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**BRIEFING PAPER**

Number 7965, 7 May 2021

# Connected and autonomous road vehicles

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# Summary

This paper considers some of the key implications of 'connected and autonomous vehicles' (CAVs) for the UK road transport sector. It includes discussion of the potential benefits of road-based CAVs; barriers to adoption; and the evolving regulatory framework.

**Types and levels of connectivity and automation**

Many modern road vehicles are capable of some level of connectivity, which enables the vehicle to communicate with its surrounding environment (e.g. providing useful information to drivers about road, traffic and weather conditions). Connectivity is closely associated with vehicle automation, in which vehicles use information from on-board sensors and systems to understand where they are, including in relation to their surroundings. Increasingly, new road vehicles are capable of some level of automation, in which the vehicle can make decisions and control aspects of driving (e.g. advanced driver assistance, lane assist and park assist).

Numerous established vehicle manufacturers and technology companies around the world are now developing and testing vehicles that can make the full range of driving decisions and take full (i.e. self-driving) control of part or all of a journey.

**Potential benefits of CAVs**

The main areas in which CAVs could deliver benefits, include making it more convenient and easier to drive, improvements to safety and in accident reductions, through reducing congestion, delivering associated economic and productivity benefits, and increasing the mobility of people currently unable to drive, including young, elderly and disabled people.

**Barriers to adoption of CAVS**

Public perceptions and attitudes towards autonomous technologies are likely to be important factors in the level and pace of adoption. Increasing public acceptance may be a considerable challenge with surveys suggest that many people are not ready to put their trust in full automation.

The development of fully autonomous vehicles will also require the resolution of ethical issues, including the moral dilemma of how a CAV should react in the event of an imminent collision in which it has the opportunity to "choose who to save" from injury or death. The House of Lords Science and Technology Committee's March 2016 report noted that this was "a conundrum faced by car manufacturers, buyers and regulators". The UK Government has not begun to address these issues of "algorithmic morality" in its domestic regulatory approach.

In 2018, the Law Commission was commissioned to review the regulatory framework. Its final report is due to be published at the end of 2021.

**Government approach**

The Government's approach to date has been to try to create the conditions in which the UK can capitalise on the opportunity to develop and market CAV, including, in the long term, autonomous or self-driving vehicles. The Department for Transport's (DfT) view is that the UK can position itself at the "cutting edge" of CAV research and development, thanks to its "permissive Regulations; thriving automotive sector; and excellent research base and innovation infrastructure".

In February 2015, the DfT published an in-depth regulatory review, which found that the existing framework did not present a barrier to testing autonomous vehicles (AV) on

public roads. It subsequently published a Code of Practice for AV testing, and established the UK Centre for Connected and Autonomous Vehicles. The Centre is supporting three projects, which are testing a range of advanced CAV in Bristol, Greenwich in south east London, and Milton Keynes and Coventry, in trials due to run until 2018.

The Government legislated through the Automated and Electric Vehicles Act 2018 to set broad parameters of how automated vehicles involved in road traffic accidents would be treated for insurance purposes.

In April 2021, the Government's consultation response confirmed that it would proceed with allowing Automated Lane Keeping Software (ALKS) type approved self-driving vehicles on GB roads, possibly as early as the end of 2021.

# 1. Technological developments and key issues

## 1.1 Types and levels of connectivity and automation

The simultaneous development of a number of vehicle technologies has opened up opportunities to develop and manufacture road vehicles with a range of "connected" and autonomous capabilities.

Connected vehicles use communications technologies that enable the vehicle to send and receive information to and from other vehicles (vehicle to vehicle—V2V) and/or "smart" road infrastructure (vehicle to infrastructure—V2I), including via mobile phone networks, the Internet and "the cloud". Typically, information is about road, traffic and weather conditions to assist the driver. V2I technology can facilitate traffic flows, for example by coordinating driving speeds with traffic light patterns. Increasingly, connected vehicles include a range of services available through any connected computer or smart phone, including videos, music etc.[1] Further variants of Connected Vehicle Technology (CVT) include "vehicle to device" (V2D, communication with devices such as mobile phones), which opens up the possibility of "vehicle to pedestrian" (V2P) and "vehicle to the cloud" (V2C) communication.[2]

Automation ranges from vehicles with already quite common "driver assistance" capabilities, including automated emergency braking (AEB), "cruise control", "lane assist" and "park assist", to full, self-driving automation. The automotive industry has identified six levels of automation, from zero (vehicle controlled entirely by a human driver) to five (full vehicle automation, with systems capable of "longitudinal and lateral dynamic driving in all situations during the entire journey" with no human driver required), as set out in the table below:[3]

| Level | Name | Description |
|---|---|---|
| 0 | No automation | Human driver completely controls the vehicle |
| 1 | Driver assistance | Individual activities which assist steering or acceleration/deceleration |
| 2 | Partial automation | Several, simultaneous activities which assist steering or acceleration/deceleration are automated |

1 See, for example, "What's driving the connected car?", *McKinsey & Company*, September 2014
2 RAC Foundation, *Readiness of the road network for connected and autonomous vehicles*, April 2017, para 1.1
3 RAC Foundation, *Readiness of the road network for connected and autonomous vehicles*, April 2017, table 2.1

| | | |
|---|---|---|
| 3 | Conditional automation | In certain driving scenarios, all dynamic, non-strategic, driving activities (e.g. vehicle control but not route choice) are automated but human is expected to intervene when requested |
| 4 | High automation | In certain driving scenarios, all dynamic driving activities are automated and vehicle can cope with human not intervening if and when requested. |
| 5 | Full automation | Always and everywhere, all dynamic driving activities are automated with no need for human interaction |

While some road vehicles are connected only and others autonomous only, the range of requisite technologies are closely related and often in development together. Collectively these vehicles are known, across the automotive industry and government, as Connected and Autonomous Vehicles (CAV).[4]

## 1.2 Key potential benefits of CAV

The main areas in which CAVs could deliver benefits include:

- Convenience and ease of driving
- Safety and accident reductions
- Reducing congestion, delivering associated economic and productivity benefits
- increasing the mobility of people currently unable to drive, including young, elderly and disabled people.

### Convenience

Some features of CAV, for example parking assistance, have been designed and developed primarily to appeal to consumers by increasing the enjoyment, ease or convenience of particular aspects of driving. The Society of Motor Manufacturers and Traders (SMMT) has noted that "stress-free driving" is the top perceived benefit of CAV for consumers.[5]

### Safety

Safety is a key benefit of CAV technologies. It is estimated that human driver error causes between 75% and 95% of all road traffic collisions.[6] By removing entirely the risk of human error from driving, full vehicle automation therefore has the potential to very substantially reduce road

4 DfT/BEIS, Driverless vehicles: connected and autonomous technologies [accessed 22 May 2017]
5 SMMT press notice, "Connected & autonomous vehicles will improve quality of life for 6 in 10 people with limited mobility, finds new study", 30 March 2017
6 House of Lords Science and Technology Committee, *Connected and Autonomous Vehicles: The Future?* (Second Report of Session 2016–17), HL 115, 15 March 2017, paras 81–2

traffic collisions and associated casualties and deaths. As the DfT has emphasised, autonomous vehicles do not get tired, stressed or distracted and are therefore less prone to mistakes.[7]

Estimates of the potential positive safety effects of fully autonomous road vehicles vary. Higher estimates, for example that, by mid-21st century, CAV will prevent 90% of road traffic fatalities and become "the great public health achievement of the century", have been dismissed by some commentators as media hype. Researchers have noted a paucity of robust data by which to compare the safety of fully autonomous vehicles with human-driven vehicles. [8]

Much will depend on the level of "market penetration" of fully autonomous vehicles, to which there are significant barriers (see section 1.3, below). In its March 2017 Report on CAV, the House of Lords Science and Technology Committee emphasised that:

