses an opportunity to transition from oil to the use of alternative fuels. Currently, more than 90% of transportation runs on oil in the EU[136] and US[137]. A main policy priority for both the EU and the United States has been to identify viable sources of alternative energy and reduce fossil fuels consumption. One of the leading alternatives has been to power vehicles through electricity.

The current barriers to this transition include a lack of a widespread charging infrastructure, prolonged charging times, and (although the electricity itself is cheaper than petroleum) storing it is expensive and the battery used is heavy. However, the introduction of lighter automated vehicles makes powering cars through electricity increasingly viable, as lighter cars will get better mileage, and can make use of smaller, lighter, less expensive batteries.

The potential to develop remote charging also increases the viability of this fuel source, and cars that drive themselves could potentially seek out charging themselves after dropping their passenger off at their destination.

#### 4.3.3.4. Total change of travelled distance

The final determining impact on the environmental impact of self-driving cars is the total change in travelled distance as a result of this technology. As described in the congestion section, the final effect of automated vehicles on total travelled distance is difficult to predict although it is likely that enhanced mobility would induce new trips and increase travel overall. This "rebound effect" is measured by the NHTSA, which when assuming a rebound rate of 10%, will predict a 2% increase in demand for vehicle-miles travelled when per mile cost of vehicle travel falls by 20%.

#### 4.3.3.5. Net effect

Given these contrasting effects, as in the case of road congestion, the overall impact of vehicle automation on emissions is still difficult to predict. Indeed, if it can be generally agreed that automation will contribute to the reduction of average vehicle emissions per kilometre, the uncertainty concerning total travelled distance raises doubts on the ultimate effect of vehicle automation on overall traffic emissions.

A recent study from Wadud, MacKenzie and Leiby (2016)[138] investigating the positive and negative effects that automated vehicles could have on vehicle emissions, points out that the diffusion of fully automated cars could – under certain circumstances – cause a net increase in carbon emission levels, mainly as a consequence of an increased car usage caused by reduced travel time costs.

### 4.3.4. Adaptation of transport infrastructure

A critical aspect concerning vehicle automation is the ability of automated systems to effectively and safely interact with transport infrastructure in all the different driving situations (e.g. interaction with different types of users, unexpected obstacles) regardless of the external conditions (e.g. bad weather and obscurity).

[136] European Commission, *Clean Power for Transport: A European alternative fuels strategy*, COM(2013) 17 final, Brussels, 24/01/2013.

[137] Davis S. C., Diegel S. W., Boundy R. G., *Transportation Energy Data Book*, 31st ed., Oak Ridge National Laboratory, Oak Ridge (USA), 2012

[138] Wadud Z., MacKenzie D, and Leiby P. N., *Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles*, in Transportation Research Part A, 86:1-18, April 2016

To this end, two different approaches might be followed; the first one consists of building sensor-based vehicles making use of existing physical infrastructure along with enhanced digital infrastructure (including satellite maps and GPS). The second approach is based on vehicle cooperation and communication and requires transport infrastructure to be connected and communicate with automated vehicles.

The two approaches are under study and testing and it is likely that both of them will be implemented in the future and possibly converge towards a combined technology.

#### *4.3.4.1. Autonomous approach*

A number of stakeholders, including Google, are developing autonomous vehicles meant for driving without the need of any infrastructure update or enhancement. These vehicles are already operating on existing road infrastructure. Because of the development and foundation of this technology on machine learning, the technology learns and adapts itself to current infrastructure – instead of infrastructure having to adapt to it.

That being said, although it is learning and overcoming discrepancies in current infrastructure, certain short-coming in infrastructure still pose challenges to this technology. Potholes and lack of signage (e.g. stop signs), that autonomous vehicle technology relies on to learn the rules for a specific area, might be difficult for self-driving vehicles. In light of this, instead of implementing new infrastructure, this approach requires ensuring the proper location, visibility and state of repair of existing infrastructure, as well as its maintenance in the future.

#### *4.3.4.2. Vehicle connection*

Connected vehicles rely on wireless technology to communicate between each other (V2V) and with the transport infrastructure (V2I). Current research and testing activities of these technologies are mainly related to truck platooning although V2V and V2I communications are expected in the future to allow for a wider range of applications; these might include dynamic routing based on real time traffic information, parking spot detection and ultimately full traffic coordination and management in urban areas.

V2I communication would require equipping existing infrastructure with transceivers able to communicate with the technology installed on the vehicle. Currently, the main system adopted for V2V communication is the Dedicated Short-Range Communication (DSRC) which used radio waves, providing fast network acquisition, low latency and highly reliable communication. However, the cost of equipping extensive portions of road network with DSRC-compliant transceivers could represent an obstacle for the implementation of V2I communication and different or complementary solutions are under study, including the implementation of cellular technology for longer-range communication[139].

One of the most delicate challenges relating to vehicle automation concerns the effective and secure management of the large amount of data needed to allow self-driving and vehicle communication. This aspect is particularly important to ensure social acceptance and consequent market penetration of automated systems.

#### *4.3.4.3. Data and cyber security*

Data security includes the ability to process, store and allow future access to a large amount of information, as well as to guarantee stable and secure vehicle-to-vehicle and vehicle-to-

[139] KPMG and SMMT, *Connected and Autonomous Vehicles – The UK Economic Opportunity*, KPMG LLP, March 2015

infrastructure communication in order to ensure efficient and safe vehicle coordination and cooperation. The diffusion of automated and connected vehicles would entail the progressive increase of the amount of data generated and recorded. A wide range of different datasets would be collected which can provide information about how and where the vehicle was driven. Third actors (e.g. IT service provider, traffic manager) may be interested in having access to data which is not limited to a short period prior to a collision. This is an area that would deserve further attention and investigation – also by means of pilot tests/experiments – to support the identification of the kind of data that could be processed, as well the measures that would allow users to deactivate and control the system.

The legislative framework concerning data ownership and management would need to be reviewed to accompany the technological development of automated systems, in order to avoid the risk of inappropriate use of data or implementation's delays[140]. In this respect, the ITS Action Plan commissioned by the European Commission in 2012 assessed potential policy measures for guaranteeing data protection and data privacy in intelligent transport systems[141]. Moreover, 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[142].

One relevant issue concerns cyber security threats, including hacking and terrorist attacks. Unrestricted access to vehicle data by third parties threatens the safety of the vehicle, occupants and other road users. Cybersecurity issues related to connected cars – e.g. with reference to the successful attempt of hacking into a vehicle and remotely controlling its driving functions – are increasingly reported by media[143]. White hat hackers working with FCA (Fiat Chrysler Automobile) were capable to take control and send commands to critical functions of the Jeep Cherokee, forcing FCA to recall 1.4 million vehicles; also BMW, Mini and Rolls-Royce vehicles have experienced hacking problems including remote unlocking, while Tesla had to fix six vulnerabilities found by computer security experts in its software[144].

These examples prove that cyber security requires further work and validation in order to prevent attacks whose impact would be critical in situations of extensive vehicle cooperation and coordination. In that regard, initiatives in support of cybersecurity have been recently taken by the automotive industry. In July 2014, the Alliance of Automobile Manufacturers constituted a voluntary information-sharing and analysis centre (Auto ISAC) to target the threat of hackers. Moreover, the European Automobile Manufacturers Association (ACEA) has agreed on principles of data protection in relation to connected vehicles.

#### 4.3.4.4. Protection of personal data

One of the key innovations of Google's driverless car project, and a model which other leaders in the field are following, is mass data agglomeration. When all of Google's different cars are out learning through experience, all the experience gathered contributes to the

[140] European Technology Platform on Smart Systems Integration (EPoSS), *European Roadmap – Smart Systems for Automated Driving*, Berlin, April 2015

[141] Stefan Eisses, Tom van de Ven, Alexandre Fievée, *ITS Action Plan. ITS & Personal Data Protection. Final Report*, Amsterdam, 04/10/2012

[142] Article 29 Data Protection Working Party, *Opinion 8/2014 on the on Recent Developments on the Internet of Things*, 16/09/2014

[143] For instance, see Jeremy Henley, *Connected Cars: Security Risks on Wheels*, Press Release, ID Experts, 04/01/2016

[144] McKinsey & Company, *Competing for the connected customer – perspectives on the opportunities created by car connectivity and automation*, Advanced Industries, September 2015

central capability of the system that controls the car. This enables the technology to always be learning and updating in real-time.

The implications of this with wide scale distribution would be for a technology that is rapidly advancing all the time with more use – a system where every user's driving helps improve the driving of all other users[145]. The flip side of this is that by creating this benefit through collecting data from every trip, the details concerning trips of an individual are theoretically no longer private. There is always concern over the potential for this data to be exploited and the negative impacts that users of automated data may experience.

As pointed out in the Roadmap on Highly Automated Vehicles prepared by the European Commission[146], **personal data protection** rules are currently provided in Directive 95/46/EC on personal data and Directive 2002/58/EC on the processing of personal data and the protection of privacy in the electronic communication sector. These laws are undergoing a reform aimed at harmonizing the number of national data protection laws in one data protection law applicable across the EU (General Data Protection Regulation) which has been proposed in 2012 by the Commission and informally agreed by Council and European Parliament in December 2015. This process will assist the initiative for automated vehicles as manufacturers and others parties will no longer have to ensure compliance with different national data protection laws. Noticeably, the GDPR will require compliance with the principles of privacy by design and privacy by default requiring that data protection is embedded into the development of business processes for products and services. This should contribute ensuring security of the systems and help preventing cyber security threats also in the case of automated vehicles.

