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2nd Report of Session 2016–17

Connected and Autonomous Vehicles: The future?

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Science and Technology Select Committee

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See Appendix 1.

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Evidence is published online at <http://www.parliament.uk/autonomous-vehicles> and available for inspection at the Parliamentary Archives (020 7129 3074).

Q in footnotes refers to a question in oral evidence.

SUMMARY

The four main findings of this report into connected and autonomous vehicles (CAV) are contained in the following list. We then explain the main actions that are required to address each of these points.

- The Government is too focussed on highly-automated private road vehicles (“driverless cars”), when the early benefits are likely to appear in other sectors, such as marine and agriculture;
- The development of CAV across different sectors needs coordination and the Government, working with key stakeholders, must get a grip on this chiefly by establishing a Robotics and Autonomous Systems (RAS) Leadership Council as soon as possible to play a key role in developing a strategy for CAV;
- There is a clear need for further Government-commissioned social and economic research to weigh the potential human and financial implications of CAV;
- This is a fast-moving area of technology and the Government has much to do, alongside industry and other partners, to position the UK so that it can take full advantage of the opportunities that CAV offer in different sectors.

Government work too focussed on road CAV

The Government must broaden its focus so that its work on CAV cuts across all sectors and does not focus so heavily on highly-automated private road vehicles. The Government must 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.

The Government should play a coordinating role

A RAS Leadership Council involving Government, industry and academia should be established as soon as possible. This is 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. The RAS Leadership Council should take a key role in developing the strategy for this sector and fulfilling the aspirations of the Industrial Strategy.

Within the roads sector the Government should play a coordinating role in bringing different stakeholders together. It should set up and a chair a forum that will allow Local Transport Authorities (LTAs), who are responsible for the majority of UK roads, to share knowledge and expertise on CAV and to be deployed as advisers on the direction of future trials and research.

In the international arena the Government should take a leading role in a number of areas, including the development of sets of standards to address the ethical issues pertaining to CAV, to govern data retention in the event of an accident and to tackle the risks associated with cybersecurity and CAV.

The Government should also ensure the UK maintains its leading role in marine CAV by being at the forefront of international negotiations on new global regulations for the use of marine CAV in international waters.

The need for Government-commissioned research

The Government's work on CAV for the roads sector has focused too heavily on research problems and testing technologies for highly automated vehicles with inadequate effort on thinking about deployment, especially user acceptance for road vehicles, or on the wide range of possible benefits from connected vehicles.

The list of potential benefits of CAV is long, but more research is required to understand the scale or indeed the likelihood of these claimed benefits. The Government should commission detailed research to challenge cherished assumptions and provide a realistic indication of the benefits CAV could provide.

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.

The Government's recently published work on the behaviour of mixed fleets is a useful starting point, but must be developed to better understand not only the behaviour of drivers but also the behaviour of other road users and pedestrians.

We challenge the expected benefits of a level of automation at which a driver takes back control of the vehicle in an emergency situation. Given the evidence that reactions could be slow and poor in such circumstances, it may be that the risks associated with this are too great to tolerate and that a way should be found to bypass Level 3 where a driver does not need to monitor the dynamic driving conditions, nor the driving environment at all times, but must always be in a position to resume control.

Preparation for deployment of highly automated road vehicles

Existing manufacturers and new entrants will carry out their own research and development (R&D) for fully automated cars if there is a clear business case for investing in these technologies. The Government should not need to invest heavily or to take the lead in this area.

Nevertheless, the Government should continue to support scientific research in robotics and related information technology at academic institutions, to ensure that the UK continues to have a world-leading research base in these crucial areas.

Whilst the Government should not be involved in research into the technology itself, it must ensure that it prepares for the deployment of fully-automated road vehicles (Levels 4 and 5 of automation) through a comprehensive testing offer for CAV to attract manufacturers and academics to the UK. This should include one or more large scale testing environments covering real world urban and rural environments.

Highways England and LTAs should engage with motor manufacturers to future-proof new infrastructure and minimise the likelihood of expensive retro-fitting.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Governance and coordination

1. Autonomous vehicles are being used, or have the potential to be used, in the roads, marine, agricultural and other sectors. But there is no clear central coordination of strategy or information sharing across the different sectors. The Government must broaden its focus so that its work on connected and autonomous vehicles (CAV) cuts across all sectors and does not focus so heavily on road vehicles. This will require greater coordination across Government and the involvement of more departments in the work of the Centre for Connected and Autonomous Vehicles (CCAV). (Paragraph 41)
2. *Whilst we note that the Government will revisit the idea of a RAS Leadership Council through the process of the Industrial Strategy, action to coordinate activities across the robotics sector, including CAV, is more urgent than this timescale would suggest. We call on the Government to establish such a Council as soon as possible, to ensure that technology and expertise is shared and the maximum economic benefit for the UK is achieved.* (Paragraph 45)
3. *The RAS Leadership Council must take the lead in this area and the Government should complement the work of this Council by taking action only in areas where the RAS Leadership Council advises it that Government action is required or where the Leadership Council is not acting.* (Paragraph 46)
4. *We agree with the House of Commons Transport Committee that the Government has not implemented a coherent, joined up transport strategy. We recommend that the Government should bring forward a wider transport strategy that places the development and implementation of CAV in the context of wider policy goals, such as increased use of public transport, and the reduction of congestion and pollution.* (Paragraph 53)
5. *The Government must continue to engage with the insurance industry and other stakeholders to ensure that proposals to protect victims where an autonomous vehicle is involved in a crash while in automated mode are workable, timely and appropriate. The Vehicle Technology and Aviation Bill is unlikely to receive Royal Assent in the current Parliamentary session therefore the Government should stand ready to reintroduce the Bill in the next Parliamentary session.* (Paragraph 59)
6. Local Transport Authorities (LTAs) are responsible for the vast majority of UK roads and, together with the Traffic Commissioners for Great Britain, need training, briefing and guidance on standards for the roads sector relating to the deployment of CAV. LTAs must also be able to pool resources in order to minimise duplication of work and maximise potential benefits of CAV. (Paragraph 66)
7. *We recommend that the Government should set up and chair a forum that will allow LTAs to share knowledge and expertise on CAV and to be involved as advisers on the direction of future trials and research.* (Paragraph 67)
8. *The Government must continue to take action to close the engineering and digital skills gap to ensure that the UK can benefit from the emerging CAV technologies. We welcome the focus on skills in the Government's Industrial Strategy Green Paper and urge the Government to find innovative solutions to this problem. These might include provisions such as those proposed in the Higher Education and Research Bill*

which aim to make it simpler and quicker for innovative and specialist providers to set up, award degrees and compete alongside existing institutions. (Paragraph 73)

Potential benefits of CAV

9. CAV have the potential to increase accessibility and mobility for those less mobile or those unable to use traditional vehicles, such as the elderly or disabled. However, they may not be suitable for some people with mobility problems, if, for example, they are unable to get into or out of a car without help. Furthermore, these benefits will only be realised with full automation and if the vehicles are both affordable and acceptable to prospective users. (Paragraph 80)
10. CAV have the potential to lower the number of road fatalities. But the eradication, or near eradication, of human error will only be realised with full automation. (Paragraph 87)
11. *CAV are not the only way to reduce road casualties. There are other means by which to achieve this and we urge the Government not to lose sight of these other possibilities. (Paragraph 87)*
12. *Our evidence indicates that platooning of trucks could be an early example of CAV deployment on roads and the Government should ensure that it carries out an early evaluation of the potential applications of connected and autonomous larger vehicles used for freight and logistics. The Government must ensure that a clear business case for platooning—and indeed for any CAV application—has been made before significant investment is made. (Paragraph 92)*
13. The theoretical potential of CAV to reduce traffic congestion varies depending on the level of vehicle autonomy and the penetration rate. While we cannot say with any certainty what the impact on congestion will be, it is possible to imagine a situation of total gridlock as CAV crawl around city centres. It is important that the right policy decisions relating to CAV are made in order to reduce the likelihood of this occurring. (Paragraph 96)
14. Whilst some of our evidence has suggested that CAV could have huge economic benefits, we are not convinced that the statistics provided have been properly substantiated. (Paragraph 102)
15. *We recommend that the Government should commission a detailed cost-benefit analysis to provide a realistic indication of the economic benefits CAV could provide in all sectors, differentiating clearly between the different applications of CAV, actual monetary gains from deployment, estimated job creation and social benefits. This will help the Government decide where the focus of its efforts should be. (Paragraph 103)*
16. *It is unclear whether CAV will lead to job creation or job losses overall. The cost-benefit analysis that we have recommended should include detailed consideration of the impact of CAV on jobs; specifically whether this will include job losses, job creation or job shifts. (Paragraph 108)*
17. There is little hard evidence to substantiate the potential benefits and disadvantages of CAV because most of them are at a prototype or testing stage. Furthermore, as with any new technology or advancements, there may be unforeseen benefits or disadvantages that have not yet presented themselves. (Paragraph 110)