> Realising the benefits of increased road safety—by reducing human error—will depend on the level of automation and level of adoption. Ageas (UK) Limited told us that while the introduction of CAV "is likely to reduce the number of accidents over time", human error is only going to be removed altogether "once all vehicles on the roads are autonomous, which may take many decades".[9]

## Congestion

By mitigating or eliminating the risk of human error, CAV are capable of travelling closer together, with shorter stopping distance.[10] CAV therefore have the potential to make more efficient use of available road space than conventional vehicles, and thereby reduce road congestion. As noted by the Parliamentary Office of Science and Technology (POST) in 2013, however, achieving these benefits would be far from straightforward, particularly while there continues to be a mix of CAV and conventional vehicles on the roads.[11]

A May 2016 research report published by the DfT found that average journey times and delays on the Strategic Road Network (SRN, motorways and major trunk roads) were likely to *increase* in the initial transition period, while fully autonomous CAV make up 25% or less of the total number of road vehicles. However, it found that substantial benefits were likely to be felt once these CAV make up 50% or more of total vehicles on the SRN—including a greater than 40% reduction in average delay "assuming 100% penetration of assertive CAV".[12]

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7 DfT, *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies*, February 2015, p 7

8 See for example, "Will driverless cars really save millions of lives? Lack of data makes it hard to know", *Washington Post*, 18 October 2016

9 House of Lords Science and Technology Committee, *Connected and Autonomous Vehicles: The Future?* (Second Report of Session 2016–17), HL 115, 15 March 2017, para 86

10 Atkins for DfT, *Research on the Impacts of Connected and Autonomous Vehicles (CAVs) on Traffic Flow: Summary Report*, May 2016, p5

11 POST, *Autonomous Road Vehicles*, POSTNOTE 443, September 2013

12 Atkins for DfT., Research on the Impacts of Connected and Autonomous Vehicles (CAVs) on Traffic Flow: Summary Report, May 2016

Reacting to the report, Steve Gooding, Director of Motoring Research at the RAC Foundation, told the BBC:

> There's a prize to be had in terms of swifter, safer journeys, but the transition to that world will be challenging. There are around 32 million conventional cars on the UK's roads—as driverless cars come in, traffic flow could initially get worse rather than better, potentially for many years. Much will depend on how an autonomous car's parameters are set and just how defensively these vehicles will be programmed to drive.[13]

Academics, including from the University of Leeds Institute for Transport Studies, are studying the interaction of CAV and conventional vehicles in an EU research project launched in May 2017 (see section 2.3 below).

Reduced stopping distances have potential benefits for the road haulage industry, including the capability of goods vehicles to travel in connected conveys, or 'platoons'.

## Increased mobility for the young, old and disabled

Road vehicles that do not require a human driver may increase the mobility of people currently unable to drive, including young, elderly and disabled people. Research for the automotive industry, published in March 2017, emphasised the potential benefits of increased mobility for these groups for access to education and employment. It found that CAVs could help "over one million people in the UK to pursue a university degree", for example. This could potentially boost individual earnings by around £8,500 per annum ten years after degree award. The potential benefits to the UK economy of broader access to education, employment and social activities for people who currently have restricted mobility are estimated at £8 billion.[14]

## Economic and productivity benefits

CAV are forecast to bring economic benefits to the UK in a number of other ways. If the congestion-reducing effects described above can be realised, they could significantly increase productivity and growth. The CBI's December 2016 report, *Unlocking Regional Growth*, estimated that reducing journey times by road within some regions of the UK could have productivity benefits of up to 14%.[15]

The congestion-reducing effects of CAV are far from certain, however, not only because of uncertainty about how they will interact with conventional vehicles during a potentially decades-long transition to full automation, as discussed above, but also because the popularity of CAVs could see more vehicles on the roads, possibly at the expense of more road space-efficient public transport ridership (see section 4.2, below).[16]

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13 "Driverless cars to 'increase congestion' says government", *BBC News*, 6 January 2017

14 Strategy& for SMMT, *Connected and Autonomous Vehicles: Revolutionising Mobility in Society*, March 2017

15 CBI, *Unlocking Regional Growth: Understanding the Drivers of Productivity across the UK's Regions and Nations*, December 2016

16 International Association of Public Transportation, *Policy Brief: Autonomous vehicles: a potential game changer for urban mobility*, January 2017

The DfT is taking seriously the potential productivity benefits of fully autonomous road vehicles, which would free-up time currently spent behind the wheel for more productive activities. It has noted that drivers spend on average six working weeks driving per year; the long term goal of reallocating this time to other tasks represents a "real opportunity" in relation to productivity gains.[17]

A central focus for government and automotive industry has been on creating the conditions in which the UK can capture a significant proportion of the global CAV R&D and manufacturing markets, and the potentially substantial economic benefits this could bring. KPMG's research for the SMMT, published in 2015, estimated the potential overall economic benefits to the UK at £51 billion per annum by 2030, including an additional 320,000 jobs, of which 25,000 would be in automotive manufacturing.[18]

## 1.3 Barriers to adoption of CAV

The DfT acknowledges that "the capability of CAV is likely to be dependent, at least in part, on user preference".[19] Public perceptions and attitudes towards autonomous technologies are also likely to be important factors in the level and pace of adoption.

### Public perceptions

Organisations testing CAV in the UK are fully cognisant of the importance of public acceptance. The GATEway project, which is testing CAV in Greenwich, acknowledges that:

> The idea of a driverless vehicle can seem unsettling, partly because it suggests a lesser amount of control, and the suffix "less" also equates to missing—in this instance, of not being complete, or lacking. Autonomous vehicles on the other hand, might engender a different reaction: as something that is made to be self-governing, that doesn't have to be operated by humans because it can work things out for itself, the autonomous vehicle represents an advanced technology that doesn't need humans to function.[20]

Increasing public acceptance may be a considerable challenge. The requisite technology for level 5 road AV already exists, but surveys suggest that many people are not ready to put their trust in it.

In the US, where adoption of level 3 automation on public roads is already well advanced (see section 3.2 below), the 2017 Tech Choice Study, a survey of 8,500 US car consumers, found declining levels of trust in driverless car technologies in all age groups other than "generation Y" (those born between 1977 and 1994). A greater proportion of both older and younger respondents reported that they

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17 DfT., *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies*, Feb 2015, p5
18 KPMG for SMMT, *Connected and Autonomous Vehicles: The UK economic opportunity*, March 2015
19 Atkins for DfT, *Research on the Impacts of Connected and Autonomous Vehicles (CAVs) on Traffic Flow: Summary Report*, May 2016
20 See, for example: GATEway project, *Exploring public attitudes towards driverless vehicles*, 17 October 2016

"definitely would not trust" autonomous vehicles technology compared to 2016 results. The proportions of 2017 respondents in each age category who unequivocally *did not* trust autonomous technology were as follows:

- Pre-Baby Boomers (born pre-1946)—49%
- Baby Boomers (1946–1964)—44%
- Generation X (1965–1976)—34%
- Generation Y (1977–1994)—17%
- Generation Z (1995–2004—22%.