The issue of **non-personal data sharing** is also important, but is not regulated at the moment with the exception of rules on repair and maintenance information (Regulation (EC) 715/2007). In several circumstances data produced by the sensors on an automated vehicle may be classified as non-personal data (in that they do not relate to an identified/identifiable individual) which are not covered by data protection legislation. The Free Flow of Data initiative – as part of the Digital Market Strategy for Europe[147] - will deal with emerging issues e.g. ownership, usability, access with regard to such non-personal data.

Resolving privacy concerns related to real time vehicle tracking, vehicle data disclosure and misuse – amongst others – will be necessary to develop advanced automation systems and even more vehicle connection and cooperation.

### 4.3.5. Wider socio-economic implications

Vehicle automation is expected to have significant socio-economic implications not only on the automotive industry but also on sectors which already are or will be connected to mobility including technology, telecommunications, insurance, transportation, and logistics, etc.

The scale of the socio-economic implications is likely dependent on the level of automation and connection of the systems that will be commercialised and penetrate the market – with

[145] Petit, J. (Centre for Telematics & Inf. Technol., Univ. of Twente, Enschede, Netherlands), *Potential Cyberattacks on Automated Vehicles*, in Intelligent Transportation Systems, IEEE Transactions on, Vol. 16 , Issue 2, April 2015

[146] European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, *GEAR 2030 Discussion Paper, Roadmap on Highly Automated vehicles*, January 2016

high and full automation having the most disruptive impact – and on the future models of ownership around private vehicles that are still uncertain at the moment.

#### *4.3.5.1. Automotive industry production*

The successful diffusion of increasingly automated and connected vehicles will require manufacturers to expand their software development skills. According to a 2015 McKinsey survey on automotive executives, 57% of the respondents anticipate that they will collaborate with third parties or external software companies for the development of their software/application programming interface (API). Although Tesla develops its software internally a number of manufacturers either outsource significant parts of their software development or acquire software companies (e.g. Continental SG acquired Elekrobit).

According to the SMMT and KPMG[148] report about the opportunities of vehicle connection and automation for the UK, car production in the UK is expected to keep growing mainly due to the demand from merging markets; nevertheless there is little certainty about the future ownership models around private vehicles, with some hypothesising that in years to come, private vehicle ownership will give way to mobility based plans whereby the user accesses a fleet vehicle. It is unclear at the present time how that would impact sales of vehicles, and whether the automotive manufacturers may in fact become fleet providers themselves.

#### *4.3.5.2. Transport service provision*

**Freight transport** is likely to draw particular benefits from truck platooning. Initial applications of this technology are expected to require the presence of a human driver on both the leading and following vehicle; in this case, positive effects will include the reduction in fuel consumption of the trucks (10% in average according to TNO) and resting time for the driver of the following vehicle (8% savings for TNO. In the longer term, the target is to remove the driver of the following vehicle thus leading to larger savings in labour time, quantified by TNO as between 15% and 25% (depending on the amount of time driven on highways) compared to the current situation[149].

The long-distance trucking industry carries about 68.5 percent of all goods shipped in the United States, and on average, drivers' pay accounts for 30 percent of its costs. Long-haul trucking is taxing on the human operator, evidenced in the fact that trucking has such an extraordinarily high turnover rate: about 98 percent annually. Truckers can also legally only drive for 11 out of every 24 hours, making for delays in transportation of goods. There is potential to improve fuel economy of trucks and cut emissions by drafting autonomous trucks, where vehicles follow each other closely to reduce air resistance in a manner that is not safe to do with human drivers. According to Freightliner, truck platooning could produce between 5.3% (3-truck platoon) and 6.0% (5-truck platoon) fuel savings on average[150].

AXA has conducted a piece of economic analysis to assess the impact of autonomous vehicles on the haulage industry[151]. In the UK the logistics industry employs more than 2 million people. Over 10% of these work in road haulage. AXA's Future of Driverless Haulage report states that the anticipated cost savings across four key categories (labour, fuel,

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147 COM(2015) 192 final, A *Digital Single Market Strategy for Europe*, May 2015
148 KPMG and SMMT, *Connected and Autonomous Vehicles – The UK Economic Opportunity*, KPMG LLP, March 2015
149 Janssen R. et al., *Truck Platooning – Driving the Future of Transportation*, TNO Mobility and Logistics, Report, February 2015
150 Freightliner Infinite Inspiration website, http://www.freightlinerinspiration.com/
151 AXA, *The Future of Driverless Haulage*, September 2015

insurance and vehicle utilisation) would bring between £33bn and £47bn of savings to the UK economy across a 10 year period. AXA note that these business savings should ultimately translate to lower costs in the end product for the consumer (potentially equating to £150 on grocery spend per household).

### *4.3.5.3. Liability and insurance costs*

Liability in case of accidents is another relevant issue which needs to be addressed opportunely in order to guarantee public acceptance and avoid future conflicts between stakeholders. While for current tests liability lies only on manufactures, it is more difficult to say who will be liable when automated vehicles are allowed to circulate on public infrastructure.

Different stakeholders have provided different answers when interrogated about the liability of their automated systems: Volvo declared that it will take full responsibility for any accidents caused by its self-driving car[152] whereas Tesla said that the driver will maintain responsibility in case of accidents occurring in Autopilot mode[153].

Insurance stakeholders pointed out that the imputed responsibility for liability will evolve as these technologies progress: while national legislation will always need to identify the subject to be held responsible for road accidents at first instance, this might shift from physical driver to car manufacturers in case of full self-driving scenarios. This in turn might lead to a reduction in insurance premiums paid by citizens and to a demand for insurance coverage from car manufacturers, but it would not be a revolutionary change in any case. As it already happens in the car industry as well as in other industries, car users could always be held responsible for accidents caused by their errors (e.g. negligence in maintaining the vehicle), whereas automakers would need to assume liability for crashes due to technological problems. In case of litigation between the two, it will always be a court that establishes the different responsibilities.

Obviously, liability will largely depend on the degree of automation of the vehicle: the higher the level of automation the higher the expected shift in liability from drivers to manufacturers. Nevertheless, establishing the boundaries of liability for the different levels of automation is not expected to be a black and white process and regulators need provide clear guidance to allow for the identification of the responsible of the accident and avoid litigation.

From the insurance industry perspective, in the short term, driver’s premiums will fall with the increased uptake of automated features (such as Autonomous Emergency Braking), though this might be compensated by the need to protect stakeholders from other risks (e.g. cyber risk, property insurance of more expensive vehicles, etc.). Particularly relevant for the insurance industry will be the assessment of the impact of different automated systems on accidents frequency and severity in order to allow for a proper quantification of the insurance premiums.

In the longer term, if the vehicles become increasingly autonomous to the point where the responsibility for the vehicles safe operation shifts from the driver to the vehicle manufacturer, car manufacturers could be called to sustain a higher share of insurance

[152] Seb Joseph, *Volvo will accept full responsibility for driverless car crashes*, TheDrum.com, 11/10/2015
[153] The Guardian, *Tesla's new autopilot system lets electric car change lanes by itself*, 15/10/2015

costs, though they could ultimately pass it back to consumer through the pricing of their product and services.

In the end, what is more likely to occur is a change in the type of risks that would require protection – with personal motorist insurance premiums expected to reduce significantly and other premiums to emerge (e.g. cyber risk) – accompanied by a different distribution of the primary risk and cost imputation – which will move from physical human driver to car manufacturers.

The extent to which this will affect balance of insurance companies, automotive industry and car users will depend on the scale of the impacts that could be generated by wider penetration of self-driving vehicles (e.g. reduction in road accidents rates) and on the way that different costs will be passed to the different stakeholders involved.

Certainly the insurance industry will need to be agile to respond to these changes and challenges, which is why a number of insurers are proactively involved in understanding the automated vehicles markets, capabilities and implications for their industry.

#### *4.3.5.4. IT sector*

As already mentioned in the previous chapter emerging and future stakeholders of transport sectors are significantly involved in the understanding and implementation of automated vehicles. The progressive increase of vehicle automation and connection is expected to generate significant opportunities for technology, telecommunication and transport network companies which can take advantage of their technologic skills to enter or increase their presence in the passenger transport market.

Potential for increased business in this areas seem high. A recent study from AllixPartners[154] points out over the next four years, the global market volume for connectivity services and hardware in the automotive sector will double from an estimated $20bn to $40bn, and more than half of it will be services and apps. The study reports data from Connected Car Forum (CCF) showing that more than 50% of vehicles sold worldwide in 2015 to be connected – either by embedded, tethered or smartphone integration - and provides forecasts indicating that every new car is likely to be connected in multiple ways by 2025.

#### *4.3.5.5. Labour market*

According to the SMMT and KPMG report, vehicle connection and automation will create a total of 320,000 new jobs in the UK by 2030; 25,000 of these are expected to be in automotive manufacturing while the remainder will come from other sectors including telecommunications, digital and media which will benefit from increased productivity, worker mobility and new market opportunities allowed by vehicle connection and automation[155].