18. Nonetheless, the UK's ambition should be to take the lead with CAV in areas where a business case can be made which shows a clear early advantage accruing to the UK. (Paragraph 111)

Further research

19. In considering the necessary future research it is important that the Government plays to the UK's strengths and that the research is not carried out, commissioned or funded by the Government where it is better carried out by industry or other stakeholders. (Paragraph 114)
20. *The Government should not need to invest or take the lead in development of autonomous cars—this is best left to industry. However, the Government should continue to invest in the fundamental scientific research in robotics and information technology that underpins autonomous cars and other CAV, and also the social, human factors and network management problems that must be understood for deployment.* (Paragraph 114)
21. We are disappointed that the Government has delayed making a decision on a new flagship test facility. A delay is particularly damaging because CAV development is a fast moving area. (Paragraph 120)
22. *The Government must put together a comprehensive testing and research offer for CAV to attract manufacturers and academics to the UK immediately. This should include one or more large scale testing environments covering real world urban and rural environments.* (Paragraph 121)
23. CAV could have negative implications for drivers' competence, making drivers complacent and overly reliant on technology. This is of particular concern in emergency situations, where a driver may react slowly to taking back control of a vehicle. It may be the case that for Level 3 vehicles the risks will be too great to tolerate. The risk of complacency also extends to other road-users who will interact with CAV, such as pedestrians and cyclists. Further research is necessary to understand these risks, including possible measures to address them. (Paragraph 131)
24. *We recommend that the Government should give priority to commissioning work to understand the main social and behavioural questions relating to CAV, in particular answering those questions identified by its own scoping study. This work should build on international research in this area. Furthermore Innovate UK and Government departments should ensure that studying behavioural aspects is an integral part of trials they fund, including access to simulation facilities if necessary.* (Paragraph 132)
25. We welcome the modelling work commissioned by the Government. This should be a starting point for further work on mixed fleet modelling to inform policy development. (Paragraph 137)
26. *This work should help to counter the possible disadvantages and negative effects of managing a mixed fleet of autonomous and non-autonomous vehicles. The research on human factors must feed in to the modelling work so that as more is understood about human interactions with CAV, the modelling work can be refined to give more accurate results.* (Paragraph 137)
27. *We were surprised that the work the Government has commissioned on micro-scale modelling was not more widely known by our witnesses. The Government should*

take steps to ensure future work in this area is more prominently planned and shared with stakeholders including LTAs. (Paragraph 138)

28. *The potential for improved crop production and reduced adverse impacts on the environment by the use of CAV in agriculture is considerable. The Government should fund appropriate R&D once a business case is made which demonstrates the advantages which will accrue. (Paragraph 141)*

International cooperation, regulation and standards

29. *We recommend that funding is allocated for cybersecurity of CAV through the upcoming Cyber Science and Technology Strategy. Cybersecurity should also form an integral part of the Government's review of the regulatory framework for CAV. (Paragraph 150)*
30. *The Centre for Connected and Autonomous Vehicles (CCAV) is well placed to take a coordinating role with regard to cybersecurity for CAV. It should involve the newly established National Cyber Security Centre in this work as well as external stakeholders and experts. (Paragraph 151)*
31. *An international effort is necessary to tackle the risks associated with cybersecurity, which are likely to rise—especially on a global scale—as the use of CAV increases. The Government could lead on this, in order to facilitate the establishment of global standards. (Paragraph 152)*
32. *Highways England and Local Transport Authorities should jointly engage with the industry to examine the potential for ensuring that new infrastructure can be future-proofed and does not need expensive retro-fitting. (Paragraph 162)*
33. *The Government must take action with Highways England to improve digital connectivity, removing 'not-spots' on British roads—in particular on the strategic road network—in order to realise the benefits of connected vehicles, which, according to the European Commission, are likely to become available in the next three years. This can be done through the Digital Economy Bill and the implementation of the Universal Service Obligation to create a ubiquitous digital network. It will also require work at an international level to ensure the development of international standards relating to connected vehicles. (Paragraph 163)*
34. *It is essential that any data gathered from CAV are used in accordance with data protection law. We welcome the fact that the Information Commissioner's Office (ICO) has undertaken initial work with vehicle manufacturers, and is launching its own call for evidence. (Paragraph 169)*
35. *However, the meaning of personal data is unclear in the context of CAV. It will be important to achieve privacy for individuals and communities, while using data to achieve efficiency and safety of CAV operations. Data relating to an individual's CAV in terms of position, speed and performance on the road cannot be regarded as entirely personal—such data is needed for public benefit if a CAV system is to operate as a whole. Good data governance will therefore be needed to secure appropriate protection of personal information while safely using and linking open and non-sensitive data. Distinctions will need to be made between commercially sensitive data owned by technology providers and open data. (Paragraph 170)*
36. *We recommend that the Government liaise with the ICO, automotive manufacturers and other interested parties, including international partners, to ensure that CAV and the data they produce comply with the relevant privacy and data protection*

legislation and that this legislation is appropriate and workable, and keeps pace with the technology. (Paragraph 171)

37. *We welcome the Government's work at an international level to draw up standards for data retention in the event of an accident involving CAV. These standards will ensure that manufacturers provide access to the necessary data in the case of an accident. The Government must also ensure that the Police and the wider criminal justice system have the necessary skills, tools and access to be able to appropriately interrogate the stored data. (Paragraph 175)*
38. The increased development and deployment of CAV raises ethical issues. The Government should keep this in mind as it takes forward its programme of regulatory reform for CAV, including taking a leading role in the development of international standards to address the ethical issues. These standards will need to ensure that companies are transparent about the way vehicles deal with these issues. (Paragraph 186)
39. *We welcome the UK's leading role in the development of international regulation for marine autonomous vehicles and encourage the Government to continue to drive forward this initiative. There is potential for significant early benefit to accrue to the UK once a new international regulatory framework is in place. (Paragraph 189)*

Connected and Autonomous Vehicles: The future?

CHAPTER 1: INTRODUCTION

Context

1. The possible applications of connected and autonomous vehicles (CAV)¹ are far-reaching, straddling a variety of different sectors. The examples provided in our evidence included—but were not limited to—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.²
2. Proponents of CAV point to anticipated benefits in convenience, efficiency, safety, environmental impact, increased mobility for some groups of society and economic benefits. Others have suggested CAV might reduce the number of driving jobs, pose security threats and raise privacy issues. Surveys have obtained mixed results on public opinion regarding CAV.
3. As well as the future applications of CAV, our evidence detailed some of the areas in which CAV are currently in use. Appendix 6 provides some examples of how CAV are already being used and trialled in the roads, aerial, marine and energy sectors.