## Ethical issues

The development of fully autonomous vehicles will also require the resolution of ethical issues, including the moral dilemma of how a CAV should react in the event of an imminent collision in which it has the opportunity to "choose who to save" from injury or death. Though very rare, situations will arise in which there is sufficient time for a CAV to decide upon on course of action which harms one person, or group of people, instead of another. In some situations they will have to decide whether to harm their passengers or people in other vehicles, or other road users and pedestrians.[21]

The House of Lords Science and Technology Committee's March 2016 report noted that this was "a conundrum faced by car manufacturers, buyers and regulators". Witnesses in its inquiry expressed divergent views, from those, including the insurance provider Aegeus UK, who argued that programming CAV to make these types of decision could be "a good thing" for road safety, to others, including the Institute and Faculty of Actuaries, who did not believe it to be either "achievable or desirable".[22]

A number of surveys, a range of which were published in the journal *Science* in June 2016, show that the public remain uneasy and conflicted on these ethical questions. In one survey, for example, 76% of respondents agreed that CAV should be programmed using algorithms designed to save the greatest number of people, even if that meant "sacrificing" its passengers. However:

> When people were asked whether they would buy a car controlled by such a moral algorithm, their enthusiasm cooled. Those surveyed said they would much rather purchase a car programmed to protect themselves instead of pedestrians. In other words, driverless cars that occasionally sacrificed their drivers for the greater good were a fine idea, but only for other people.[23]

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21 See, for example: "Will your driverless car be willing to kill you to save the lives of others?", *The Guardian*, 23 June 2016

22 House of Lords Science and Technology Committee, *Connected and Autonomous Vehicles: The Future?* (Second Report of Session 2016–17), HL 115, 15 March 2017, paras 176–86

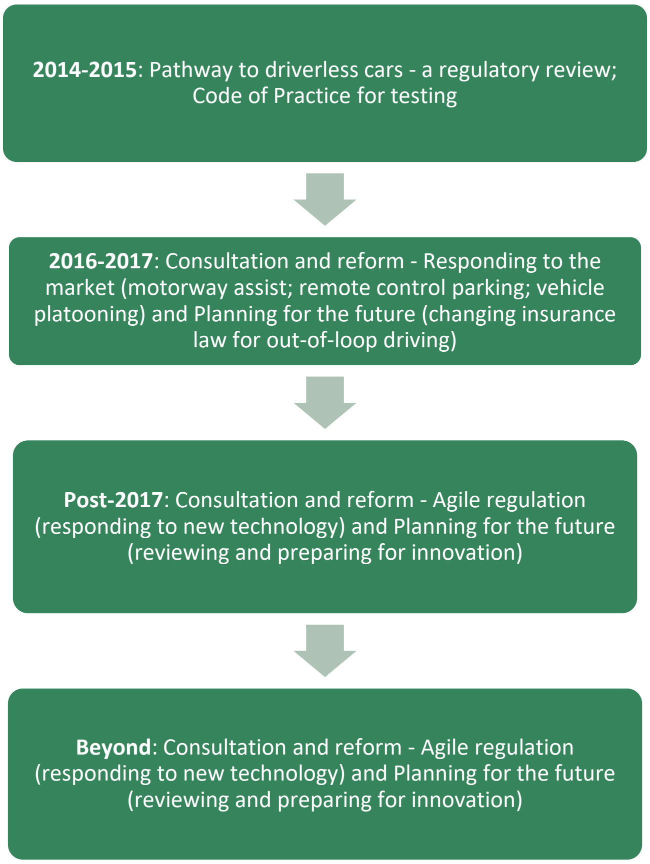
23 Ian Sample, "Will your driverless car be willing to kill you to save the lives of others?" *Guardian*, 23 June 2016

The UK Government has not begun to address these issues of "algorithmic morality" in its domestic regulatory approach (see section 2.1 below); the House of Lords Science and Technology Committee urged the Government to "keep them in mind" during its programme of regulatory reform.[24]

[24] House of Lords Science and Technology Committee, *Connected and Autonomous Vehicles: The Future?* (Second Report of Session 2016–17), HL 115, 15 March 2017, para 186

# 2. The ‘pathway to driverless cars’ in the UK

The Government set out its approach to regulatory reform, in order to develop and implement autonomous vehicle use on UK roads, as follows:[25]




## 2.1 Regulatory review and Code of Practice for vehicle testing, 2015

The DfT undertook a detailed review of regulations for AV, publishing a review report in February 2015. The main focus of the review was on ensuring that regulations did not act as a barrier, allowing the UK to be “at the forefront of the testing and development of the technologies that will ultimately realise the goal of driverless vehicles”.[26]

The central finding of the review was that the existing legal and regulatory framework was not a barrier to the testing of automated vehicles on public roads, providing that a human test driver, with

25 Adapted from: DfT, *Pathway to Driverless Cars: Proposals to support advanced driver assistance systems and automated vehicle technologies*, 11 July 2016, p9

26 DfT, *The Pathway to Driverless Cars: Summary report and action plan*, 11 February 2017, p7

responsibility for the safe use of the vehicle, is present and "alert and ready to resume control" of the vehicle if necessary.[27]

The review found that greater clarity of the term "safe use of vehicles" was required, and concluded that clarity would best be provided, during the vehicle-testing phase, via a non-statutory Code of Practice.[28]

The Code of Practice for testing autonomous vehicles was published in July 2015. It sets out the safety and general requirements and responsibilities of testing organisations, including that:

- Responsibility rests with the testing organisation;
- Vehicles under testing must comply with all relevant road traffic law;
- Test drivers must hold the appropriate driving licence and receive training appropriate to the vehicle;
- Testing organisations should conduct risk analyses of any proposed tests and have appropriate risk management strategies; and
- The statutory requirements on the holding of insurance apply.[29]

## 2.2 Second wave of regulatory reform, 2016-17

In July 2016, the DfT consulted on its broader regulatory approach to Advanced Driver Assistance Systems (ADAS) and Automated Vehicle Technology (AVT). Its strategic aim was to "shape the way technology emerges to ensure people and businesses in the UK are among the first to benefit".[30]

The consultation paper did not propose any immediate fundamental regulatory changes, principally because in the testing phase of AV on public roads a suitably qualified human driver would remain responsible throughout the journey, as set out in the Code of Practice. Current driving prohibitions, including of careless, drink and drug driving would continue to apply.

The DfT proposed a "pragmatic and proportionate approach, with a rolling programme of regulatory reform", with flexibility to adapt to technological developments and market-readiness:

> By taking a step-by-step approach, and regulating in waves of reform, we will be able to learn important lessons from real-life experiences of driving of increasingly automated vehicles. We can then apply these lessons when considering what further changes will be required and are appropriate to allow the safe use of technology that is yet to be developed. This will complement the lessons learnt from testing fully-automated vehicles both on test

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27 DfT, *The Pathway to Driverless Cars: Summary report and action plan*, 11 February 2017, p25

28 DfT, *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies*, 11 February 2015, chapter 10

29 DfT, *The Pathway to Driverless Cars: A Code of Practice for testing*, July 2015

30 DfT, *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies*, 11 February 2015, p5

> tracks and public roads, providing the government with the evidence on which to support future policy decisions.[31]

The consultation proposed some changes to the approach to UK motor vehicle insurance (in the UK unlike in some other countries, the driver, rather than the vehicle, must be insured against liabilities). It noted that the UK approach worked well in relation to both conventional vehicles and those equipped with ADAS, as in all cases the driver must be ready to take control, and retains responsibility, at all times. It acknowledged, however, that the development of more advanced AVT, in which the vehicle itself has greater control, was beginning to break down this approach. It therefore proposed to amend the UK motor insurance framework, to ensure that use of autonomous vehicles "continues to be insured when AVs reach the market, which we expect to happen in five to ten years".[32]

The initial proposal was to:

> […] extend compulsory motor insurance to cover product liability to give motorists cover when they have handed full control over to the vehicle […]. And, that motorists (or their insurers) rely on courts to apply the existing rules of product liability (under the Consumer Protection Act) and negligence (under the common law) to determine who should be responsible.[33]

The DfT also proposed revisions to a number of Highway Code Rules and Construction and Use Regulations[34] in relation to remote control parking,[35] motorway pilot,[36] and HGV platooning (see section 4.3 below).