In the long term, professional drivers are expected to suffer when full automation is implemented in public transport, passenger cars and trucks. Currently, there are 3.5 million professional truck drivers in the US and another 5.2 million people employed whose livelihoods are affected by or linked to the trucking industry[156]; in the EU available data indicate that close to 2.4 million people are active in the road freight sector in the 23

[154] AlixPartners, *The Worldwide Automotive Growth Is Slowing Down, Particularly in the BRICS. At the Same Time, the Industry Face Huge Technological Challenges. C.A.S.E.*, Press Release, 23/06/2015

[155] KPMG and SMMT, *Connected and Autonomous Vehicles – The UK Economic Opportunity*, KPMG LLP, March 2015

[156] American Trucking Association

member states for which data are available. The scale of the impact will depend on the necessity of the presence of a driver inside the vehicle once truck platooning is implemented.

The AXA report also recognises that the increased use of autonomous vehicles could have a negative impact on the employment figures for drivers within the haulage industry. However, they note that there is natural wastage in the numbers of drivers, particularly as drivers retire. Furthermore, increased levels of autonomy do not necessarily eliminate the need for drivers (due to the need to unload at their destination, manoeuvre the vehicle at depots etc.).

Similarly, taxi, transport network companies and transit drivers are threatened by the possibility of being replaced by self-driving vehicles in light of the significant cost reduction that these advanced automated systems would allow. The overall effect of vehicle automation is therefore expected to be a shift in the labour market where demand for lower skilled drivers is substituted by a higher need for skilled workers– mainly experts in software developments, telecommunications, etc.

### 4.3.6. Other social impacts: transport accessibility, affordability and land use

#### *4.3.6.1. Transport accessibility and affordability*

With the initial introduction of autonomous vehicles, it is anticipated that the wealthy will be able to afford this technology before lower socio-economic segments of the population – shown through Tesla owners' access to automated driving. An impact of this very well may be a resulting crash risk disparity between the rich and poor, though this should be limited to the short run, as the price of this technology should ultimately trickle down to regular car prices.

Another potential negative impact is that driverless vehicle technology can distract from investment and capacity building of public transport[157]. Users that would typically take transit may switch to shared autonomous vehicles if they are significantly more convenient at a comparable price. This may cause transit to be starved of ridership, resulting in lower cost recovery of transit infrastructure, and eventually reduction of services or increases in fare, both of which will perpetuate loss of users to AVs. Transit is an important transportation tool, and many individuals rely on it for their mobility, and it is an especially important service for lower socioeconomic commuters.

On the other hand, a real, life changing positive impact of automated vehicles is improved mobility for those unable to drive currently, such as persons who are disabled, elderly, or too young. This technology could increase independence for these groups, leading to a reduction in isolation and giving them access to essential services. Google identified this opportunity for the technology in a video they made showing a blind individual conducting tasks with a Google driverless car that he would typically face significant challenges in accomplishing[158].

In the US, a large percent of public transit agencies' budgets go towards providing paratransit services to these population groups (14-18% of their budget), providing an

[157] Arieff A., *Driving Sideways*, New York Times, 23/07/2013

[158] abcNEWS, Blind Man Tests Google's Self-Driving Car, available at http://abcnews.go.com/Technology/video/blind-man-tests-googles-driving-car-16033479

essential service but one that is not economically efficient for these agencies. Automated vehicles could provide the more convenient mobility for these groups and provide wider societal benefits by reducing the proportion of public funds spent on service that reaches a small, but important part of the population.

##### *4.3.6.2. Land use*

The impact of highly autonomous vehicles on land use patterns is unclear but the technology does have the potential to change it in significant ways. Because of the aforementioned reduction in demand on the operator to get from origin to destination, the rider may be willing to live further from their regular destinations. A potential impact of this could be more sprawled and dispersed development.

On the other hand, automated vehicles also have the potential to have the exact opposite effect on urban area. It is estimated that approximately 31% of space in the central business district of 41 major US cities is devoted to parking[159]. With smarter vehicles there would be the potential far lower demand for parking, especially if there is a shift away from personal vehicles towards widespread Shared Self-Driving vehicles.

### 4.3.7. Ethics and public acceptance

##### *4.3.7.1. Ethics*

Data security and privacy will come along with ethical concerns regarding the definition of the data to collect as well as their ownership, sharing, storage and purpose; additionally, ethics will play a key role in the definition of the legislative framework regulating the use and management of such data.

Another important ethical issue concerns the behaviour of highly automated and self-driving vehicles in case of unavoidable accidents; determining the most acceptable loss in case of crash (e.g. should the driver try to avoid a child or an old man in cases collision would regard both?) will require an ethical debate among stakeholders as this aspect will arguably influence public acceptance of vehicle automation.

##### *4.3.7.2. Public acceptance*

User safety, data security, protection of personal data and ethical concerns altogether will determine public acceptance and consequent market penetration of automated systems. Public authorities and private stakeholders will need to provide credible answers to all these concerns as well as prove the environmental, economic, social and safety benefits of driving automation in order to gain public trust and set the ground for the diffusion of automated driving.

The results of the 2015 McKinsey survey on vehicle connectivity and automation conducted on 3,184 recent car customers in Germany, US and China highlighted that significant work needs to be done to reach wide public acceptance. Indeed, only 61% of the respondents declared to be in favour of the legalisation of cars with autonomous functions. Moreover, only 49% stated that, while purchasing a car, they would opt for a model with fully autonomous functions – i.e. no possibility of human driving – providing it had no extra costs; indeed this percentage would increase to 79% if the autonomous cars would allow

[159] Donald Shoup, *Cruising for Parking*, Access, No. 30, 2007

the option of conventional driving[160], showing some reluctance in trusting the new technology.

A recent Eurobarometer survey on autonomous system showed that a third of people (35%) would be comfortable travelling in autonomous or driverless cars. However, the majority of respondents (61%) are still uncomfortable with the idea of using an autonomous car – an absolute majority of respondents claim that they would not be comfortable with travelling in one in 23 Member States. People seem more comfortable with autonomous cars transporting goods: four out of ten (42%) could accept this[161].

### 4.3.8. Impact of other EU policies

A number of EU policies interact with automated vehicles. In Chapter 3.4.1 we already pointed out that amendments to Directive 2007/46/EC on vehicle approval and the EU Roadworthiness Directive (Directive/2014/45/EU) will be needed to accompany the development and market penetration of these solutions. Also the deployment of truck platooning in Europe could be require a change the Regulation (EC) 561/2006 and Regulation (EU) No 165/2014 of the European Parliament and of the Council (repealing Regulation (EEC) 3821/85) regarding driving/resting times and digital tachograph, respectively.

Indeed research and development on automated and connected vehicles clearly needs a strong cooperation between the actions taken by the EU in the areas of digital agenda, research, growth, justice and transport. This is actually reflected in the joint work on these themes between:

- DG CONNECT - that manages the Digital Agenda for Europe (DAE), defining the role of ICT to enable Europe to succeed in its ambitions for 2020;
- DG RESEARCH – responsible for Horizon 2020, the financial instrument implementing the Innovation Union by 2020;
- DG GROW – dealing with Product Liability Directive and Vehicle Approval Directive;
- DG JUST – in charge of personal data protection legislative framework; and.
- DG MOVE – in charge of transport policy.

The role of DG CONNECT in supporting automated and connected vehicles is certainly a clear one as a number of policies under its supervision can strongly affect the full exploitation of benefits in this field. For example V2V and V2I connections can greatly benefit from rules that reduce the costs of data transmissions, such as roaming legislation that regulates the international charges for telecommunication services within Europe and defines the maximum charges that could be applied for telephony and data services.

Since 2013 the European Parliament has been striving to remove incremental costs applied for foreign countries, with the objective to create a common market and break down national barriers. In July 2015[162] the EU Parliament vote to amend the current regulation in order to cancel roaming fees by mid-2017[163] – the final vote on the deal reached between

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[160] McKinsey & Company, *Competing for the connected customer – perspectives on the opportunities created by car connectivity and automation*, Advanced Industries, September 2015

[161] European Commission – Digital Agenda for Europe, *Robots: the more Europeans know them, the more they like them*, Press Release, 15/06/2015

[162] The Guardian, *Europe finally abolishes mobile phone roaming charges*, 27/10/2015

[163] European Commission – Digital Agenda for Europe, *Roaming Tariffs,* webpage, http://ec.europa.eu/digital-agenda/en/roaming-tariffs

the European Parliament and the EU Council on the European single market for electronic communication was adopted on 27/10/2015[164]. Finally, in the 9/9/2015 EP resolution on the implementation of the 2011 White Paper on Transport, the European Parliament emphasised the positive impact of digitalisation on the efficiency and productivity of the transport sector[165].

Data privacy issues should also be dealt with as part of the development of wider and deeper connectivity and sharing of data. Existing technologies such as Event Data Recording systems and eCall devices are already posing questions on data usage, as discussed in a study undertaken by Steer Davies Gleave for the European Parliament[166]. In future, the collection and processing of data from automated vehicles would need to fulfil the provisions included in the rules established by the EU for protection of personal data protection which are currently under revision.