Key actions to date

Government

4. The Government has been active in responding to the potential for the UK offered by CAV, particularly in the roads sector.
5. The 2010–15 Coalition Government identified Robotics and Autonomous Systems (RAS) as one of the ‘Eight Great Technologies’ to be supported by their Industrial Strategy. CAV are a type of RAS. The RAS 2020 Strategy (see paragraphs 12 and 13) defined RAS as:

“[I]nterconnected, interactive, cognitive and physical tools, able to variously perceive their environments, reason about events, make or revise plans and control their actions. They perform useful tasks for us in the real world, extending our capabilities, increasing our productivity and reducing our risks.”³

1 See paragraphs 18–23 and Appendix 5 for definitions of terms used in this report.

2 [Q 1](#) (Iain Forbes), [Q 11](#) (Prof Simon Blackmore and Dr Rob Buckingham), [Q 63](#) (John Hayes CBE MP) and written evidence from Pupils 2 Parliament ([AUV0016](#)), Transport for Greater Manchester (TfGM) ([AUV0027](#)), Prof James Scanlan, University of Southampton ([AUV0030](#)), Prof Simon Blackmore, Harper Adams University (HAU) ([AUV0034](#)), Innovate UK ([AUV0037](#)), Deloitte LLP ([AUV0045](#)), Prof Sarah Sharples and colleagues, University of Nottingham ([AUV0049](#)), Research Councils UK (RCUK) ([AUV0053](#)), Zurich Insurance plc ([AUV0068](#)), the Royal Aeronautical Society ([AUV0077](#)), AutoNaut Ltd ([AUV0079](#)), the Met Office ([AUV0081](#)), Rolls-Royce ([AUV0083](#)) and HM Government ([AUV0084](#))

3 Special Interest Group: Robotics and Autonomous Systems, *RAS 2020 Robotics and Autonomous Systems* (July 2014): <https://connect.innovateuk.org/documents/2903012/16074728/RAS%20UK%20Strategy?version=1.0> [accessed 20 December 2016]

6. Together, the Eight Great Technologies were allocated £600 million, with the Government aiming to work with leadership groups in each one to encourage their development. RAS was allocated £35 million.⁴
7. In the Queen's Speech on 18 May 2016, the Government confirmed its intention to introduce a Modern Transport Bill to "ensure the United Kingdom is at the forefront of technology for new forms of transport, including autonomous and electric vehicles".⁵ Furthermore, with regards to CAV, the Department for Transport's (DfT) stated aim is to "maintain the UK's world-leading position for developing and testing connected and autonomous road vehicle technology".⁶ On 22 February, the Government introduced a Vehicle Technology and Aviation Bill to the House of Commons⁷ which contained provisions relating to insurance for automated vehicles.
8. In July 2015 the Government formed the Centre for Connected and Autonomous Vehicles (CCAV) to co-ordinate the Government's action on CAV, leading policy development and stimulating research and development (R&D) alongside Innovate UK. CCAV's website claims that the UK is one of the best countries for car makers and others to develop and test CAV technologies because of its flexible regulations, thriving automotive sector, and excellent research base and innovation infrastructure.
9. The DfT carried out a review of the regulations for testing CAV in the UK, which concluded in February 2015, and subsequently published a Code of Practice⁸ outlining how to conduct testing in compliance with UK law. The DfT has indicated that it will periodically review this Code of Practice to keep it up-to-date in the light of testing.⁹
10. CCAV issued a call for evidence on the UK testing ecosystem for CAV, which closed in July 2016.¹⁰ The DfT and CCAV opened a consultation in July 2016, soliciting opinions on a range of issues regarding CAV, in particular focusing on their proposals to amend regulations, insurance legislation, and the Highway Code.¹¹
11. On 23 January 2017, the Government published its Industrial Strategy Green Paper, *Building our Industrial Strategy*.¹² This suggested that autonomous

4 Rt Hon David Willetts, Speech on Eight great technologies, 24 January 2013: <https://www.gov.uk/government/speeches/eight-great-technologies> [accessed 10 January 2017]

5 Cabinet Office, *Queen's Speech 2016* (18 May 2016): <https://www.gov.uk/government/speeches/queens-speech-2016> [accessed 20 December 2016]

6 DfT, *Single departmental plan 2015 to 2020* (Updated 12 October 2016), section 1.1: <https://www.gov.uk/government/publications/dft-single-departmental-plan-2015-to-2020/single-departmental-plan-2015-to-2020> [accessed 20 December 2016]

7 [Vehicle Technology and Aviation Bill](#) [Bill 143 (2016–17)]

8 DfT, *The Pathway to Driverless Cars: A Code of Practice for testing* (July 2015): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/446316/pathway-driverless-cars.pdf [accessed 20 December 2016]

9 DfT, *The Pathway to Driverless Cars: Summary report and action plan* (February 2015): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/401562/pathway-driverless-cars-summary.pdf [accessed 9 January 2017]

10 BEIS and Innovate UK, *Driverless vehicle testing facilities: call for evidence* (26 May 2016): <https://www.gov.uk/government/consultations/driverless-vehicle-testing-facilities-call-for-evidence> [accessed 9 January 2017]

11 CCAV, *Pathway to Driverless Cars: Proposals to support advanced driver assistance systems and automated vehicle technologies* (July 2016): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/536365/driverless-cars-proposals-for-adas-and_avts.pdf [accessed 10 January 2017]

12 HM Government, *Building our Industrial Strategy: Green Paper* (January 2017): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/586626/building-our-industrial-strategy-green-paper.pdf [accessed 1 February 2017]

vehicles might be a suitable candidate to receive funding under its previously announced Industrial Strategy Challenge Fund. The Government also undertook to:

“[C]ement the UK’s position as a go-to destination for the development of this technology by establishing a new testing ecosystem, using both controlled and real world environments. We will announce the location of the coordinating hub for this project by spring 2017.”¹³

RAS 2020 Strategy

12. To stimulate collaboration and innovation in RAS capabilities, a RAS ‘Special Interest Group’ (SIG), comprising academics and industrialists, was established in 2013 with support from the Technology Strategy Board (now called Innovate UK).
13. The SIG subsequently produced RAS 2020, a national strategy for RAS, in July 2014.¹⁴ Its objective was “to capture value in a cross-sector UK RAS innovation pipeline through co-ordinated development of assets, challenges, clusters and skills” and it made eight recommendations aimed at realising that goal.¹⁵ The Government response to the RAS 2020 national strategy was published in March 2015.¹⁶

Why we launched this inquiry

14. We decided to launch an inquiry into CAV in September 2016 against the background set out in the previous paragraphs. We recognised that this was an area in which technology was developing at a rapid pace and where the Government needed to make policy decisions and investment decisions to enable the UK to receive the maximum possible amount of economic benefit.
15. Forecasting the pace of technological change is perilous and predicting the pace of economic and social change is even more so. Whilst we cannot predict the future and we cannot anticipate all the changes that CAV might bring about, long-term developments in CAV have the potential to bring about transformational change to society. These changes will only take place if society is willing to both pay for and adapt its behaviour to fit the technology. This report is our attempt to stop and think about these potential changes and to encourage the Government and other stakeholders to do the same.
16. Our call for evidence¹⁷ set out a number of questions in the following areas:
 - The impacts and benefits of CAV; and
 - The creation of an enabling environment, including R&D, real world operation and wider governance issues.

13 HM Government, *Building our Industrial Strategy: Green Paper* (January 2017): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/586626/building-our-industrial-strategy-green-paper.pdf [accessed 1 February 2017]

14 Special Interest Group: Robotics and Autonomous Systems, *RAS 2020 Robotics and Autonomous Systems* (July 2014): <https://connect.innovateuk.org/documents/2903012/16074728/RAS%20UK%20Strategy?version=1.0> [accessed 20 December 2016]

15 *Ibid.*

16 Cabinet Office, ‘Response to the Robotics and Autonomous Systems Strategy’, (March 2015): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/414382/BIS-15-215-Greg-Clark-to-Professors-Buckingham-and-Lane-RAS-Strategy.pdf [accessed 9 January 2017]

17 See Appendix 3

17. Whilst our call for evidence made clear that we were keen to receive evidence about the use of CAV in all sectors, the evidence we received related overwhelmingly to the use of CAV in the roads sector. This report therefore is similarly weighted towards the consideration of the use of CAV in the roads sector.