The DfT's consultation response was published in January 2017. It reported that, broadly, its proposed incremental approach had received positive support. While some respondents had urged a more proactive approach to regulatory reform, the Government had been convinced by significant support to proceed with its rolling programme. , reiterating that:[37]

The Government stated that it had amended its insurance proposal in response to feedback received via the consultation. In particular, there were concerns about the co-existence of product liability insurance law with the current compulsory motor insurance framework, to the effect that "product liability law and insurance practice have inherent

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31 DfT, *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies*, 11 February 2015, p8

32 DfT, *Pathway to driverless cars: Consultation on proposals to support Advanced Driver Assistance Systems and Automated Vehicles - Government Response*, 6 January 2017, p7

33 DfT, *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies*, 11 February 2015, p12

34 *Road Vehicles (Construction and Use) Regulations 1986* (SI 1986/1078), as amended

35 See: "REVIEW: BMW's Remote Control Parking System Tested in Real Life", *BMW Blog*, 26 July 2016

36 Daimler AG, *Motorway Pilot & Co*, 10 June 2015

37 DfT, *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies*, 11 February 2015, p9

restrictions which would not easily enable the underlying policy objectives in respect of motor accidents to be met".[38]

The Government's view was that, at the current stage of AVT development, making changes to product liability law to facilitate the adoption of AV would be disproportionate. Rather, the Government proposed to take account of the above concerns by explicitly including AVs in the compulsory motor insurance framework, by way of amendment of Part VI of the *Road Traffic Act 1988*, and establishing a "single insurer model, where an insurer covers both the driver's use of the vehicle and the AV technology".[39] This would:

> […] ensure that the driver is covered both when they are driving, and when they have activated the ADF. In the event of a collision while the ADF was active, the innocent victim (both inside and/or outside of the vehicle) would be able to claim from the insurer.
>
> […]
>
> Where the manufacturer is found to be liable, the insurer will be able to recover against the manufacturer under existing common law and product liability laws.[40]

The Government argued this approach would allow the insurance industry the freedom to offer "whichever products they wish". It would also allow manufacturers the freedom to offer to take full liability for incidents occurring as a result of their AVT, should they so wish.[41]

The Government intended to set out a list of vehicles or types of vehicles to be regarded as AVs, and therefore subject to the new insurance requirement, alongside measures to support electric cars, drones and commercial space flight, in a planned *Modern Transport Bill*, announced in the 2016 Queen's Speech.[42] In the event, the measures were set out in a *Vehicle Technology and Aviation Bill*, published in February 2017, which was subsequently enacted through the Automated and Electric Vehicles Act 2018 (see below).

## 2.3 Automated and Electric Vehicles Act 2018

On 22 February 2017 the Government published a Vehicle Technology and Aviation Bill. The Bill fell following the snap general election called in June 2017. The provisions in Part 1 of the Bill, which set out the broad parameters of how automated vehicles involved in road traffic accidents would be treated for insurance purposes, were reintroduced through the Automated and Electric Vehicles Act 2018, which received Royal Assent on 19 July 2018. Part 1 of the Act provides for:

38 DfT, *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies*, 11 February 2015, p10
39 DfT, *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies*, 11 February 2015, p10
40 DfT, *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies*, 11 February 2015, pp10-11
41 DfT, *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies*, 11 February 2015, p12
42 HMG, *Queen's Speech 2016: background briefing notes*, 18 May 2016, pp17-18

- A requirement that the Secretary of State maintain a list of relevant automated vehicles to which the legislation would apply;
- The conditions under which the insurer would be liable for damage due to an accident;
- Limitation of insurers' liability for damage when the injured party contributed to the cause of the accident; and
- Limitation of insurers' liability if the operating system of the car was tampered with, or if updates to the system were not installed or updated by the insured.

A comprehensive summary and analysis of the Act and it's provisions can be found in HC Library briefing paper CBP 7965

## 2.4 UK vehicle trials, 2017-18

The Government established the Centre for Connected and Autonomous Vehicles (CCAV) in July 2015. The CCAV is a joint DfT/Department for Business, Enterprise and Industrial Strategy (BEIS) policy unit, with responsibility for:

- innovating policy development in this sector;
- delivering a programme of research, development, demonstration, and deployment activity, worth up to £200 million, through Innovate UK;
- providing co-ordination across DfT, BEIS and the rest of government; and
- being the single contact point for stakeholder engagement.[43]

CCAV, BEIS and Innovate UK are supporting three CAV trials:

- the GATEway Project in Greenwich, south east London;
- VENTURER in Bristol and south Gloucestershire; and
- the UK Autodrive project in Milton Keynes and Coventry.

The Greenwich project was launched 2015. It is led by TRL, a leading UK transport research centre. The project is conducting a number of trials, expected to be completed in 2017:

  - **Automated passenger shuttle trials**: exploring the use of automated shuttle vehicles as a small scale transport service;
  - **Automated urban deliveries trials**: using automated vehicles for last mile transportation; potentially from a local delivery depot to a residential neighbourhood;
  - **Remote teleoperation demonstrations**: where a human operator is able to manoeuvre or recover a fully automated vehicle to a safe mode of operation; and

43 DfT/BEIS, Driverless vehicles: connected and autonomous technologies [accessed 22 May 2017]

- **High-fidelity simulator trials**: to investigate how drivers of regular vehicles respond and adapt their behaviour to the presence of automated vehicles on the roads.[44]

VENTURER is a consortium of public, private and academic experts, which aims to establish the southwest of England as a leading CAV test centre. Its first trials took place at the University of the West of England campus during 2016. Further trials are planned in south Gloucestershire and Bristol city centre during 2017 and 2018, both in a "realistic simulated environment" and on public roads. The trials "go hand-in-hand with developing an understanding of the insurance and legal implications of increased vehicle autonomy".[45] The project released the results of its first trial in June 2017.[46]

UK Autodrive is the largest of the testing consortia, including automotive manufacturers Ford, Jaguar Land Rover and Tata, as well as advanced engineering companies, insurance firms and academics. It is testing road-based CV; road-based AV; and connected and pavement-based CAV "pods". The project's first trials took place at HORIBA MIRA's proving ground in the Midlands. Trials of AV are due to take place on closed-off roads in Coventry and Milton Keynes in autumn 2017.

The project aims to:

- Integrate autonomous and connected vehicles into real-world urban environments;
- Show how autonomous and connected vehicles could solve everyday challenges such as congestion;
- Demonstrate the commercial operation of electric-powered self-driving "pods" at a city scale; and
- Provide insight for key stakeholders and decision-makers, including legislators, insurers and investors.

It is due to be completed in autumn 2018.[47]

Separately, academics from the University of Leeds Institute for Transport Studies (ITS) are involved—with the Technical University of Munich, Greek Institute of Communication and Computer Systems and BMW, Fiat and Bosch—in the EU's interACT project, launch in May 2017. The three-year project intends to:

> […] develop novel, holistic interaction concepts for AVs that will enable the integration of AVs in mixed traffic environments, in a safe and intuitive way. […] and substantially improve the communication and cooperation strategy between AVs and other traffic participants.[48]

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44 GATEway Project, *FAQs: About the trials* [accessed 7 June 2017]
45 VENTURER, *About* [accessed 7 June 2017]
46 VENTURER press notice, "VENTURER Trial 1 Results", 5 June 2017
47 UK Autodrive, *The UK Autodrive project* [accessed 7 June 2017]
48 Leeds ITS, interACT' [accessed 25 May 2017]

## 2.5 House of Lords Science and Technology Committee Report, March 2017

The House of Lords Science and Technology Committee held an extensive inquiry into CAVs in 2016-17. It published its final report, Connected and Autonomous Vehicles: The future?, in March 2017. The report emphasised the very broad potential applications for CAV, including:

> […] aerial, marine, public roads, private and public transport (including metro and rail), space, military, warehousing, ambulance services, precision agriculture, inspection and monitoring of resources, working in dangerous and hazardous environments (such as nuclear facilities) and the delivery of humanitarian supplies […][49]

The Report came to four main conclusions in relation to the development of CAV in the UK, and the Government's role in supporting development and adoption.