Insurance and liability issues might also need to be addressed at the EU level. At present insurance for driver liability is addressed by Directive 2009/103/EC which sets that all vehicles in the EU are to be insured against third party liability and defines minimum thresholds for personal injury and property damage cover. Product liability is covered by Directive 85/374/EEC and national rules. In the long run, as higher automated vehicles circulate on EU roads, the legislative framework might need to be updated to take into account of the increased contribution of technology in determining vehicle's action and to clarify how responsibilities are distributed between drivers and vehicle and technological devices providers in case of accident.

**KEY FINDINGS**

- Different stakeholders and experts have **different views on the timescale** for placement and growth of automated vehicle in the global market.

- The development of automated **passenger vehicles** over the next few decades is expected to be driven by two different approaches: evolutionary and revolutionary. The **evolutionary approach** will probably lead to the implementation of increasingly automated systems (level 2 to 4) in the short (next 5-10 years) and middle term (10-20 years); the **revolutionary approach** is expected to be feasible on a large scale in a farther time horizon (more than 20 years) as full automation (level 5) requires more advanced technological systems, as well as greater modification to the current international and national regulatory frameworks – though use restricted to specific circumstances could occur earlier.

- As for **freight transport**, platooning represents the most investigated application of heavy vehicle automation and connection. Truck platooning is expected to follow an incremental pathway consisting in the progressive reduction of the responsibilities of the driver/s sitting in the following vehicle/s until full replacement would ultimately occur. When full automation would be available, also the driver sitting in the leading vehicles could be removed and platoons of full self-driving trucks could circulate on roads.

[164] European Parliament, *European single market for electronic communications ***II,* Texts Adopted [P8_TA-PROV(2015)0367]

[165] European Parliament, *Resolution of 9 September 2015 on the implementation of the 2011 White Paper on Transport: taking stock and the way forward towards sustainable mobility* (P8_TA-PROV(2015)0310)

- **Urban mobility** and public transport will arguably follow a different pathway towards full automation compared to those of cars and trucks. Urban environment systems are expected to follow the so called "everything somewhere" approach (as defined by ITF). This pathway consists of the development of highly automated vehicles whose application is initially limited to specific environments (e.g. airports, campuses, exhibition centres, etc.) and then gradually opens up to less protected circumstances.

- In theory **road safety** could significantly benefit from the recourse to automated systems as this could reduce accidents due to human errors, which are claimed to be responsible for 90% of road accidents. Yet, to date the effective safety performance of automated systems has yet to be demonstrated. A number of technical challenges still need to be addressed – such as the ability of highly automated systems to perform under poor weather or visibility conditions and correctly recognise obstacles and understand infrastructure elements – and little evidence is still available to date on the potential risks involved in switching between automated and manual control as well as on those associated to the coexistence on the road of automated and human driven vehicles. In addition to this, even if highly automated systems would be proved to be completely safe in the different circumstances, the extent to which they could contribute to improve safety on EU roads will depend on their rate of penetration on circulating fleet – which is likely to be a relatively long process.

- Due to the contrasting effects automated and connected vehicles can have on road traffic - as potential gains deriving from increased capacity could be balanced off by increased demand for road transport - it is hard to establish what will be the net effect of driving automation on **road congestion** and **emissions**. Regardless of this uncertainty though, it is undeniable that self-driving would reduce the social cost of congestion – by reducing the opportunity cost of travel time and allowing vehicle users to dedicate to other activities while travelling.

- Looking at the other outcomes and issues that could be generated by increasing recourse to driving automation, a key challenge concerns the **effective and secure management** of the large amount of **data** needed to allow self-driving and vehicle communication. This aspect is particularly important to ensure social acceptance – which is another area of concern at present - and make sure that potential benefits of automated and connected vehicles can be exploited at best.

- This is an area where there is substantial **scope for intervention at EU level**. For example V2V and V2I connections can greatly benefit from rules that reduce the costs of data transmissions, such as roaming legislation; the same is true for provisions sustaining further standardisation allowing for full interoperability across different devices and software. The collection and processing of data from automated vehicles would also need to fulfil the provisions included in the rules established by the EU for protection of personal data which are currently under revision.

[166] Steer Davies Gleave, *Technical Development and Implementation of Event Data Recording in the Road Safety Policy*, commissioned by the European Parliament's Committee on Transport and Tourism, 2014

# 5. CONCLUSION AND RECOMENDATIONS

## 5.1. Introduction

In this chapter we summarize the main implications of potential increase in vehicle automation in light of the expected impacts and pathways presented in Chapter 4 and present our recommendations for future action in this field.

## 5.2. Findings and Conclusions

Some **automated driving technology** is already available today, while others are being deployed in commercially available vehicles. Fully automated systems could be ready for commercial production in coming years but it is not clear at present, when this will occur and to what extent vehicles will be capable of self-driving in all circumstances.

There are two incremental paths towards full automation. The automotive industry is mainly following an **evolutionary approach**, developing increasingly automated assistance systems to improve driving safety and comfort; new entrants, such as technology companies, are mainly focussing on fully automated vehicles capable of running without a driver, taking forward a **revolutionary approach**. Some early attempts of integration of the two approaches seem to be occurring in the US, though, and might pave the way for new patterns of development.

Although **connected** and automated vehicles are two distinct concepts, they are firmly linked to one another. Technologies that can connect vehicles with other vehicles or infrastructure are already in use in non-automated vehicles and they are a crucial element to accompany the development of more advanced levels of vehicle automation both in passenger and freight transport.

Road safety, emissions and congestion reduction, and social inclusion are the main benefits commonly expected by the diffusion of automated systems across the different transportation systems. However, there is still little quantitative evidence about the actual effects of automation on these aspects.

**Road safety** is expected to improve with vehicle automation, yet this effect still needs to be tested on a large scale and may not be immediate. Although advocates of vehicle automation argue its potential for reducing over 90% of the total road accidents – as this is the approximate percentage related to human errors – evaluating the actual effect of the adoption of automated systems on road safety is far more complicated.

Firstly, the implementation of highly and fully automated systems (Level 4 and 5 of the SAE's classification) is still far from being achieved and we are many decades away from ubiquity, thus significantly reducing the number of accidents caused by human error.

The most likely situation over the next 30-40 years is one where manual, assisted and automated driving will coexist and alternate depending on the situation and context; therefore, human drivers will remain responsible for a number of driving operations (steering, monitoring the external environment, manually driving in specific situations) and consequently human errors will continue to cause accidents. Moreover, it is not yet clear how human drivers will behave (e.g. drivers of traditional vehicles could attempt to join a platoon) and if new risky situations might arise (e.g. in the switch between manual and automated driving mode) in such a mixed automation context.

Therefore we believe that a **thorough assessment of safety implications** of automated systems – including pilot tests and implementations – should be conducted in order to estimate their likely effects on traffic accidents' frequency and severity, and identify potential risks from improper human behaviour. Findings from such assessment should inform regulatory actions to mitigate the identified risks (e.g. compulsory training for proper use of automated systems or fines for hazardous behaviours) and accompany the introduction of this technology (e.g. new rules will probably be needed with respect to driving tests) in order to guarantee that the overall effect of vehicle automation on road safety will be positive.

Moreover, to guarantee the safety of automated vehicles it will be necessary to provide appropriate **requirements on functional validation** – including standardised test procedures and validation methods – against which the safety performance of automated systems can be measured and assessed (e.g. measurement procedures for the validation of environment sensor system). This is particularly important for highly and fully automated systems, in which the human driver will not be responsible for monitoring the system or providing fallback performance.

Potential benefits are expected also on reduced congestion and environmental impact of road transport, though their scale and net impact is quite unclear at the moment. In terms of reduction of **vehicles emissions** and **congestion**, research suggests that two-truck platoons might reduce fuel consumption by around 10% compared to traditional transportation, and that platooning could yield up to a 500% increase of hourly capacity per lane. Environmental benefits are also expected from automated systems regulating acceleration and braking and route choice; additionally, traffic management optimization and the reduction of road accidents might further increase effective road network capacity.

In our view, further research is needed to better quantify effective fuel consumption and emissions reductions provided by different automated and connected systems. Moreover, a more precise assessment of actual capacity increase due to vehicle platooning and Cooperative Adaptive Cruise Control (CACC) systems might inform planning decisions such as dedicating lanes or specific areas to connected vehicles, rather than building new infrastructure. Transport and spatial planning authorities should pay attention to these aspects and the EU should encourage a proper assessment due to their relevance for environmental policies and targets.

Automated systems are also expected to provide a number of **other social and economic benefits**. These will include improved mobility for young, elderly and disabled people and the possibility to undertake tasks and activities other than driving a car or truck– thus reducing the opportunity cost of the time spent in the vehicle and the labour cost, respectively. Moreover, vehicle automation and connection are expected to generate new jobs in the automotive, technology, telecommunication and freight transport industry – particularly in relation to IT services.

Increasing driving automation would also impact on **professional drivers**: they would be required to interact with the new technologies put on the market and might face a lower labour demand in the long term once full self-driving vehicles will be available for public or freight transport. We expect this change to occur over several years, and we believe that education and training will have a crucial role in this either to train professional drivers to enable them to use new emerging technologies and, most importantly, to teach new generations the skills they need to be prepared to work in a more connected and technological society where new professions might replace ones that could no longer be needed.

Training would also be needed for all drivers – for example as part of the driving licence release process - to equip them with the skills needed to use new technologies and devices.