Terminology

18. A whole variety of terms were used in the evidence we received to describe the technology which is the subject of this report. Amongst these were driverless vehicles (or cars), autonomous vehicles, automated vehicles, highly automated vehicles and connected vehicles.
19. Whilst accepting that a case could probably be made for using any one of these terms, throughout this report we use the term ‘connected and autonomous vehicles’ (CAV). This echoes the term widely used by the Government—most notably in the name of the organisation it set up to co-ordinate its action on autonomous vehicles, the ‘Centre for Connected and Autonomous Vehicles’ (CCAV).
20. Connected vehicles are vehicles that use any of a number of different communication technologies to communicate with the driver, other vehicles on the road (vehicle-to-vehicle [V2V]), roadside infrastructure (vehicle-to-infrastructure [V2I])¹⁸, and the ‘cloud’.¹⁹
21. Autonomous vehicles are those in which operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking and are designed so that the driver is not expected to monitor constantly the roadway while operating in self-driving mode.
22. Some vehicles are both autonomous and connected whilst others are connected vehicles only and others are autonomous only. They are often referred to by the composite term ‘connected and autonomous vehicles’.
23. We have not considered remote control vehicles (RCV) or drones (unmanned aerial vehicles) in this report. An RCV differs from an autonomous vehicle in that the RCV is always controlled by a human and takes little or no positive action autonomously. Examples of RCV include the majority of the probes to the other planets in our solar system and the devices used by bomb-squads to defuse or detonate explosives.

Levels of automation

24. In January 2014, the Society of Automotive Engineers produced a report which identified six levels of driving automation spanning from no automation (Level 0) to full automation (Level 5).²⁰ Figure 1 below, which is reproduced from a March 2015 report commissioned by the Society of Motor Manufacturers and Traders (SMMT), *Connected and Autonomous*

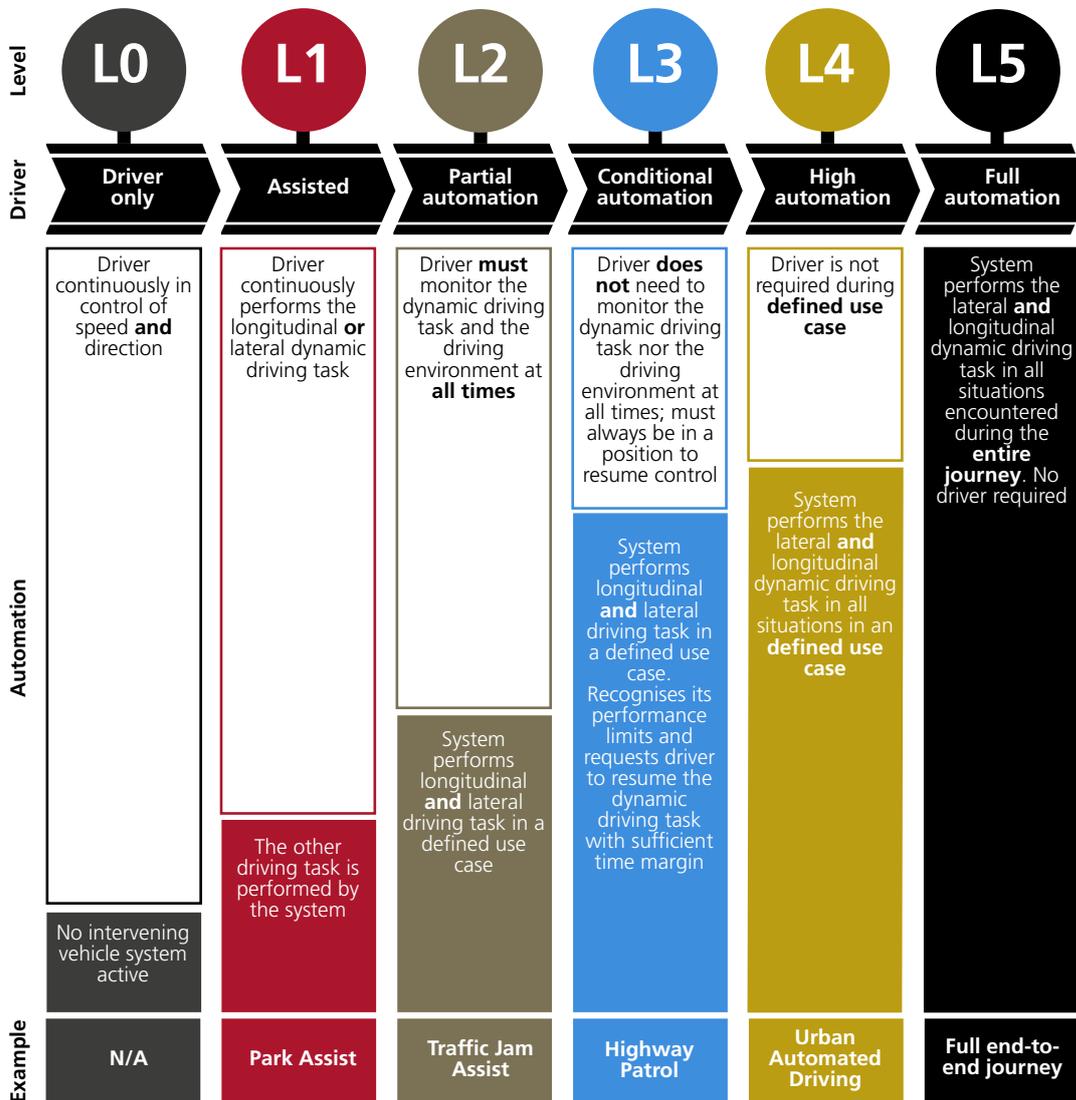
18 V2V [Vehicle-to-vehicle] communication enables information about an incident or dangerous road conditions to be sent by the first vehicles at a scene to alert those following; V2I [vehicle-to-Infrastructure] communication lets vehicles report traffic flows and road conditions to control centres to help network management and mobilise emergency services and salt gritting as necessary. V2I also enables broadcasting of information to a larger area than V2V.

19 In the simplest terms, cloud computing means storing and accessing data and programmes over the internet. The cloud is a metaphor for the internet.

20 SAE International, *Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems* (January 2014): https://www.sae.org/misc/pdfs/automated_driving.pdf [accessed 9 January 2017]

Vehicles: The UK Economic Opportunity,²¹ illustrates the six different levels of autonomy. These levels of autonomy cover road vehicles only.

Figure 1: Defined levels of automation (for road vehicles)



Source: KPMG and the Society of Motor Manufacturers & Traders (SMMT), *Connected and Autonomous Vehicles: The UK Economic Opportunity* (March 2015): <https://www.smmt.co.uk/wp-content/uploads/sites/2/CRT036586F-Connected-and-Autonomous-Vehicles-%E2%80%93-The-UK-Economic-Opportu...1.pdf> [accessed 12 January 2017]

25. Much of the evidence we received referred to these six levels of automation for road vehicles and we refer to them throughout this report.

Structure

26. In Chapter Two we analyse the actions the Government has taken and needs to take to co-ordinate R&D into CAV and robotics technology through Innovate UK and CCAV. We also discuss other areas, including a wider transport strategy and skills, where there is a need for Government coordination and oversight. In Chapter Three we consider some of the

21 KPMG and the SMMT, *Connected and Autonomous Vehicles: The UK Economic Opportunity* (March 2015): <https://www.smmt.co.uk/wp-content/uploads/sites/2/CRT036586F-Connected-and-Autonomous-Vehicles-%E2%80%93-The-UK-Economic-Opportu...1.pdf> [accessed 20 December 2016]

potential social and economic benefits CAV could bring. In Chapter Four we set out what R&D, commissioned by the Government and others, needs to be carried out over the short and medium term to ensure the benefits of the deployment of CAV are maximised and potential drawbacks minimised. Finally, in Chapter 5, we consider the international cooperation, regulation and standards which will be necessary to allow the full benefits of CAV to be realised.