It found that **the UK Government had been too focused on road-based CAV, particularly the development of highly automated, privately-owned cars**. It recommended the Government broaden its approach, and:

> […] not allow hype and media attention around driverless cars to cause it to lose sight of the many potential benefits that CAV can provide in areas outside the roads sector and within the roads sector for public transport vehicles and lorries.[50]

It recommended that **the UK Government play a coordinating role in setting up, as soon as possible, a Robotics and Autonomous Systems (RAS) Leadership Council** (see section 5.2 below), including government, industry and academia. The central aim of the Council should be to "ensure that expertise and knowledge are shared across all sectors so as to obtain the maximum economic and societal benefits to the UK of CAV." It further recommended the UK Government take a leading role in the development of international CAV standards, including those pertaining to ethical issues.[51]

The Report found that **government-backed research had been too focused on technical problems and testing technologies, with "inadequate effort on thinking about deployment**, especially user acceptance for road vehicles, or on the wide range of possible benefits from connected vehicles." It concluded that, broadly:

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49 House of Lords Science and Technology Committee, *Connected and Autonomous Vehicles: The Future?* (Second Report of Session 2016–17), HL 115, 15 March 2017, para 1

50 House of Lords Science and Technology Committee, *Connected and Autonomous Vehicles: The Future?* (Second Report of Session 2016–17), HL 115, 15 March 2017, summary, p3

51 House of Lords Science and Technology Committee, *Connected and Autonomous Vehicles: The Future?* (Second Report of Session 2016–17), HL 115, 15 March 2017, summary, p3

> The main social and behavioural questions relating to CAV remain largely unanswered and the Government should give priority to commissioning and encouraging research to provide answers.[52]

Finally, the Committee recommended the Government take action to prepare for the deployment of highly automated CAV (levels 4 and 5), through a **comprehensive testing offer for CAV to attract manufacturers and academics to the UK**. It recommended that Highways England and Local Transport Authorities "should engage with motor manufacturers to future-proof new infrastructure and minimise the likelihood of expensive retrofitting".[53]

## 2.6 Law Commission regulatory review

In 2018, the CCAV requested the Law Commission of England and Wales and the Scottish Law Commission to undertake "a far-reaching review of the legal framework for automated vehicles".

To date, the Law Commission has held three consultations, with the final report due to be published in the final quarter of 2021:

- In November 2018, the Law Commission consulted on safety assurance and legal liability. The analysis of responses and interim findings were published in June 2019.
- In October 2020, the Law Commission consulted on the regulation of remotely operated fleets of automated vehicles and their relationship with public transport. The analysis of responses and interim findings was published in May 2020.
- In December 2020, the Law Commission issued its final consultation, which draws on responses to both previous papers to formulate overarching proposals for a regulatory framework for automated vehicles. The proposals in consultation paper 3 include:
  - The creation of distinctive rules for two types of automated vehicle: Category-1 AVs that might require human driving for part of a journey (for example, AVs that only drive themselves on the motorway) and Category-2 AVs that can complete a whole journey unaided and without a user in the vehicle (such as a remotely operated taxi fleet).
  - Proposals to enhance safety, for the deployment of AVs on British roads and during their lifetime. This covers vehicle approval as well as software updates and cybersecurity risks. It includes a shift away from the criminal enforcement of traffic rules towards a new no-blame safety culture including a new range of regulatory sanctions.
  - New legal roles to reflect legal responsibilities arising from automated driving: for developers of AVs, users of AVs that

52 House of Lords Science and Technology Committee, *Connected and Autonomous Vehicles: The Future?* (Second Report of Session 2016–17), HL 115, 15 March 2017, summary, p4

53 House of Lords Science and Technology Committee, *Connected and Autonomous Vehicles: The Future?* (Second Report of Session 2016–17), HL 115, 15 March 2017, summary, p4

are less than drivers but more than passengers (the user-in-charge), and AV fleet operators.

## 2.7 Automated Lane Keeping System consultation, 2020-21

The UNECE Automated Lane Keeping System (ALKS) Regulation was approved in June 2020, and entered into force in January 2021.This Regulation provides a framework to allow vehicles fitted with this technology to come to market and be used on roads in Great Britain.

Following the agreement in the UNECE for the ALKS Regulation, from August to October 2020, the Government consulted on the use of Automated Lane Keeping System (ALKS) on Great Britain's motorways. In particular, it sought views on:

- ensuring the safe use of ALKS, including whether ALKS met the definition of automation in the Automated and Electric Vehicles Act 2018 (AEVA)
- ensuring fair delegation of responsibility between the driver and the vehicle
- performing activities other than driving when the system is engaged
- using the system at higher speeds

The consultation response was published in April 2021. This confirmed that the Government intended to proceed with allowing ALKS type approved self-driving vehicles on GB roads, possibly as early as the end of 2021.

### What is an Automated Lane Keeping System (ALKS)?

ALKS is effectively a beefed-up blend of two existing technologies: lane-keeping assistance (LKA) and adaptive cruise control (ACC). It is a vehicle technology that keeps the vehicle within its lane and controls its speed for extended periods without further driver input. It is a 'conditionally automated' system, meaning that it controls all aspects of the dynamic driving task with the expectation that the human driver will respond to a request to intervene. At present, the system is intended for use at low speeds on motorways

Alongside the ALKS announcement, the DfT published a separate consultation on proposed amendments to the Highway Code rules. The consultation concludes on 28 May 2021.

# 3. Global developments

## 3.1 Range of CAV developers

Established automotive manufacturers and technology start-up companies across the world are now engaged in CAV research and development. In May 2017, CB Insights listed 44 automotive brands and "tech heavyweights", many working in partnership, that are investing heavily in CAV.  For example:

- BMW with Intel and Mobileye;
- DAF, Daimler, Iveco, MAN, Scania, and Volvo working together on trials of truck platooning in mainland Europe;
- General Motors with Lyft, the digital ride-hailing platform, and US technology start-up Cruise Automation, testing AV in Arizona; and
- Baidu, the Chinese web services corporation.[54]

## 3.2 Tesla, Google (Waymo), Apple and Uber

Perhaps the two most well-known CAV brands are Tesla and Google (known as Waymo since December 2016). They are taking very different approaches.

**Tesla**'s models S and X, are on the market and being driven on public roads in the UK and Europe. They have been equipped with "highway autopilot" software, in which the driver can temporarily relinquish control of driving functions (level 3 automation), since October 2014. In current models the autopilot function is only suitable for particular driving conditions:

> For Autopilot to engage, Tesla's system needs to be able to "see" the road clearly and sense the markings on the road […] When all conditions are met, a graphic between the Model S' dials shows that the car is detecting the road ahead. After that, engaging Autopilot is as simple as pulling the Tesla's left stick twice.[55]

Early versions of the software allowed drivers to remove their hands from the wheel in autopilot mode, but issued warnings to the driver to be ready to take back control of steering. The vehicle would bring itself to a safe halt if these were ignored.[56]

In 2015 and 2016 there were media reports, and videos posted on the Internet, of Teslas veering off course on bends in the road and swerving out of driving lanes. Some videos show drivers not following advice to

54 "44 Corporations Working On Autonomous Vehicles", *CB Insights*, 18 May 2017
55 "Tesla Autopilot review: We test Elon Musk's autonomous tech in the UK", *alphr.com*, 22 April 2017
56 "Tesla update forces you to keep your hands on the wheel… or else", thenextweb.com, 23 September 2016

remain ready to take immediate control when the vehicle is in autopilot mode.[57]

There have been accidents involving Teslas in autopilot mode, including a fatal collision in May 2016 on a highway in Florida, when a Model S was reported to have "failed to distinguish a white tractor-trailer crossing the highway against a bright sky". [58] This led to criticism of Tesla for releasing the technology before it was ready, and being "so out in front of federal highway regulations that there were no rules against it".[59] Since 2016, software updates have made it clearer that the driver's hands should stay on the wheel in autopilot mode, even when the car is steering itself.[60]

Since October 2016, Tesla models have had the requisite in-built hardware for level 5 autonomous driving. The necessary software to enable level 5 autonomous driving in practice will be updated in stages, as autonomous functions are approved in local markets and jurisdictions.