We believe that driving automation could deliver significant productivity gains to the freight and logistic sector, though monitoring would be needed to verify that this gains are passed to consumers through reduced product prices.

As for the passenger sector, automated and connected cars can also sustain the shift towards a **new mobility scenario** where more sustainable transport solutions can replace the traditional car ownership/car usage paradigm. Rapid progresses in technology and telecommunication sectors, in parallel to vehicle automation, may accelerate the development of sharing, transport network and automated taxi services. European, national and local authorities should support and/or coordinate such applications in order to favour the development of new vehicles and ride sharing solutions which have the potential to reduce road transport externalities (e.g. emissions, congestion, space for parking).

Physical and technological infrastructure will play a crucial role in the development of automated and connected driving solutions. **Infrastructure requirements** will need to established in order to guarantee that automated and connected systems can safely operate; to this end, it will be necessary to determine which infrastructure elements, topologies and characteristics will be suitable for the different automation levels and who should be responsible for providing and maintaining the physical and digital infrastructure.

As higher levels of automation come to the market, the role of software will become increasingly important: it needs to be completely reliable and up-to-date and able to provide enough information to take the right decisions at the right time. Requirements about data and data transmission standards, quality, security and content must also be established in order to guarantee data security and protection.

When establishing such measures, particular attention must be paid to privacy concerns due to the fact that vehicle automation and connection require the use and analysis of an enormous amount of data. Therefore, it will be necessary to specify which information will possible to collect (e.g. route, speed, origin and destination of trips), who will own and maintain these data and what use of such data will be allowed (e.g. traffic management) in order to guarantee users' safeguards and avoid data misuse.

Road users should also be educated to adapt their behaviours accordingly and make best use of the potential benefits of this technology. This could include such measures as vehicle cooperation, allowing for fuel consumption reduction and optimum route choice decreasing travel times.

**Liability** in case of accidents is another relevant issue which needs to be addressed opportunely in order to guarantee public acceptance and avoid future conflicts between stakeholders. While for current tests liability lies only on manufactures, it is more difficult to say who will be liable when automated vehicles are allowed to circulate on public infrastructure. We believe that imputed responsibility for liability will evolve as these technologies progress: national legislation will always identify the subject to be held responsible for road accidents at first instance, but this might shift from physical driver to car manufacturers in case of full self-driving scenarios. Nevertheless, establishing the boundaries of liability for the different levels of automation is not expected to be a black and white process and regulators need to provide clear guidance to allow for the identification of the responsible of the accident and avoid litigation.

**Ethics** is another relevant theme to consider as self-driving vehicles will be asked to make complex ethical decisions currently taken by human beings; in this sense, the extreme and most controversial case concerns the decision of who should be killed in a road accident if it happens that you have two or more potential victims to hit with the car (e.g. a child and an old man). The way in which automated vehicles should behave in these and other dilemma situations need to be addressed before highly and fully automated systems responsible for all driving tasks and operations will be available on public roads.

Autonomous vehicle **regulation** should ensure safety and accompany their development preventing possible market failures. As for the test of prototypes, we have seen that different countries have passed rules that enables the testing, licencing and operation of this technology on public roads, but there seems to be little coordination across the actions taken by different jurisdictions.

At present there is little evidence of regulatory actions addressing the potential usage of autonomous vehicles on a large scale. Indeed this is a difficult task at the moment given the existing level of uncertainty on future pathways. Yet, amendments to existing international and European regulations concerning vehicle operation and design – on one hand - and driver behaviour – on the other hand – would be required in order to permit a wide implementation of a number of automated systems.

For example, by allowing automatically commanded steering functions only up to 10 km/h, UN Regulation No.79 does not permit the implementation of some systems belonging to Level 2 or above. Similarly, the Vienna Convention creates a barrier to the implementation of Level 4 and 5 systems, as it requires – even in its amended version – the presence of a driver in every moving vehicle or combination of vehicles (Art. 8), defining the driver as any person who drives a motor vehicle on a road (Art. 1). Also the deployment of truck platooning in Europe could require amendments to Regulation (EC) 561/2006 and Regulation (EEC) 3821/85 regarding driving/resting times and digital tachograph, respectively.

If the issues described above – which are synthetized in Table 5 below - are not properly tackled, public acceptance of automated vehicles – and consequently their market penetration – could be put at risk. Indeed, if stakeholders will not be able to be reassured in a timely fashion about safety and security of automated systems along with ethical, liability and social concerns, a widespread diffusion of these new technologies could be challenged, mining also the possibility to exploit expected potential benefits on road safety, network capacity and emissions reduction.

**Table 5: SWOT analysis about vehicle automation**

| AUTOMATED DRIVING SWOT ANALYSIS | |
|---|---|
| **Strengths** | **Weaknesses** |
| • Potential for accidents reduction as over 90% of road accidents involve human error<br>• Potential for emissions reduction thanks to platooning and more efficient driving<br>• Potential for capacity increase due to more efficient use of the infrastructure and route choice<br>• Social inclusion as young, elderly and disabled people might use full automated vehicles<br>• Reduction of cost congestion as users might dedicate themselves to other activities while on the vehicle<br>• Reduction of labour costs as vehicles can drive themselves without the need of a human driver | • Safety of automated systems (including infrastructure requirements) and ability to perform in all the situations and conditions are to be proved yet<br>• Cyber-security and system failure risks<br>• Protection of personal data and ethical concerns<br>• Advanced automated systems might be expensive<br>• International and/or national regulations need to be revised to allow implementation of many automated systems<br>• Liability in case of accidents<br>• Fragmentation of the competences within the EC directorates with regard to the need of establishing an EU global legislative framework on driverless cars |
| **Opportunities** | **Threats** |
| • Continuous advancements in technology and telecommunication sectors can accelerate vehicle automation and connection<br>• Automated and connected vehicles can support the diffusion of car sharing and transport networking services, leading to the development of a new mobility paradigm based on vehicles and ride sharing rather than car ownership<br>• Driving automation benefits might help achieve EU targets such as safety, congestion and emission reduction<br>• Vehicle automation and connection might favour the creation of new areas of business, and high skilled jobs (particularly in IT) | • Public acceptance due to privacy, safety and security concerns might delay the implementation of these systems<br>• Slow market penetration might delay the diffusion of these systems and consequently the achievement of its benefits<br>• Traffic increase due to enhanced mobility and increased competitiveness of road transport and consequent increase of emissions and congestion<br>• Negative impact on low skilled workers, particularly trucks and taxi drivers (labour market) |

## 5.3. Recommendations

The following table summarises the findings of our analysis and provides recommendation.

**Table 6: Lesson learned, recommendations and an assessment of developments in vehicle automation**

| Issue | Lessons learned | Recommendations |
|---|---|---|
| **Automated *and* connected vehicles** | Although connected and automated vehicles are two distinct concepts, they are firmly linked to one another. Technologies that can connect vehicles with other vehicles or infrastructure are already in use in non-automated vehicles – an example being the e-call device that can connect vehicles with emergency services in case of road accident. | A single roadmap needs to guide the development of connected and highly automated vehicles as most of the potential benefits that can be generated by driverless vehicles strongly depend on the extent to the communicate with other vehicles and/or the rest of the environment. In this respect the roadmap set by the European Commission at the opening of the GEAR 2030 initiative seems to take this point as a key consideration. |
| **Testing of different levels of automation** | A variety of driving assistance systems of Level 0 (no automation), Level 1 (driver assistance) and a smaller number of Level 2 (part automation) technologies are already on the market. Research and Development of more advanced automation systems up to Level 3 (conditional automation), Level 4 (high automation) and level 5 (full automation) is already underway.<br><br>Tests and pilots in this area are being taken forward with contributions from a variety of organisations, including vehicle manufacturers, information technology companies and public authorities interested in the implementation of full self-driving technologies. Testing of higher levels of automated vehicles is mainly subject to national rules, as countries have the possibility to derogate to standard traffic rules and international conventions for testing exercises. | Worldwide, different approaches have been adopted at a national level to allow testing of highly automated vehicles. To some extent different countries are competing with one another to create the most favourable conditions for testing and attract investment in this area. The different actions taken at national level should nevertheless be encompassed within strong international cooperation to make best use of growing expertise and know-how in this area, as well as to set the foundation for a smoother global process of getting highly automated vehicles to market.<br><br>In this respect the framework present at the United Nations (UNECE) seems ideally placed to deal with these issues. Stronger cooperation among EU MSs could be lead also by the European Commission. To avoid creating additional barriers to research and innovation in this area, a soft approach would be recommended, which could take the form of voluntary agreements or codes of practices between relevant authorities in order to set an harmonised approach on aspects like: requirements for test driver or recording of data, liability during testing, infrastructure requirements, cyber-security, public education of testing, cross-border testing, etc. |