Working methods and acknowledgements

27. The membership of the Committee is set out in Appendix 1. We issued a call for evidence on 15 September 2016, which is contained in Appendix 3. In November 2016 we took oral evidence from 20 witnesses. We received 88 written submissions. A list of witnesses is included in Appendix 2. We have also drawn on earlier consultations and publications. A glossary of acronyms and key terms used can be found in Appendix 5.
28. In addition to holding oral evidence sessions, we visited the Greenwich GATEway project on 6 December 2016.²² Starship Technologies demonstrated their personal delivery device to us on 13 December 2016.²³
29. We would like to record our particular thanks to the Greenwich GATEway project, the Royal Borough of Greenwich and the Thames Clipper company for their help with the practical arrangements for our visit.
30. Our Specialist Adviser for this inquiry was Professor Eric Sampson, Newcastle University. We have been fortunate to benefit from his expertise and enthusiasm, which have contributed greatly to our work.

Government response

31. We look forward to receiving a written response to this report from the Government and we will seek a debate in the House as soon as possible thereafter.

22 GATEway Project (Greenwich Automated Transport Environment): <https://gateway-project.org.uk/> [accessed 10 January 2017]

23 Starship Technologies: <https://www.starship.xyz/> [accessed 10 January 2017]

CHAPTER 2: GOVERNANCE AND COORDINATION

32. In this Chapter we analyse the actions the Government has taken and needs to take to co-ordinate research and development (R&D) into connected and autonomous vehicles (CAV) and robotics technology through Innovate UK and the Centre for Connected and Autonomous Vehicles (CCAV). We also discuss other areas, including a wider transport strategy and skills, where there is a need for Government coordination and oversight.

The Centre for Connected and Autonomous Vehicles (CCAV)

33. The centrepiece of the Government's work on CAV has been the establishment of the CCAV, a joint unit between the Department for Transport (DfT) and the Department for Business, Energy and Industrial Strategy (BEIS). It was established in July 2015 to "keep the UK at the forefront of the development and deployment of [CAV] technology".²⁴ Iain Forbes, Head of the CCAV, told us that the Centre had four broad objectives:
- to build a world class industry in this sector in the UK;
 - to prepare the UK for deployment of autonomous vehicles, including any necessary regulatory changes;
 - to get maximum value from the R&D programme, into which the Government has invested £100 million; and
 - to look at cybersecurity issues.²⁵
34. In the Autumn Statement 2013, the Government set out plans to encourage "the development of driverless cars in the UK".²⁶ In the March 2015 Budget, the then Chancellor of the Exchequer, the Rt Hon George Osborne MP, announced a £100 million Intelligent Mobility Fund for research into CAV, to be match-funded by industry. This money would be allocated through a series of funding competitions by CCAV working closely with Innovate UK.²⁷ The winners of the first competition (for £20 million) were announced in February 2016, with eight collaborative R&D projects and 13 feasibility studies receiving funding.²⁸ A second competition (for £35 million) is currently open.²⁹ This funding is in addition to that which has already been allocated to the three driverless car trials (see Box 1). Innovate UK has also funded a number of CAV projects in the marine sector.

24 Written evidence from HM Government ([AUV0084](#))

25 [Opening statement in oral evidence](#) (Iain Forbes)

26 HM Treasury, *Autumn Statement 2013*, Cm 8747, December 2013: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/263942/35062_Autumn_Statement_2013.pdf [accessed 9 February 2017]

27 Innovate UK is the UK's innovation agency, a non-departmental public body sponsored by BEIS. Its responsibility is to drive growth by working with companies to de-risk, enable and support innovation: <https://www.gov.uk/government/organisations/innovate-uk> [accessed 10 January 2017]

28 BEIS and DfT, Press Release: *Driverless cars technology receives £20 million boost* (1 February 2016): <https://www.gov.uk/government/news/driverless-cars-technology-receives-20-million-boost> [accessed 5 January 2017]

29 Innovate UK, 'Connected and autonomous vehicles: apply for business funding' (12 August 2016): <https://www.gov.uk/government/news/connected-and-autonomous-vehicles-apply-for-business-funding> [accessed 5 January 2017]

Box 1: CAV Road Trials

GATEway Project Greenwich

GATEway (Greenwich Automated Transport Environment) is an £8 million research project, led by the Transport Research Laboratory (TRL), to understand and overcome the technical, legal and societal challenges of implementing automated vehicles in an urban environment.

Taking place in the Royal Borough of Greenwich, the project aims to trial and validate a series of different use cases for CAV, including driverless shuttles and automated urban deliveries.³⁰

VENTURER

VENTURER brings together a partnership of public, private and academic experts in order to establish the South West as a world class test site facility for CAV. VENTURER focuses on the users as well as the technology enabling CAV, in order to understand the blockers and drivers to wide scale adoption of CAV capability.³¹

UK Autodrive

A consortium of technology and automotive businesses, local authorities and academic institutions who are working together on a major three-year UK trial of self-driving vehicle and connected car technologies. The trial will culminate in a series of urban demonstrations on selected public roads and footpaths in the host cities of Milton Keynes and Coventry. As well as showcasing the latest technology, UK Autodrive is also investigating other important aspects of automated driving—including safety and cybersecurity, legal and insurance issues, public acceptance for CAV and the potential business models for turning automated driving systems into a widespread reality.³²

A2/M2 Connected Corridor

The DfT and its partners (Highways England, Kent County Council and Transport for London) are designing a flagship “connected vehicle corridor” on the A2/M2 London to Dover route, a £15 million living laboratory for deploying a range of services and wireless communications technologies that [connected] vehicles will need to operate.³³ This is part of a wider Connected Europe Facility project.³⁴

35. It should be noted that Innovate UK funds a number of Catapult centres which are “a network of world-leading centres designed to transform the UK’s capability for innovation in specific areas and help drive future economic growth”.³⁵ The Transport Systems Catapult submitted written evidence to our inquiry, but other Catapults such as the Future Cities Catapult and the Digital Catapult also have an interest in the development of CAV.

30 GATEway Project, ‘About’: <https://gateway-project.org.uk/about/> [accessed 10 January 2017]

31 VENTURER, ‘About’: <http://www.venturer-cars.com/#section-about> [accessed 10 January 2017]

32 UK Autodrive, ‘Frequently asked questions’: <http://www.ukautodrive.com/frequently-asked-questions/> [accessed 10 January 2017]

33 Supplementary written evidence from HM Government (AUV0095)

34 European Commission, *CEF-Transport, Northsea-Mediterranean Corridor*: <https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport/projects-by-country/multi-country/2015-eu-tm-0159-s> [accessed 13 January 2017]

35 Catapult, ‘About Catapult’: <https://catapult.org.uk/about-us/about-catapult/> [accessed 24 February 2017]

36. We received evidence that the CCAV and Innovate UK were carrying out their roles effectively. Five AI Inc told us that the CCAV had been extremely effective³⁶ and ITS United Kingdom said “Innovate UK and CCAV are functioning well as co-ordinators ... for the research, and would appear to be acting precisely according to the political priorities set for them.”³⁷ However, support for CCAV and Innovate UK was not unanimous. Professor Paul Newman told us that, while Innovate UK deserved credit, he was concerned that the pace at which autonomous vehicle initiatives were happening was too slow.³⁸ Peak Power made a similar point:
- “There is no evidence of real success to date, or indication [Innovate UK and the CCAV] have appreciated the strategic long term value of AVs [autonomous vehicles] to UK industry, [the] UK economy, and the ‘winner takes all’ urgency to the opportunity.”³⁹
37. Whilst, on balance, the evidence showed that CCAV and Innovate UK had been operating well within their narrowly defined remits, there was some criticism of the Government’s overall strategy for CAV, particularly in the non-roads sectors.
38. Professor David Lane told us that the Government had only just scratched the surface,⁴⁰ while Professor Newman said that the CCAV model should be extended across all of Government.⁴¹ Furthermore, the Society of Motor Manufacturers and Traders (SMMT) told us that it should be extended to involve the Department for Culture, Media and Sport (DCMS), given the prominent role of telecommunications and the tech sector in the development and deployment of CAV (see the section on Infrastructure in Chapter Five, paragraphs 170–180).⁴²
39. By its own admission the Government’s predominant focus so far has been on the roads sector.⁴³ However, we heard of the current use and real potential of CAV in other sectors, including marine, agriculture and hazardous environments. Professor Simon Blackmore told us that he believed that autonomous agricultural vehicles would have a bigger impact on agriculture than driverless cars will on the road because there is an opportunity to significantly reduce the cost of crop production and reduce adverse impacts on the environment.⁴⁴ The UK Atomic Energy Authority (UKAEA) pointed out the large opportunities for CAV in hazardous environments, for example when dealing with nuclear waste.⁴⁵ The Institute of Marine Engineering, Science & Technology (IMarEST) also told us about the wide ranging potential benefits in the marine sector from autonomous vehicles.⁴⁶
40. In 2016, the Cabinet Office convened a time-limited working group to support information sharing and coordination of government activities on Robotics and Autonomous Systems (RAS). The departments represented were: BEIS