### Legislative and regulatory initiatives in the United States

**In the US, individual States have responsibility for the relevant regulation and legislation. The National Conference of State Legislatures (NCSL) states that since 2012, at least 41 states and Washington D.C. have considered legislation related to autonomous vehicles.[61]**

**In September 2016, the US Department of Transportation and National Highway Traffic Safety Administration (NHTSA) published the first Federal Automated Vehicles Policy, which sets out guidance on the safe development of "highly autonomous vehicles" (HAV) to States and manufacturers.[62]**

At the outset of its project in 2009, **Google** had intended to follow a similar path to Tesla, developing "semi-autonomous" vehicles, in which the human driver remained "in the loop" and ready to take over driving. After initial testing of similar vehicles, however, it observed "a range of distracted-driving behaviour that included falling asleep". In July 2016, a representative of the project told the *New York Times*:

> We saw stuff that made us a little nervous […] The experiment convinced the engineers that it might not be possible to have a human driver quickly snap back to "situational awareness," the reflexive response required for a person to handle a split-second crisis. [63]

57 "What happens when Tesla's AutoPilot goes wrong: owners post swerving videos", *The Guardian*, 21 October 2015; and "Tesla owners are ignoring autopilot safety advice and putting the results on YouTube", *The Verge*, 21 October 2015
58 "Tesla driver dies in first fatal crash while using autopilot mode", *The Guardian*, 1 July 2016
59 "A Fatality Forces Tesla to Confront Its Limits", *The New York Times*, 1 July 2016
60 ' Tesla update forces you to keep your hands on the wheel… or else', thenextweb.com, accessed 25 May 2017
61 NCSL, *Autonomous vehicles* [updated 5 June 2017]
62 NHTSA/US Department of Transportation, *Federal Automated Vehicles Policy: Accelerating the Next Revolution In Roadway Safety*, September 2016
63 "Tesla and Google Take Different Roads to Self-Driving Car", *New York Times*, 4 July 2016

Now Waymo's objective is to develop a level 5 AV in which humans entirely relinquish control and become passengers throughout the whole journey. It is testing a fleet of AV with no brake pedals, accelerators or steering wheels—human passengers are entirely "out of the loop". The vehicles are currently designed to travel no faster than 25 miles per hour. There are not intended for faster highway/motorway travel; but they "might one day be able to function as robotic taxis in stop-and-go urban settings". A number of US States, including Arizona and California, have permitted testing on public roads. The vehicles are not expected to be ready to market until 2019, at the earliest.[64] In April 2017, Waymo launched the first trial of its vehicles by members of the public, in Phoenix, Arizona.[65]

**Uber** has deployed AV—with a driver ready to take over control—in its commercial ride-hailing fleet in Pittsburgh since August 2016.[66] In December 2016, Uber began using AV in its fleet in San Francisco. Almost immediately, however, it was forced to suspend its use of AVs, under threat of legal action by the California Department of Motor Vehicles, as it had not been granted the necessary licence.[67] In February 2017, Uber began deploying its AV in Tempe, Arizona, with the approval of State Governor Doug Ducey, whose 2015 Executive Order encourages "any necessary steps to support the testing and operation of self-driving vehicles on public roads" in the State.[68] Uber suspended use of AV in Tempe for three days in March 2017, after one of its vehicles was involved in a collision.[69] In December 2020, it was reported that Uber had sold its self-driving car business for a reported $4bn (£3bn) to Aurora, a start-up that makes sensors and software for autonomous vehicles and is backed by Amazon and Sequoia Capital.

In April 2017, **Apple**, working with Lexus, was granted a licence to test AV in California.[70] It was reported in April 2017 that 29 organisations—including Ford, General Motors, BMW, and Volkswagen—had so far been granted Californian AV testing licences.[71]

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64 "Tesla and Google Take Different Roads to Self-Driving Car", *New York Times*, 4 July 2016
65 Waymo, *Be an early rider* [accessed 25 May 2017]
66 "Uber's First Self-Driving Fleet Arrives in Pittsburgh This Month", *Bloomberg.com*, 18 August 2016
67 "Uber cancels self-driving car trial in San Francisco after state forces it off road", *The Guardian*, 22 December 2016
68 "Uber's self-driving cars are now picking up passengers in Arizona", *The Verge*, 21 February 2017
69 "Uber resumes self-driving program three days after Arizona crash", *Reuters*, 27 March 2017
70 "Apple granted self-driving test permit", *BBC News*, 14 April 2017
71 "Meet the iCar? Apple to test self-driving vehicles in California", *The Guardian*, 14 April 2017

# 4. Implications of CAV for the UK road transport sector

## 4.1 Road infrastructure

In April 2017, the RAC Foundation emphasised that, to date, "very little research has been done" on the readiness of the UK's road infrastructure for widespread adoption of highly automated CAV.[72]

In practical policy-making terms, the report found that the greatest challenges for road infrastructure will come with widespread sharing of roads between level 0–2 vehicles and level 5 vehicles, which would require "road networks capable of accommodating or restricting the full range of interactions between mixed traffic".[73]

The report notes that a number of policy considerations arise, including:

- Whether or not to separate CAV from non-CAV traffic;
- Whether to regulate the minimum level of automation that a vehicle must have, and the speed of transition to the minimum level;
- The degree of personal choice which should be allowed to drivers regarding whether to turn off some or all of the automated features on their vehicles; and
- The degree to which CAV systems are standardised or harmonised across countries.[74]

It also notes implications for road maintenance. AVs "are likely to require road markings, signs and signals to be maintained to a much higher level than is currently the case". Road surfaces may also require maintenance to a higher standard; the report speculates that potholes could be "extremely dangerous" in the context of CAV use, particularly "in a traffic lane carrying vehicles in a platoon, where vehicles follow each other very closely".[75]

More broadly, the RAC Foundation concluded that CAV were "unlikely to develop to their fullest potential without advanced planning by transport policy makers, planners and engineers to ensure infrastructure change is adequate",[76]

The report set out two broad competing visions of the future adoption of CAV:

72 RAC Foundation, *Readiness of the road network for connected and autonomous vehicles*, 7 April 2017, p26
73 RAC Foundation, *Readiness of the road network for connected and autonomous vehicles*, 7 April 2017, p6
74 RAC Foundation, *Readiness of the road network for connected and autonomous vehicles*, 7 April 2017, p26
75 RAC Foundation, *Readiness of the road network for connected and autonomous vehicles*, 7 April 2017, p16
76 RAC Foundation, *Readiness of the road network for connected and autonomous vehicles*, 7 April 2017, p26

1. Fully autonomous, independent, self-driving vehicles that can work with the existing infrastructure, or a simplified version thereof; and

2. CAVs which are only fully autonomous where the road infrastructure permits, and switch between levels of autonomy—for example, vehicles that travel in convoy but only on suitable roads.[77]

Within these two broad scenarios, there were "many variants", for example CAVs always physically separated from other road users; CAVs separated in some places but not others; and CAVs retaining conventional driver capability, so a human driver can take over in certain places, such as in mixed traffic or urban areas.[78]

The report noted that policy makers need to make "an important conceptual choice" between:

- The vehicles being in charge—or a human driver taking over control only in certain circumstances (sometimes called the **"everything everywhere"** option); and
- The human driver being in charge, with automation to aid performance in certain situations (known as **"something everywhere"**).[79]

The report concluded that:

> Whether either, both, neither, or a compromise between these strategies is backed by government policy will have a significant bearing on the rate at which CAVs penetrate the UK market—and, correspondingly, on the scale of safety, social and economic benefits that this could secure.[80]