| Issue | Lessons learned | Recommendations |
|---|---|---|
| **Place into market of different levels of automation** | Within existing rules, barriers exist against global market launch of automation Levels 3, 4 and 5 and, in some cases, national provisions could also challenge the use of Level 2.<br><br>Some stakeholders have called for further action to set a legislative framework that could support the development of these technologies at international level, looking jointly at provisions dealing with behavioural aspects (such as UNECE WP1) and with regulation and technological aspects (such as UNECE WP29). | UNECE work in this area – such as the ongoing initiative to amend UN R79 - is fundamental to preventing legislative barriers limiting introduction to market, including lower levels of automations that are ready to be deployed in the short term, as well as paving the way for bringing higher level of automation to market. The European Commission, as a member of UNECE WP29, is in a position to advocate that the regulations should not hamper innovation. As pointed out by a recent Commission working paper[167], "*a step-by-step and flexible approach could be followed, which would allow the early approval of some specific automated driving technologies before implementing a blanket set of rules*". |
| **Future pathways** | As for passenger cars, implementation of increasingly automated systems (levels 2 to 4) can be expected in the short (next 5-10 years) and medium term (10-20 years); fully automated vehicles are expected to be feasible on a large scale in a further time horizon (more than 20 years) – though use restricted to specific circumstances could occur earlier. For freight transport, truck platooning is expected to follow an incremental path, consisting of a progressive reduction of the responsibilities of the driver/s sitting in the following vehicle/s until full replacement would ultimately occur. Urban environment systems are expected to follow a pathway where application of highly automated vehicles will initially be limited to specific environments (e.g. airports, campuses, exhibition centres, etc.) and then gradually open up to less protected circumstances. | International, national and local policies and actions – such as research and innovation support, revision of legal and policy framework - should accompany the uptake of increasingly automated vehicles in the different environments. The C-ITS platform and the GEAR 2030 initiative are primary candidates to inform the strategies to be taken in this respect. Significant attention also needs to be given to the local/urban dimension – and related stakeholders - as many of the potential benefits of autonomous and connected cars seem to reach their highest potential at that level. As level 2 to 4 automated systems could be ready for large use on motorway networks in the short term, further attention should be given to the extent that this would interact with other innovations in the EU, for example Electronic Tolling Systems and other C-ITS applications, to guide the definition of the features that will distinguish EU road corridors in the near future. |

[167] European Commission (2015), *Better regulations for innovation-driven investment at EU level*, Commission Staff Working Document, SWD(2015) 298 final.

| Issue | Lessons learned | Recommendations |
|---|---|---|
| **Potential impact of large scale introduction of highly automated vehicles on road transport external effects** | The progressive uptake of highly automated and connected vehicles has the potential to improve the safety of EU roads as well as to reduce congestion and polluting/GHG emissions from road transport. Yet, to date, there is little evidence on the net effect that a massive penetration of highly automated vehicles would have on traffic congestion and related polluting emissions, or the extent to which they might improve safety for the different road users. | A thorough assessment of safety implications of automated systems – including pilot tests and implementations – should be conducted in order to estimate their likely effects on traffic accident frequency and severity and identify the potential risks from other (human) road user. Further research is also needed to better quantify effective fuel consumption and emissions reductions provided by different automated and connected systems. The creation of a shared knowledge system of outcomes of tests and pilots is recommended; the findings stored in this knowledge sharing database will then need to be used to inform relevant national and international legislative provisions. |
| **Other potential impacts of large scale introduction of highly automated vehicles** | Highly automated vehicles could support greater social inclusion and transport accessibility as young, elderly and disabled people might make use of them in daily life. Vehicle automation and connection might also favour the creation of new areas of business, with highly skilled jobs.<br>Automated and connected vehicles may also support the diffusion of car sharing and transport networking services, which in turn could have land usage implications - as less parking space would be needed on public roads – as well as enhancing the potential benefits of driverless vehicles on road safety and environment. | European, national and local authorities should support and/or coordinate the development of sharing, transport network and automated taxi services in order to favour the development of new driverless vehicles and ride sharing solutions which have the potential to reduce road transport externalities (e.g. emissions, congestion, space for parking). |

| Issue | Lessons learned | Recommendations |
|---|---|---|
| **EU policies interested to support large scale introduction of highly automated vehicles** | A number of EU policy makers are interested in the research and development, testing and placement into market of highly automated and connected vehicles. The most relevant areas are Digital Agenda for Europe, Horizon 2020, Transport Policy (i.e. road vehicle approval, road worthiness, driving licence), personal data protection and product liability. | Amendments to a number of EU directives would be needed to accompany highly automated and connected vehicles coming to market and ensure greatest exploitation of their benefits.<br><br>Examples are:<br>• Directive 2007/46/EC on vehicle approval and the EU Roadworthiness Directive (Directive/2014/45/EU).<br>• Regulation (EC) 561/2006 and Regulation (EEC) 3821/85 regarding driving/resting times and digital tachograph (for truck platooning).<br>• Directive 95/46/EC on data protection.<br>• Directive 2009/103/EC – on motor vehicle insurance - and Directive 85/374/EEC on product liability.<br>• Directive 2006/126/EC on requirements for driving licences and Directive 2003/59/EC on training and initial qualifications of professional drivers.<br><br>Consequently, a number of national laws would also need to be changed.<br><br>The ongoing reform of Directive 95/46/EC on personal data and Directive 2002/58/EC on the processing of personal data and the protection of privacy in electronic communications would also need to provide a harmonised framework for the treatment of road users' data in a more connected environment. Greater cooperation between industry players and data protection authorities and experts is also recommended to facilitate compliance of increasingly levels of vehicle automation and connection with the EU personal data protection legislative framework. |

# REFERENCES

## Reports


- Adaptive – Automated Driving Applications and Technologies for Intelligent Vehicles, *System Classification and Glossary*, Deliverable D2.1, February 2015
- American Association of Motor Vehicle Administrators (AAMVA) – Autonomous Vehicles Information Sharing Group, *Analysis of Laws Enacted in Jurisdictions (An Introduction to AAMVA AV Law Comparisons),* Executive Summary, October 2014
- Anderson, J. M. et al., *Autonomous Vehicle Technology – A Guide for Policymakers*, RAND Corporation, Santa Monica (USA), 2014
- Article 29 Data Protection Working Party, *Opinion 8/2014 on the on Recent Developments on the Internet of Things*, 16/09/2014
- AXA, *The Future of Driverless Haulage*, September 2015
- CityMobil Project, *Advanced Transport for the Urban Environment*, Brochure, November 2011
- Davis S. C., Diegel S. W., Boundy R. G., *Transportation Energy Data Book*, 31st ed., Oak Ridge National Laboratory, Oak Ridge (USA), 2012
- Department for Transport, *The Pathway to Driverless Cars – Summary Report and action plan*, London, 2015
- Department for Transport, *The Pathway to Driverless Cars: A Code of Practice for testing – Moving Britain Ahead*, London, 2015
- Department for Transport, *The pathway to driverless cars: a detailed review of regulations for automated vehicle technologies*, London, February 2015
- Eisses S., Van de Ven T., Fievée A., I*TS Action Plan. ITS & Personal Data Protection. Final Report*, Amsterdam, 04/10/2012
- ENO Center for Transportation, *Preparing a Nation for Autonomous Vehicles: Opportunities, Barriers and Policy Recommendations*, Paper, 2010
- ERTRAC, *Automated Driving Roadmap*, Brussels, July 2015
- European Commission, *Better regulations for innovation-driven investment at EU level*, Commission Staff Working Document, SWD(2015) 298 final.
- European Parliament, *Automated vehicles in the EU*, Briefing, January 2016
- European Parliament, Directorate-General for Internal Policies of the Union, Policy Department B: Structural and Cohesion Policies, *Research for TRAN Committee - The World is Changing. Transport, Too,* Brussels, January 2016
- European Technology Platform on Smart Systems Integration (EPoSS), European Roadmap – Smart Systems for Automated Driving, Berlin, April 2015
- Federal Ministry of Transport and Digital Infrastructure, *Strategy for Automated and Connected Driving – Remain a lead provider, become a lead market, introduce regular operations*, Berlin, September 2015

- Folsom T. C., *Energy and Autonomous Urban Land Vehicles,* Technology and Society Magazine, Vol. 31, No. 2, 2012
- Insurance Institute for Highway Safety, *New Estimates of Benefits of Crash Avoidance Features on Passenger Vehicles*, Status Report, Vol. 45, No. 5, May 2010
- International Organization of Motor Vehicle Manufacturer (OICA), *Automated Driving Submitted by the experts of OICA as input to the IWG ITS/AD*, Presentation, Berlin, 15/06/2015
- International Transport Forum (OECD/ITF), *Automated and Autonomous Driving – Regulation under uncertainty*, Corporate Partnership Board Report, Paris, 2015
- Janssen R. et al., *Truck Platooning – Driving the Future of Transportation*, TNO Mobility and Logistics, Report, February 2015
- KPMG and SMMT, *Connected and Autonomous Vehicles – The UK Economic Opportunity*, KPMG LLP, March 2015
- Le Gouvernement de la Republique Française, *La Nouvelle France Industrielle – Présentation des feuilles de route des 34 plans de la nouvelle France industrielle*, Dossier de presentation, September 2014
- Maxime Flament (ERTICO), *Sub-WG on Legal and Regulatory issues*, iMobility Forum WG Automation in Road Transport, Presentation, 17/09/2015
- McKinsey & Company, *Competing for the connected customer – perspectives on the opportunities created by car connectivity and automation*, Advanced Industries, September 2015
- Miller A., Avery M., *Autonomous Emergency Braking, the next seat belt?*, Tatcham Research
- Petit, J. (Centre for Telematics & Inf. Technol., Univ. of Twente, Enschede, Netherlands), *Potential Cyberattacks on Automated Vehicles*, in Intelligent Transportation Systems, IEEE Transactions on, Vol. 16 , Issue 2, April 2015
- PSA Peugeot Citroën – Innovation by PSA, *Enabled automatic E-call & B-call*, Presentation at the ITS World Congress, Bordeaux (France), October 2015
- Royal Automobile Club of Victoria (RACV), *Effectiveness of ABS and Vehicle stability Control System,* Research Report, April 2004
- SAE International – On-Road Automated Vehicle Standards Committee, *Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems,* Information Report, January 2014
- SafetyNet, *SafetyNet Final Activity Report*, January 2009
- Spieser K., Treleaven K., Zhang R., Frazzoli E., Morton D., Pavone M., *Toward a Systematic Approach to the Design and Evaluation of Automated Mobility-on-Demand Systems – A Case Study in Singapore*, in Meyer G., Beiker S. (editors), Road Vehicle Automation – Lecture Notes in Mobility, Springer, 2014
- Steer Davies Gleave, *Technical Development and Implementation of Event Data Recording in the Road Safety Policy*, commissioned by the European Parliament's Committee on Transport and Tourism, 2014
- Swedish Transport Agency – Road and Rail Department – Traffic and Infrastructure unit, *Autonomous driving – Pilot study*, Report, August 2014