36 Written evidence from Five AI Inc ([AUV0013](#))

37 Written evidence from ITS United Kingdom ([AUV0036](#))

38 Written evidence from Prof Paul Newman, University of Oxford ([AUV0041](#))

39 Written evidence from Peak Power ([AUV0043](#))

40 Written evidence from Prof David Lane CBE ([AUV0050](#))

41 Written evidence from Prof Paul Newman, University of Oxford ([AUV0041](#))

42 Written evidence from the SMMT ([AUV0058](#))

43 Written evidence from HM Government ([AUV0084](#))

44 Written evidence from Prof Simon Blackmore, Harper Adams University ([AUV0034](#))

45 Written evidence from UKAEA and RACE ([AUV0032](#))

46 Written evidence from the IMarEST ([AUV0064](#))

(then Department for Business, Innovation and Skills and Department of Energy and Climate Change), DfT, Department for Environment, Food and Rural Affairs, Cabinet Office, Ministry of Defence (MoD), Department of Health and DCMS, plus a number of relevant agencies including the Engineering and Physical Sciences Research Council (EPSRC) and Innovate UK.⁴⁷ This working group has now been wound down.

41. **Autonomous vehicles are being used, or have the potential to be used, in the roads, marine, agricultural and other sectors. But there is no clear central coordination of strategy or information sharing across the different sectors. The Government must broaden its focus so that its work on connected and autonomous vehicles (CAV) cuts across all sectors and does not focus so heavily on road vehicles. This will require greater coordination across Government and the involvement of more departments in the work of the Centre for Connected and Autonomous Vehicles (CCAV).**

Robotic and Autonomous Systems (RAS) Leadership Council

42. One of the recommendations of the RAS 2020 Strategy (see paragraph 13) was the formation of a RAS Leadership Council, bringing together industry, academia and government to provide “independent advisory oversight of planning and execution of the strategy”.⁴⁸ In responding to the Strategy in March 2015, the then Universities Minister, the Rt Hon Greg Clark MP, stated that the Government intended to establish a RAS Leadership Council.⁴⁹
43. The RAS Leadership Council has not yet been set up, as the House of Commons Science and Technology Committee has pointed out, with the Government stating that things have moved on and a number of other activities have been introduced in this area. The House of Commons Committee went on to recommend that the Leadership Council should be established as soon as possible.⁵⁰
44. Dr Rob Buckingham, Director of the UKAEA, warned us that, without the coordination the RAS Leadership would provide, the different strands of RAS—including autonomous vehicles—would remain working within silos and would all underperform.⁵¹ The point was also made by Rolls-Royce that the parallel development of autonomous road vehicles, alongside other sectors, could result in advantageous advances where there is overlap in the technologies required.⁵² Nick Hurd MP, the Minister of State for Climate Change and Industry, told us that the Government thought the RAS Leadership Council was still the right idea, but it needed to revisit it through the process of the Industrial Strategy.⁵³

47 Supplementary written evidence from HM Government ([AUV0095](#))

48 Special Interest Group: Robotics and Autonomous Systems, *RAS 2020 Robotics and Autonomous Systems* (July 2014): <https://connect.innovateuk.org/documents/2903012/16074728/RAS%20UK%20Strategy?version=1.0> [accessed 5 January 2017]

49 HM Government, *Response to the Robotics and Autonomous Systems Strategy* (March 2015) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/414382/BIS-15-215-Greg-Clark-to-Professors-Buckingham-and-Lane-RAS-Strategy.pdf [accessed 5 January 2016]

50 House of Commons Science and Technology Committee, *Robotics and artificial intelligence* (Fifth Report, Session 2016–17, HC 145), p 37

51 [Q 17](#) (Dr Rob Buckingham)

52 Written evidence from Rolls-Royce ([AUV0083](#))

53 [Q 67](#) (Nick Hurd MP)

45. ***Whilst we note that the Government will revisit the idea of a RAS Leadership Council through the process of the Industrial Strategy, action to coordinate activities across the robotics sector, including CAV, is more urgent than this timescale would suggest. We call on the Government to establish such a Council as soon as possible, to ensure that technology and expertise is shared and the maximum economic benefit for the UK is achieved.***
46. ***The RAS Leadership Council must take the lead in this area and the Government should complement the work of this Council by taking action only in areas where the RAS Leadership Council advises it that Government action is required or where the Leadership Council is not acting.***

Fitting the CAV strategy into a wider transport strategy

47. There is a risk that if CAV are widely available and easy to use, in particular fully automated Level 5 vehicles, they could have a negative impact on the use of other modes of transport, for example walking and cycling or public transport. This was highlighted by Pupils 2 Parliament: “[CAV] could encourage more people to make more journeys, even very short ones, by car, and so stop getting exercise by walking.”⁵⁴
48. Dr Debbie Hopkins of the Transport Studies Unit at the University of Oxford told us of the risk that “investments in CAV technology may cancel out some of the positive social and environmental effects of current and recent transport policies”.⁵⁵
49. Transport for London stated that its priority was to promote walking, cycling and public transport and that it would be “important to ensure that business models for deployment of autonomous vehicles do not detract from these objectives, working alongside public transport to enhance mobility in the city overall”.⁵⁶
50. Rt Hon John Hayes MP, Minister of State and the DfT, said that the future of transport, including CAV, needed to be thought about in a holistic way:
- “It is really important that we do not hurtle in one direction with our public transport policy only to be hurtling in a different one with autonomous vehicles.”⁵⁷
51. While this reassurance from the Minister is welcome, we received evidence that holistic thinking is currently lacking in Government. The Chartered Institution of Highways and Transportation (CIHT) told us that:
- “[T]here is no clear national motoring strategy that sets out how private vehicles integrate with other transport modes both on the highways and other networks.”⁵⁸
52. Furthermore, the House of Commons Transport Committee concluded in its report *Motoring of the future* that: “The DfT has not implemented a

54 Written evidence from Pupils 2 Parliament ([AUV0016](#))

55 Written evidence from Dr Debbie Hopkins, University of Oxford ([AUV0021](#))

56 Written evidence from Transport for London ([AUV0087](#))

57 [Q 67](#) (John Hayes CBE MP)

58 Written evidence from the CIHT ([AUV0082](#))

coherent, joined-up strategy to link the development and implementation of new automotive technology to the achievement of its wider policy goals.”⁵⁹

53. ***We agree with the House of Commons Transport Committee that the Government has not implemented a coherent, joined up transport strategy. We recommend that the Government should bring forward a wider transport strategy that places the development and implementation of CAV in the context of wider policy goals, such as increased use of public transport, and the reduction of congestion and pollution.***

Insurance and liability

54. We heard that changes will be needed to the motor insurance regime in order to cover vehicles operating in autonomous mode.
55. Currently after an accident the insurer of the at-fault driver pays out on insurance claims by third parties who suffer damage. For semi- or fully autonomous vehicles there may be occasions when an accident occurs and the car is in fully autonomous mode. In this case the ‘driver’ is not necessarily liable and liability could lie with the manufacturer of the vehicle.
56. The Government launched a consultation on 11 July 2016 on proposals for changes to motor insurance to cover CAV.⁶⁰ In its consultation the Government suggested that motor insurance should also include product liability for (semi-) autonomous cars as well as traditional motor liability (for when the driver is in control). This insurance would also cover the ‘driver’ as they may be a victim if the car is in autonomous mode. Provisions relating to insurance for automated vehicles were included in the Vehicle Technology and Aviation Bill which was introduced to the House of Commons by the Government on 22 February.⁶¹
57. The evidence received from insurance companies and insurance industry bodies suggested the broad thrust of the Government’s proposals had been welcomed by the industry, but there were some remaining issues, particularly around product liability.
58. In its response to the consultation the Government said it would modify the proposals to be brought forward in the light of the feedback from the insurance industry:

“[The Government] will now extend compulsory motor vehicle insurance creating a single insurer model to protect victims where the AV [autonomous vehicle] causes a crash in automated mode. The victim will have a direct right against the motor insurer and the insurer in turn will have a right of recovery against the responsible party to the extent there is a liability under existing laws, including under product liability laws.”⁶²

59 Transport Committee, *Motoring of the future* (Eighth Report, Session 2014–15, HC 429)

60 CCAV, *Pathway to Driverless Cars: Proposals to support advanced driver assistance systems and automated vehicle technologies* (July 2016): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/536365/driverless-cars-proposals-for-adas-and_avts.pdf [accessed 10 January 2017]

61 *Vehicle Technology and Aviation Bill* [Bill 143 (2016–17)]

62 CCAV, *Pathway to Driverless Cars: Proposals to support advanced driver assistance systems and automated vehicle technologies* (July 2016): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/536365/driverless-cars-proposals-for-adas-and_avts.pdf [accessed 10 January 2017]

59. *The Government must continue to engage with the insurance industry and other stakeholders to ensure that proposals to protect victims where an autonomous vehicle is involved in a crash while in automated mode are workable, timely and appropriate. The Vehicle Technology and Aviation Bill is unlikely to receive Royal Assent in the current Parliamentary session therefore the Government should stand ready to reintroduce the Bill in the next Parliamentary session.*

Providing guidance to Local Transport Authorities (LTAs) and Traffic Commissioners for Great Britain

60. In England, Wales and Scotland, Local Transport Authorities (LTAs), which are often local authorities, are responsible for the maintenance and management of the majority of roads. We received evidence from three large LTAs (Transport for London, Transport for West Midlands and Transport for Greater Manchester) and Darren Capes from City of York Council—a smaller LTA, containing urban, suburban and rural areas, representative of many LTAs around the country. Traffic Commissioners for Great Britain are responsible for the licensing and regulation of those who operate heavy goods vehicles, buses and coaches, and the registration of local bus services. They are assisted in this work by deputy Traffic Commissioners, who preside over a number of public inquiries.
61. LTAs need to make decisions on policy and funding as current highway systems, such as traffic management systems, reach the end of their life. We heard that, as some level of connectivity and automation of vehicles in the future seems to be inevitable, it is important that LTAs receive guidance from the Government on how the deployment of CAV will impact on the systems and infrastructure required. Mr Capes said, “I feel that most local authorities are not yet sufficiently prepared to deliver it.”⁶³
62. John Hayes MP told us that the Government has funded the Technology Transport Forum to work with LTAs. The forum “will be the guide to set out what autonomous vehicles can do for different localities and how local authorities can play their part in this”.⁶⁴
63. However, Mr Capes suggested that the work of the forum does not go far enough in supporting LTAs, many of whom do not have a clear understanding of how CAV may operate on the UK road network.⁶⁵
64. Furthermore, planning for city centre development often involves timescales of 10–15 years or more and the lack of guidance for local authorities on the deployment of CAV makes this type of planning difficult, as highlighted by Mr Capes in oral evidence. Mr Capes also stated that LTAs “need to do this against a backdrop of pressure to reduce costs and find further efficiencies in delivering services”.⁶⁶
65. Transport for Greater Manchester (TfGM) “believe it is the role of Government to work with transport authorities to ensure AV are able to meet safety restrictions [for multi-modal urban spaces] from the outset, otherwise AV implementation will be fragmented and unsustainable”.⁶⁷ Atkins said

63 [Q 40](#) (Darren Capes)

64 [Q 71](#) (John Hayes CBE MP)

65 Supplementary written evidence from Darren Capes ([AUV0093](#))

66 [Q 40](#) (Darren Capes)

67 Written evidence from TfGM ([AUV0027](#))

that the Government needs to provide a unified approach for LTAs for the implementation of Mobility as a Service, a potential application of CAV, otherwise the overall value to the UK will be reduced.

66. **Local Transport Authorities (LTAs) are responsible for the vast majority of UK roads and, together with the Traffic Commissioners for Great Britain, need training, briefing and guidance on standards for the roads sector relating to the deployment of CAV. LTAs must also be able to pool resources in order to minimise duplication of work and maximise potential benefits of CAV.**
67. *We recommend that the Government should set up and chair a forum that will allow LTAs to share knowledge and expertise on CAV and to be involved as advisers on the direction of future trials and research.*

Skills shortage

68. We were told that there was a skills shortage in the CAV sector, and more widely for RAS. The RAS 2020 strategy said:

“It will not be possible to achieve the vision in this strategy without a strong skill base. It is vitally important that investment is made at an early stage so that innovation is not starved of its primary resource.”⁶⁸

69. In October 2016, the Transport Systems Catapult published a report, *Intelligent mobility skills strategy: Growing new markets in smarter transport*.⁶⁹ It concluded that, in the wider intelligent mobility sector, which encompasses CAV technologies, the UK faces a potential skills gap of 742,000 people by 2025.⁷⁰ The House of Commons Science and Technology Committee report, *Robotics and Artificial Intelligence*, published in October 2016, echoed the findings of the Transport Systems Catapult.⁷¹
70. Cranfield University told us that the shortage of engineers facing the UK threatened the development of CAV technology and the creation of applications for CAV.⁷² Professor Newman questioned the effectiveness of the UK’s education system in delivering people with the right skills for the CAV sector. He said:

“I cannot overstate the importance of this: we need about 10,000 more engineers a year. We need to plough money into universities to teach information engineering, data engineering and software. Our future economy is not going to be about bending pieces of metal or shaping plastic; it’s going to be about making weightless software.”⁷³

Investment to deliver people with the right skills for the CAV sector is also necessary in schools and in the further education sector.

68 Special Interest Group: Robotics and Autonomous Systems, *RAS 2020 Robotics and Autonomous Systems* (July 2014): <https://connect.innovateuk.org/documents/2903012/16074728/RAS%20UK%20Strategy?version=1.0> [accessed 20 December 2016]

69 Transport Systems Catapult, *Intelligent Mobility Skills Strategy: Growing New Markets in Smarter Transport* (October 2016): <https://tics.shef.ac.uk/wp-content/uploads/2016/10/IM-Skills-Strategy-2016-1-compressed.pdf> [accessed 1 March 2017]

70 Written evidence from Prof Paul Newman, University of Oxford (AUV0041)

71 House of Commons Science and Technology Committee, *Robotics and Artificial Intelligence* (Fifth Report, Session 2016–17, HC 145)

72 Written evidence from Cranfield University (AUV0086)

73 Written evidence from Prof Paul Newman, University of Oxford (AUV0041)

71. In a similar vein the House of Lords Committee on Digital Skills concluded that there was a shortage of medium and high-level digital skills in the UK.⁷⁴
72. The Government made clear that it was aware of the skills gap and that it was considering actions to improve the situation.⁷⁵ The DfT also told us that it had launched a Transport Infrastructure Skills Strategy, which included a commitment to 30,000 apprenticeships by the end of the Parliament in the road and rail sectors.⁷⁶ The Higher Education and Research Bill when introduced to the House of Lords⁷⁷ contained provisions which sought to promote new providers of Higher Education to help meet the national skills shortage. The Government hoped these provisions “will level the playing field for high quality new entrants, making it simpler and quicker for innovative and specialist providers to set up, award degrees and compete alongside existing institutions”.⁷⁸ The Technical and Further Education Bill seeks to help “boost the country’s productivity by addressing skill shortages and ensuring high quality technical education”.⁷⁹
73. ***The Government must continue to take action to close the engineering and digital skills gap to ensure that the UK can benefit from the emerging CAV technologies. We welcome the focus on skills in the Government’s Industrial Strategy Green Paper and urge the Government to find innovative solutions to this problem. These might include provisions such as those proposed in the Higher Education and Research Bill which aim to make it simpler and quicker for innovative and specialist providers to set up, award degrees and compete alongside existing institutions.***