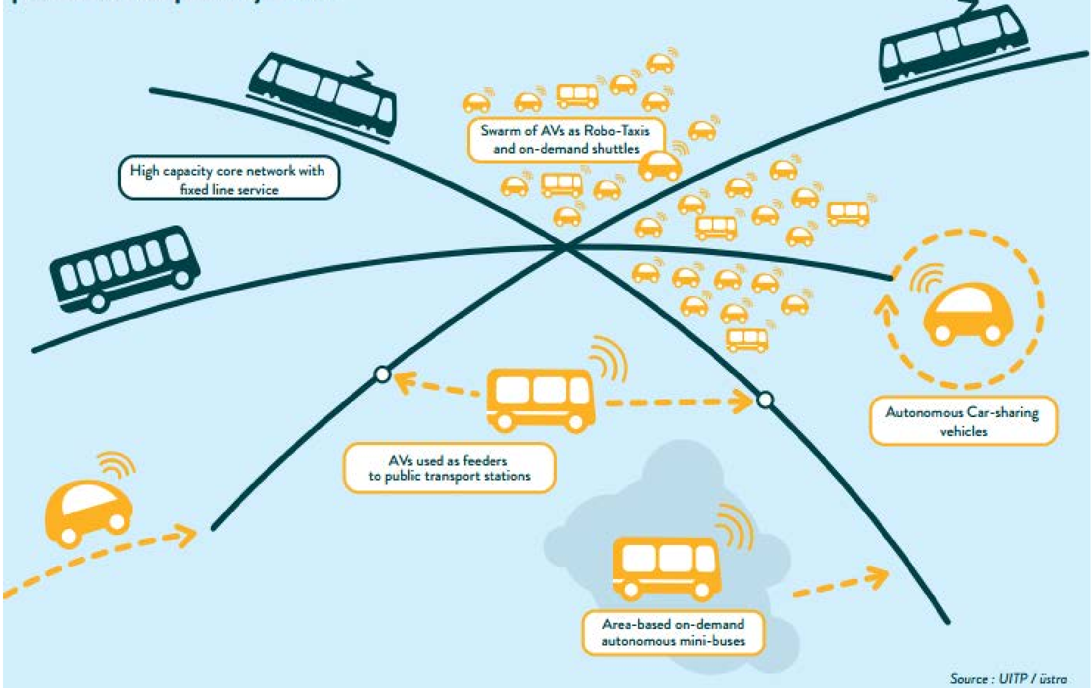
While acknowledging that "it is early days", and impossible to predict accurately exactly how CAV will develop and be adopted in the UK, the report emphasised that "Governments need to decide on the level of automation that will be supported and how this will be implemented".[81]

## 4.2 Public transport or "on demand mobility services"?

In January 2017, the International Association of Public Transport (UITP) set out in a policy briefing a vision for a future in which AV facilitate "affordable, sustainable and convenient mobility options to all citizens including less mobile persons, the elderly, children and people living in suburban or rural areas".[82] However, much depends on the model of

[77] RAC Foundation, *Readiness of the road network for connected and autonomous vehicles*, 7 April 2017, p2
[78] RAC Foundation, *Readiness of the road network for connected and autonomous vehicles*, 7 April 2017, p3
[79] RAC Foundation, *Readiness of the road network for connected and autonomous vehicles*, 7 April 2017, p3
[80] RAC Foundation, *Readiness of the road network for connected and autonomous vehicles*, 7 April 2017, p3
[81] RAC Foundation, *Readiness of the road network for connected and autonomous vehicles*, 7 April 2017, p26
[82] International Association of Public Transportation, *Policy Brief: Autonomous vehicles: a potential game changer for urban mobility*, January 2017, p1

AV delivery. UITP argues it will only be achieved "if public authorities and public transport companies take an active role now".[83] The following graphic from the report shows possible applications of autonomous vehicles as part of a diversified public transport system:[84]



Possible applications of autonomous vehicles (AVs) as part of a diversified public transport system

UITP emphasised that AVs could bring about huge reductions in urban congestion, but only "if AVs are introduced in fleets of shared autonomous vehicles of different sizes", integrated into public transport networks. This approach would "reinforce an efficient, high capacity public transport network".[85] However, the paper set out two alternative scenarios which could have negative outcomes:

- Proliferation of privately-owned AVs, which would be "unsustainable" and lead to more traffic and congestion; and/or
- Fleets of shared AVs *competing* with traditional public transport networks, which would facilitate increased mobility but be less efficient.[86]

UITP therefore argued that:

> Now is the time to start preparing the right regulatory framework for AVs to ensure they will serve cities' policy objectives. With current traffic rules, AVs will be seen as comfortable private cars that could well drive around empty to avoid paying parking charges, increasing car traffic and urban sprawl. Public transport,

83 International Association of Public Transportation, Policy Brief: Autonomous vehicles: a potential game changer for urban mobility, January 2017, p1
84 International Association of Public Transportation, Policy Brief: Autonomous vehicles: a potential game changer for urban mobility, January 2017, p2
85 International Association of Public Transportation, Policy Brief: Autonomous vehicles: a potential game changer for urban mobility, January 2017, p2
86 International Association of Public Transportation, Policy Brief: Autonomous vehicles: a potential game changer for urban mobility, January 2017, p5

> walking and cycling would lose market share and doing nothing is therefore not an option.[87]

Traditional car manufacturers are beginning to move into the "transport services" market. For example, Volkswagen has established its MOIA brand, which plans to offer "ride-hailing commuter shuttle services" in Germany, delivered via IT-based platforms similar to Uber, Lyft etc. MOIA see this as laying "foundations for the development of future mobility business models such as the on-demand operation of driverless cars."[88] The *Financial Times* reported:

> When you combine ride-hailing and autonomy, you get an interesting result: ride-hailing and other kinds of on-demand mobility become cheaper and much more convenient. That makes it harder to see why people would want to own their own cars.[89]

This is part of a trend, particularly in cities, towards thinking not only about integrated urban transport systems, but also about **'mobility as a service' (MaaS)**—digital platforms offering subscription-based, on-demand, integrated, multi-modal mobility.[90]

## 4.3 Employment in the transport sector

As noted above, the development of CAV in the UK is forecast by the automotive industry to create some 320,000 new jobs across the technology and communications sectors, and automotive manufacturing, by 2030.[91]

Concerns have been expressed, however, about the potential long-term effects of CAV on people currently employed as drivers. More than 950,000 people were employed as drivers in the road transport sector in 2016, including:

- 315,000 large goods vehicle drivers;
- 251,000 van drivers;
- 119,000 bus and coach drivers;
- 232,000 taxi/private hire drivers and chauffeurs; and
- 34,000 driving instructors.[92]

In the long term all of these jobs are potentially at risk from CAV adoption. Recent developments in semi-autonomous trucks and HGV platooning have led to concerns about jobs in the road haulage sector. Semi-autonomous truck technology is being adopted in the US,[93] and in April 2016 a connected and semi-autonomous HGV convoy completed

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87 International Association of Public Transportation, *Policy Brief: Autonomous vehicles: a potential game changer for urban mobility*, January 2017, p5
88 Volkswagen AG, *MOIA* [accessed 23 May 2017]
89 "Why would you want to buy a self-driving car?", *Financial Times*, 7 December 2016
90 See, for example, The MaaS Alliance and MaaS Global, [both accessed 23 May 2017]
91 KPMG for SMMT, *Connected and Autonomous Vehicles: The UK economic opportunity*
92 ONS, *People in employment by status, occupation and sex*, EMP04, April–June 2016
93 See, for example, Uber, *The Future of Trucking* [accessed 25 May 2017]

a 2,000 kilometre journey from Sweden to the Netherlands in the European Truck Platooning Challenge.[94]

In the March 2016 Budget, the UK Government announced its intention to trial HGV platooning, albeit with a driver in each of the vehicles.[95] The trials have not yet taken place. The *Financial Times* reported in November 2016 that the project had "stalled after several major European manufacturers snubbed the project".[96]

Some organisations, including the Road Haulage Association (RHA), have argued that the UK's roads are not suitable for HGV platooning. Rod Mackenzie, RHA's Director of Marketing, Communications and Public Affairs, said in March 2017:

> […] our motorways are peppered with exit and entry points—[platoons of HGVs] causing queues for vehicles trying to join and leave the motorway will simply create even more congestion.
>
> Of course the auto-pilot facility has the ability to remove human error and mistake—but what happens if the engine goes wrong?
>
> The haulage industry is increasingly IT led and we embrace technology—but not at the expense of safety or practicality. The experts have it all to prove as far as we are concerned.[97]