- Zia Wadud (University of Leeds), Don MacKenzie (University of Washington), and Paul Leiby (Oak Ridge National Laboratory), *Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles*, in Transportation Research Part A, 86:1-18, April 2016


## Policy and legislation


- European Commission, *Towards a European road safety area: policy orientations on road safety 2011-2020*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2010) 389 final, Brussels, 20/07/2010
- European Commission, *Clean Power for Transport: A European alternative fuels strategy*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2013) 17 final, Brussels, 24/01/2013
- European Commission, *Digital Single Market Strategy for Europe*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2015) 192 final, 06/05/2015
- European Commission, *Roadmap on Highly Automated vehicles*, GEAR 2030 Discussion Paper, January 2016
- European Parliament, *European single market for electronic communications ***II*, Texts Adopted [P8_TA-PROV(2015)0367]
- European Parliament, *Resolution of 9 September 2015 on the implementation of the 2011 White Paper on Transport: taking stock and the way forward towards sustainable mobility* [P8_TA-PROV(2015)0310]
- United Nations Economic Commission for Europe (UNECE) – Inland Transport Committee – Working Party on Road Traffic Safety, *Report of the sixty-eighth session of the Working Party on Road Traffic Safety*, Geneva, 24-26/03/2014
- United Nations Economic Commission for Europe (UNECE) – Inland Transport Committee, *Status of the implementation of the Road Map on Intelligent Transport Systems*, Geneva, 15/12/2015
- United Nations Economic Commission for Europe (UNECE) – Inland Transport Committee, *UNECE and automated vehicles – Informal document WP.29-167-04,* November 2015
- United Nations Economic Commission for Europe (UNECE), *Convention on Road Traffic, Amendment 1*, Vienna, 08/11/1968
- United Nations, *Convention on Road Traffic*, Geneva, 19/09/1949, in United Nations, Treaty Series, vol. 125, p. 3


## Press Releases


- AlixPartners, *The Worldwide Automotive Growth Is Slowing Down, Particularly in the BRICS. At the Same Time, the Industry Face Huge Technological Challenges. C.A.S.E.*, Press Release, 23/06/2015
- ARUP, *'UK Autodrive' consortium wins competition to develop driverless cars*, 03/12/2014,

*http://www.arup.com/News/2014_12_December/02_Dec_Consortium_wins_competition_to_develop_driverless_cars.aspx*

- Cellnex, *Cellnex Telecom colabora con Applus IDIADA en el desarrollo de un Sistema de Comunicación Inteligente entre vehículos para una gestión segura y eficiente de la conducción*, 10/06/2015, *https://www.cellnextelecom.com/content/uploads/2015/06/NdP_Cellnex-Telecom_Idiada_Piloto-VRAIN_def.pdf*
- DAF, *DAF and TNO demonstrate 'EcoTwin'*, Eindhoven, 27/03/2015, *http://www.daf.com/en/news-and-media/articles/global/2015/q1/27-03-2015-daf-and-tno-demonstrate-ecotwin#*
- Delphi Press Releases, *Delphi Successfully Completes First Coast-to-Coast Automated Drive*, 02/04/2015, *http://investor.delphi.com/investors/press-releases/press-release-details/2015/Delphi-Successfully-Completes-First-Coast-to-Coast-Automated-Drive/default.aspx*
- Engineering and Physical Sciences Research Council (EPSRC), *Jaguar Land Rover and EPSRC announce £11 million autonomous vehicle research programme*, 09/10/2015, *https://www.epsrc.ac.uk/newsevents/news/jlrannouncesautonomousvehicalresearchprogramme/*
- European Commission – Digital Agenda for Europe, *Robots: the more Europeans know them, the more they like them*, Press Release, 15/06/2015, *http://ec.europa.eu/digital-agenda/en/roaming-tariffs*
- French Ministry of Ecology, Sustainable Development and Energy, Direction générale des Infrastructures, des Transports et de la Mer, *SCOOP@F – Test deployment project of cooperative intelligent transport systems*, May 2014, *http://www.developpement-durable.gouv.fr/IMG/pdf/49b_DGITM_scoop_GB_2p_def_web.pdf*
- General Motors-Chevrolet Media, *Chevrolet-FNR and All-New Chevrolet Malibu Make Global Debut at Shanghai GM Gala Night*, 19/04/2015, *http://media.gm.com/media/cn/en/chevrolet/news.detail.html/content/Pages/news/cn/en/2015/april/0419_chevrolet.html*
- General Motors Corporate Newsroom, *GM Exploring Mobileye Advanced Mapping With OnStar Data*, 05/01/2016, *http://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2016/Jan/0105-onstar.html*
- Google Official Blog, *What we're driving at*, 09/10/2010, *https://googleblog.blogspot.it/2010/10/what-were-driving-at.html*
- Groupe Renault, *NEXT TWO: the autonomous car made in Renault*, 24/01/2014, *https://group.renault.com/en/news/blog-renault/next-two-the-autonomous-car-made-in-renault/*
- ID Experts, *Connected Cars: Security Risks on Wheels*, Press Release, 04/01/2016, *https://www2.idexpertscorp.com/blog/single/connected-cars-security-risks-on-wheels*
- NHTSA, U.S. Department of Transportation Releases Policy on Automated Vehicle Development – Provides guidance to states permitting testing of emerging vehicle technology, May 2013, *http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development*

- PostBus, *Autonomous shuttles run for the first time*, 17/12/2015, *https://www.postauto.ch/en/news/autonomous-shuttles-run-first-time*
- PSA Peugeot Citroën, *A PSA prototype car travels from Paris to Bordeaux in autonomous mode*, Paris, 02/10/2015, *http://www.psa-peugeot-citroen.com/en/media/press-releases/psa-prototype-car-travels-paris-bordeaux-autonomous-mode*
- Safe Road Trains for the Environment (SARTRE), *First demonstration of SARTRE vehicle platooning*, 17/01/2011, *http://www.sartre-project.eu/en/press/Documents/Press%20release%2020110117%20First_test_platooning%20doc.pdf*
- Scania Group Newsroom, *Scania lines up for platooning trials*, 04/04/2012, *http://newsroom.scania.com/en-group/2012/04/04/scania-lines-up-for-platooning-trials/*
- Swisscom, *Swisscom reveals the first driverless car on Swiss roads*, Berne, 12/05/2015, *https://www.swisscom.ch/en/about/medien/press-releases/2015/05/20150512-MM-selbstfahrendes-Auto.html*
- Toyota Global Newsroom, *New Toyota Test Vehicle Paves the Way for* Commercialization *of Automated Highway Driving Technologies*, 06/10/2015, *http://newsroom.toyota.co.jp/en/detail/9753831/*
- TRL, *Greenwich's digital credentials driven home after TRL-led consortium wins £8m trial to pilot futuristic automated vehicles*, 03/12/2014, *http://www.trl.co.uk/news-hub/trl-press-releases/2014/december/greenwichs-digital-credentials-driven-home-after-trl-led-consortium-wins-%C2%A38m-trial-to-pilot-futuristic-automated-vehicles/*
- UBER Newsroom, *Uber and Carnegie Mellon University: A Deeper Partnership*, 09/09/2015, *https://newsroom.uber.com/2015/09/cmupartnership/*
- UNECE, *UNECE works on new standards to increase the safety of trucks and coaches*, 12/05/2011, *http://www.unece.org/press/pr2011/11trans_p10e.html*
- Valeo, *Valeo unveils its autonomous vehicle at ITS Bordeaux 2015*, Paris, 10/05/2015, *http://www.automotiveitnews.org/articles/share/1002879/*
- Volvo Car Group Global Newsroom, *Volvo Car Group initiates world unique Swedish pilot project with self-driving cars on public roads*, 02/12/2013, *https://www.media.volvocars.com/global/en-gb/media/pressreleases/136182/volvo-car-group-initiates-world-unique-swedish-pilot-project-with-self-driving-cars-on-public-roads*
- NHTSA, *Response to Google Letter of 12 November 2015*, February 2016. Available at: *http://isearch.nhtsa.gov/files/Google%20--%20compiled%20response%20to%2012%20Nov%20%2015%20interp%20request%20--%204%20Feb%2016%20final.htm*


### Articles in newspaper or webzines


- Arieff A., *Driving Sideways*, New York Times, 23/07/2013, *http://opinionator.blogs.nytimes.com/2013/07/23/driving-sideways/*
- Bloomber *Business, General Motors Salvages Ride-Hailing Company Sidecar for Parts*, 19/01/2016, *http://www.bloomberg.com/news/articles/2016-01-19/general-motors-salvages-ride-hailing-company-sidecar-for-parts*

- Bloomberg Business, *Google to make driverless cars an Alphabet company in 2016*, 16/12/2015, *http://www.bloomberg.com/news/articles/2015-12-16/google-said-to-make-*driverless*-cars-an-alphabet-company-in-2016*
- Charlie Constant, *ESP: Electronic Stability Program*, in Car-engineer.com, 12/15/2012, *http://www.car-engineer.com/esp-electronic-stability-program/*
- Chris Bryant*, VW, BMW, and Daimler agree €2.8bn deal for Nokia Here digital maps*, Financial Times, 03/08/2015*, http://www.ft.com/intl/cms/s/0/3431f50a-39a7-11e5-8613-07d16aad2152.html#axzz3si5Jv6dM*
- Claire Cain Miller, Nick Bilton, *Google's Lab of Wildest Dreams*, The New York Times, 13/11/2011, *http://immagic.com/eLibrary/ARCHIVES/GENERAL/GENPRESS/N111113M.pdf*
- Coches autónomos, *Un dispositivo permitirá circular sin conductor a los vehículos tradicionales*, 30/09/2014, *http://www.cochesinconductor.com/2014/09/un-dispositivo-permitira-circular-sin-conductor-a-los-vehiculos-tradicionales/*
- Danielle Muoio, *4 self-driving French cars successfully made a 360-mile trip with no test driver*, Business Insider UK – Tech News, 05/10/2015, *http://uk.businessinsider.com/four-self-driving-cars-traveled-360-miles-in-france-2015-10*
- Donald Shoup, *Cruising for Parking*, Access, No. 30, 2007, *http://shoup.bol.ucla.edu/CruisingForParkingAccess.pdf*
- Elena Roditi, *Voitures autonomes: les initiatives du législateur français*, Alain Bensoussan Avocats, 04/11/2014*, http://www.alain-bensoussan.com/voitures-autonomes/2014/11/04/*
- Forbes, *Is Faraday Apple's Automotive 'Beard?'*, 09/11/2015, *http://www.forbes.com/sites#/sites/jimgorzelany/2015/11/09/is-faraday-apples-automotive-beard/#5adc1cb31c87*
- Kazuaki Nagata, *Robot Taxi plans to have Fujisawa residents test driverless car for supermarket rides*, The Japan Times, 01/10/2015, *http://www.japantimes.co.jp/news/2015/10/01/business/robot-taxi-plans-fujisawa-residents-test-driverless-car-supermarket-rides/#.VjN3RrerTct*
- Matt Richtel, Conor Dougherty, *Google's Driverless Cars Run Into Problem: Cars With Drivers*, The New York Times, 01/09/2015, *http://www.nytimes.com/2015/09/02/technology/personaltech/google-says-its-not-the-driverless-cars-fault-its-other-drivers.html?_r=2*
- NBC News, *Uber Working With University of Arizona to Create Self-Driving Cars*, 25/08/2015*, http://www.nbcnews.com/tech/tech-news/uber-working-university-arizona-create-self-driving-cars-n415886*
- Nil Sanyas, V*oitures sans pilote: des premiers tests sur les routes françaises dès 2015*, NextInpact, 08/07/2014, *http://www.nextinpact.com/news/88577-voitures-sans-pilote-premiers-tests-sur-routes-francaises-des-2015.htm*
- Peter Sayer, *French self-driving car goes for a spin around Paris monument*, PCWorld, 27/03/2015, *http://www.pcworld.com/article/2903372/french-selfdriving-car-goes-for-a-spin-around-paris-monument.html*
- Phys.org, *Google releases more details on self-driving car accidents*, 05/06/2015, *http://phys.org/news/2015-06-google-self-driving-car-accidents.html*

- Ron Amadeo, *Driving (or kind of not driving) a Tesla Model S with Autopilot*, ArsTechnica, 15/10/2015, *http://arstechnica.com/cars/2015/10/driving-or-kind-of-not-driving-a-tesla-model-s-with-autopilot/*
- Safe Car News, *UN amends Vienna Convention on Road Traffic to allow driverless cars*, 21/05/2014, *http://safecarnews.com/un-amends-vienna-convention-on-road-traffic-to-allow-driverless-cars/*
- Seb Joseph, *Volvo will accept full responsibility for driverless car crashes*, TheDrum.com, 11/10/2015, *http://www.thedrum.com/news/2015/10/11/volvo-will-accept-full-responsibility-driverless-car-crashes*
- The Guardian, *China's Baidu could beat Google to self-driving car with BMW*, 10/06/2015, *http://www.theguardian.com/technology/2015/jun/10/baidu-could-beat-google-self-driving-car-bmw*
- The Guardian, *Crash involving self-driving Google car injures three employees*, 17/07/2015, *http://www.theguardian.com/technology/2015/jul/17/crash-self-driving-google-car-injures-three*
- The Guardian, *Documents confirm Apple is building self-driving car*, 14/08/2015, *http://www.theguardian.com/technology/2015/aug/14/apple-self-driving-car-project-titan-sooner-than-expected*
- The Guardian, *Europe finally abolishes mobile phone roaming charges*, 27/10/2015, *http://www.theguardian.com/technology/2015/oct/27/europe-abolishes-mobile-phone-roaming-charges*
- The Guardian, Tesla's new autopilot system lets electric car change lanes by itself, 15/10/2015, *http://www.theguardian.com/technology/2015/oct/15/teslas-new-autopilot-system-lets-electric-car-change-lanes-by-itself*
- Traffic Technology Today, *Netherlands to test AVs on public roads*, 06/02/2015, *http://www.traffictechnologytoday.com/news.php?NewsID=66095*


### Webpages


- Adaptive website, *https://www.adaptive-ip.eu/index.php/objectives.html*
- ATKINS, *VENTURER consortium - autonomous vehicles*, *http://www.atkinsglobal.com/en-gb/projects/venturer-driverless-cars*
- Audi website, *History of piloted driving*, *http://www.audi.com/com/brand/en/vorsprung_durch_technik/content/2014/10/history-piloted-driving.html*
- Autonomous Labs website, *http://autonomos-labs.com/history/*
- Bosch Mobility Solutions, *Active Safety*, *http://products.bosch-mobility-solutions.com/en/de/driving_safety/driving_safety_systems_for_passenger_cars_1/active_safety/active_safety_2.html#*
- Catapult Transport Systems, *Driverless Pods*, *https://ts.catapult.org.uk/pods*
- CityMobil Project website, *http://www.citymobil-project.eu/*
- CityMobil2 Project website, *http://www.citymobil2.eu/en/About-CityMobil2/Overview/*
- Companion Project website, *http://www.companion-project.eu/*

- DAVI website, *http://davi.connekt.nl/partnership/*
- Defense Advanced Research Projects Agency (DARPA) website, *http://www.darpa.mil/*
- EasyMile website, *http://easymile.com/mobility-solution/*
- European Automobile Manufacturers Association (ACEA), *Research and Innovation, http://www.acea.be/industry-topics/tag/category/research-and-innovation*
- European Commission, *Climate Action – Reducing CO2 emissions from passenger cars, http://ec.europa.eu/clima/policies/transport/vehicles/cars/index_en.htm*
- European Commission, *Digital Agenda for Europe – Roaming Tariffs*, *http://ec.europa.eu/digital-agenda/en/roaming-tariffs*
- European Commission, *Mobility and Transport – Road safety*, *http://ec.europa.eu/transport/road_safety/index_en.htm*
- Freightliner Infinite Inspiration website, *http://www.freightlinerinspiration.com/*
- General Motors' ASEP project website, *www.gmasep.org*
- Mercedes-Benz website, *Autonomous long-distance drive*, *https://www.mercedes-benz.com/en/mercedes-benz/innovation/autonomous-long-distance-drive/*
- Next – The Future of Transportation, website, *http://www.next-future-mobility.com/*
- Safran Group website, *http://www.safran-group.com/*
- The Center for Internet and Society (CIS), *Automated Driving: Legislative and Regulatory Action*, *http://cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action*
- Ulm University website, *https://www.uni-ulm.de/index.php?id=53474*
- University of Michigan – Mobility Transformation Center, *Mcity Test Facility*, *http://www.mtc.umich.edu/test-facility*
- Vinnova, FFI - Strategic Vehicle Research and Innovation, *http://www.vinnova.se/en/FFI---Strategic-Vehicle-Research-and-Innovation/#*
- Vinnova, *Transportation, http://www.vinnova.se/en/Our-acitivities/Search-for-programme/Transportation/*
- VisiLab website, *http://vislab.it/*

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