In evidence to the House of Lords Science and Technology Committee's inquiry, the SMMT reiterated that it expected the development and deployment of connected vehicles to be associated with significant job creation, while autonomous vehicles were likely to lead to a "shift in employment".[98] The Transport Minister, John Hayes, also expected a transition to new types of employment. While he did not envisage CAV would lead to a net reduction in employment, he told the Committee that "we may well see change".[99]

Other witnesses were gloomier; for example Enders Analysis, which provides research and analysis for communications industries, told the Committee that: "Automation will likely lead to the loss of many jobs in the transportation sector, notably in low-wage positions such as taxi and bus drivers".[100]

94 "Self-driving truck convoy completes its first major journey across Europe", *The Verge*, 7 April 2016
95 PQ 31728 [Driverless Vehicles: Large Goods Vehicles] 23 March 2016
96 "UK driverless truck plan stalls after manufacturers pull out", *Financial Times*, 15 November 2016
97 RHA press notice, "Driverless trucks – the UK road network just isn't up to the job says RHA", 15 March 2017
98 House of Lords Science and Technology Committee, *Connected and Autonomous Vehicles: The Future?* (Second Report of Session 2016–17), HL 115, 15 March 2017, paras 104–5
99 House of Lords Science and Technology Committee, *Connected and Autonomous Vehicles: The Future?* (Second Report of Session 2016–17), HL 115, 15 March 2017, para 106
100 House of Lords Science and Technology Committee, *Connected and Autonomous Vehicles: The Future?* (Second Report of Session 2016–17), HL 115, 15 March 2017, para 107

The Committee concluded that it was "unclear whether CAV will lead to job creation or job losses overall" and that the Government should consider this as part of a detailed cost-benefit analysis.[101]

[101] House of Lords Science and Technology Committee, *Connected and Autonomous Vehicles: The Future?* (Second Report of Session 2016–17), HL 115, 15 March 2017, para 108

# 5. Broader considerations

## 5.1 Cyber security

In 2013 the Parliamentary Office of Science and Technology (POST) noted that CVT in road vehicles would "need to be robust in case of corruption or cyber-attack".[102]

Actual and theoretically possible breaches of CVT have been reported in the media. For example, in 2015 ethical hackers, using a laptop, took control of a Jeep Cherokee's steering remotely and drove it into a ditch.[103] In February 2017, it was reported that a "simulated hack" had shown that it was possible for hackers to disable a number of different CAV models. Josh Corman, founder of The Cavalry, the grassroots cyber protection organisation that conducted the simulated hack, said:

> The promise of autonomous and connected vehicles is that they can, should and will dramatically improve safety, crash avoidance and crash survival. […] The peril is that these markets, which are very large parts of our relative economies, are built on trust—and if we're cavalier about security and privacy concerns in our march to embrace the benefits, that trust won't just be eroded, it will be shattered.[104]

The Government considered cyber security as part of its 2015 detailed regulatory review. It noted that conventional road vehicles have always been vulnerable to "malicious intervention" (cutting of brake cables; tampering with steering gear etc.) but acknowledged that tampering with CVT "could be conducted remotely and could potentially affect a number of vehicles at the same time".[105]

The review noted that relatively common features such as "remote key fobs and keyless access, Bluetooth connectivity, Wi-Fi and mobile internet connections, and even tyre pressure monitoring systems" could all contribute to the vulnerability of a vehicle, forming part of a potential "attack surface".[106]

The Government, however, emphasised that:

> There should be a strong incentive for vehicle manufacturers to ensure that their vehicles are robust and secure against cyber-attack and other malicious interventions. No manufacturer would want their products to be perceived to be vulnerable by their customers. Vehicle manufacturers will need to continue to ensure that their electronic systems do not have unintended vulnerabilities and are robust to the latest cyber-crime techniques.[107]

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102 POST, *Autonomous Road Vehicles*
103 "Hackers 'remotely carjack' Jeep from 10 miles away and drive it into a ditch", *The Independent*, 22 July 2015
104 "Connected cars: the security challenge for autonomous vehicles", *Institution of Engineering and Technology*, 21 February 2017
105 DfT, *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies*, Feb 2015, pp106-7
106 DfT, *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies*, Feb 2015, p106
107 DfT, *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies*, Feb 2015, p107

The regulatory review did not identify any immediate action points for the UK Government, but did note that UN Regulation 116 "is formulated to ensure that vehicle manufacturers put in place measures to prevent unauthorised use" and stated that if it were "felt that further regulation is required to ensure that manufacturers adequately address cyber security issues then it may be appropriate to update this".[108]

## 5.2 Beyond road transport

The applications of CAV are far broader than road transport, for example CAV are being used in **agriculture**[109] and in "challenging environments" such as **nuclear power** and **mining**.[110]

They are also part of a much broader trend towards automation through Robotics and Autonomous Systems (RAS), including intelligent machines that can complete ever more complex tasks and learn through experience. In October 2016, the House of Commons Science and Technology considered some of the broad implications of RAS.[111] The potential labour market effects have been explored by numerous organisations, including the OECD,[112]the Parliamentary Office of Science and Technology,[113] and the Resolution Foundation.[114]

108 DfT, *The Pathway to Driverless Cars: A detailed review of regulations for automated vehicle technologies*, Feb 2015, p107
109 See, for example, ASI Autonomous Solutions, *The future of farming* [accessed 23 May 2017] and "In the future, will farming be fully automated?", *BBC News*, 25 November 2016
110 See, for example, RACE, *Enabling Growth* [accessed 23 May 2017]
111 House of Lords Science and Technology Committee, *Connected and Autonomous Vehicles: The Future?* (Second Report of Session 2016–17), HL 115, 15 March 2017
112 OECD, *Future of Work* [accessed 23 May 2017]
113 Op cit., *Automation and the Workforce*
114 Resolution Foundation, *Robot Wars: Automation and the labour market*, July 2016

# Glossary of abbreviations

**ADAS**—Advanced Driver Assistance Systems, for example cruise/lane control and "hands free" parking.

**AEB**—Advanced Emergency Braking, in which a road vehicle can take into account the traffic conditions ahead and apply braking if the human driver fails to respond appropriately.

**AV**—Autonomous Vehicle, capable of making driving decisions and controlling part, or all, of a journey, without requirement for a human driver. Levels of automation range from 0–5.

**AVT**—Autonomous Vehicle Technology, encompassing the range of automated functions.

**CAV**—Connected and Autonomous Vehicle, umbrella term used across government and the automotive industry; connected and autonomous technologies are closely related and often developed together.

**CCAV**—Centre for Connected and Autonomous Vehicles, a joint policy unit of the Department for Transport and the Department for Business, Enterprise and Industrial Strategy, which is supporting a number of CAV trials in the UK.

**CVT**—Connected Vehicle Technology, enables road vehicles to communicate via mobile data networks, the Internet and "the cloud".

**HAV** (commonly used in the US)—Highly Autonomous Vehicle, falling into the higher levels in the 0–5 scale of vehicle automation.

**MaaS**—Mobility as a Service, subscription-based, on-demand mobility services delivered via digital platforms.

**RAS**—Robotics and Autonomous Systems, broader, cross-sectoral term for "interconnected, interactive, cognitive and physical tools, able to variously perceive their environments, reason about events, make or revise plans and control their actions".[115]

**V2D**—Vehicle to device communication, which enables a connected vehicle to communicate with devices such as smart phones. This opens of the possibility of **vehicle to pedestrian (V2P)** and **vehicle to the cloud (V2C)** communication.

**V2I**—Vehicle to Infrastructure technology, which enables vehicles to communicate with road infrastructure, for example receiving and transmitting information about road, traffic and weather conditions, or facilitating coordination of driving speeds with traffic light patterns.

**V2V**—Vehicle to Vehicle technology, which enables vehicles to communicate and coordinate with each other, for example allowing them to travel closely together in a connected convoy or

115 RAS Special Interest Group, *Robotics and Autonomous Systems*, July 2014

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Number 7965
7 May 2021