74 Select Committee on Digital Skills, *Make or Break: The UK’s Digital Future* (Report of Session 2014–15, HL 111)

75 Written evidence from HM Government ([AUV0084](#))

76 Written evidence from HM Government ([AUV0084](#))

77 [Higher Education and Research Bill](#) [Bill 107 (2016–17)]

78 BEIS, *Higher Education and Research Bill: factsheet*: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/543500/bis-16-285-higher-education-research-bill-summary.pdf [accessed 12 January 2017]

79 [Explanatory notes on the Technical and Further Education Bill](#) [Bill 76 (2016–17)]

CHAPTER 3: POTENTIAL BENEFITS OF CAV

74. Our evidence cited a wide range of potential social and economic benefits connected and autonomous vehicles (CAV) could bring. In this Chapter we consider those benefits most frequently mentioned and those that we believe will have the biggest impact: increased accessibility and mobility; improved road safety; transporting freight; reduced congestion; and economic benefits. The scale of the benefit which might accrue in each case cannot be determined without further research.

Increased accessibility and mobility

75. One of the most frequently cited benefits of CAV was the potential for increased accessibility and mobility for less mobile people unable to use traditional vehicles—such as the elderly or disabled.⁸⁰ The Transport Research Laboratory (TRL) said that CAV “can open up independent mobility for elderly and disabled travellers to help them achieve better health, social and economic outcomes”.⁸¹
76. Michael Hurwitz, Director of Transport Innovation at Transport for London, told us how “the accessibility potential is significant”.⁸² He said that of all Londoners, around 39% used the London Underground every week, but this dropped to 16% for the disabled community and 23% for those over 65.⁸³ CAV have the potential therefore to provide alternative means of transport for those groups.
77. This increased social inclusion was not limited to the less mobile but could also improve public transport in remote rural areas. Transport for Greater Manchester (TfGM) said that CAV could “provide more efficient door-to-door solutions for public transport users and enable mass transit options to access more remote or dispersed communities and out-of-town employment areas, where it is currently unsustainable to provide a traditional public transport scheduled service”.⁸⁴
78. However, Dr Hopkins said that the claim made about the elderly and disabled significantly benefiting from CAV was “particularly problematic”. She said that these benefits would “only accrue with level-5 automation”, which, according to some commentators, “will only become widely available after 2030”.⁸⁵
79. In addition, in the light of their cost premium, Dr Hopkins queried whether CAV would be “affordable and acceptable” to the elderly and disabled.⁸⁶ Claire Depré, Head of the Sustainable and Intelligent Transport Unit in DG

80 [Q 64](#) (John Hayes CBE MP) and written evidence from RazorSecure Limited ([AUV0018](#)), the United Kingdom Atomic Energy Authority (UKAEA) and Remote Applications in Challenging Environments (RACE) ([AUV0032](#)), the British Parking Association (BPA) ([AUV0038](#)) and Weightmans ([AUV0080](#))

81 Written evidence from the TRL ([AUV0039](#))

82 [Q 44](#) (Michael Hurwitz)

83 [Q 44](#) (Michael Hurwitz)

84 Written evidence from TfGM ([AUV0027](#)). See also [Q 44](#) (Darren Capes): “Certainly rural authorities are finding it increasingly hard to provide high-quality bus services into rural communities. The demographic of the rural communities is ageing faster than the city communities, and we face a real issue around how we provide transport for those communities. Autonomy has a real role to play in allowing people currently excluded from car-driving to have some form of personal mobility. For rural communities that is a real plus point.”

85 Written evidence from Dr Debbie Hopkins, University of Oxford ([AUV0021](#))

86 Written evidence from Dr Debbie Hopkins, University of Oxford ([AUV0021](#))

Move at the European Commission, also acknowledged that this technology would be expensive when introduced, and stressed therefore that “we need to think about getting the benefit for society as a whole”.⁸⁷

80. **CAV have the potential to increase accessibility and mobility for those less mobile or those unable to use traditional vehicles, such as the elderly or disabled. However, they may not be suitable for some people with mobility problems, if, for example, they are unable to get into or out of a car without help. Furthermore, these benefits will only be realised with full automation and if the vehicles are both affordable and acceptable to prospective users.**

Improved road safety

81. Another potential benefit expected from CAV was improved road safety. A number of witnesses highlighted that human error is a causal factor in 90–95% of road traffic accidents.⁸⁸ CAV are expected to reduce such errors.
82. There are a number of uncertainties around the 90–95% figure. CAVT Ltd said that this figure came from the US National Highway Transportation Safety Administration (NHSTA) and that it was “unwise to apply USA data directly to UK conditions”, and that for the UK the human error figure in 2013 was considerably lower at 75%.⁸⁹ It arrived at this figure by normalising DfT statistics, though it did not provide details on how this was done.
83. Regardless of the magnitude of the possible reduction of fatalities, our evidence highlighted examples of where CAV technology is already improving road safety.⁹⁰ The Association of British Insurers (ABI) and Thatcham Research told us that “a VW Golf VII fitted with AEB [autonomous emergency braking] technology was involved in 45% fewer insurance claims for third-party injury than equivalent vehicle models that did not have this technology”.⁹¹
84. The potential for increased road safety has also been acknowledged at the EU level. On 30 November 2016, the European Commission adopted *A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility* (see paragraphs 158–163).⁹² The strategy notes how in the very near future vehicles will interact directly with each other and road infrastructure, with such cooperation expected “to significantly improve road safety”.⁹³
85. Referring to the strategy, Ms Depré suggested that in order to achieve increased road safety, the technology must be sophisticated and as good as—if not better—than a human’s ability to drive.⁹⁴

87 [Q 22](#) (Claire Depré)

88 [Q 27](#) (Mike Hawes), [Q 32](#) (John McCarthy and Prof Nick Reed), [Q 64](#) (John Hayes CBE MP) and written evidence from AXA UK ([AUV0017](#)), BMF ([AUV0019](#)), Ageas (UK) Limited ([AUV0042](#)) and the ABI and Thatcham Research ([AUV0051](#))

89 Written evidence from CAVT Ltd ([AUV0061](#))

90 [Q 41](#) (Michael Hurwitz)

91 Written evidence from the ABI and Thatcham Research ([AUV0051](#))

92 European Commission, ‘Intelligent transport systems: Cooperative, connected and automated mobility (C-ITS)’: https://ec.europa.eu/transport/themes/its/c-its_en [accessed 13 December 2016]

93 Communication from the Commission on A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility, [COM\(2016\) 766](#)

94 [Q 22](#) (Claire Depré)

86. 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”.⁹⁵
87. **CAV have the potential to lower the number of road fatalities. But the eradication, or near eradication, of human error will only be realised with full automation. CAV are not the only way to reduce road casualties. There are other means by which to achieve this and we urge the Government not to lose sight of these other possibilities.**

Transporting freight

88. Lorry platooning was highlighted as an early example of CAV close to deployment. Platooning is where one lorry leads and makes the decisions for those behind that are wirelessly connected to form a road-train. The European Commission-funded Safe Road Trains for the Environment (SARTRE) project⁹⁶ has already trialled platooning on three motorway routes in northern Europe.
89. Platooning was said to bring benefits in relation to fuel economy, the environment, safety and congestion.⁹⁷ Mike Wilson, Chief Highways Engineer at Highways England, said: “Potentially it has significant benefits, not only in efficiently moving the lorries around the network—the trials that have been undertaken elsewhere have demonstrated efficiency with vehicles travelling closer together, they are more fuel-efficient because the wind resistance on the following vehicles is less”.⁹⁸ Mike Hawes, Chief Executive Officer of the Society of Motor Manufacturers and Traders (SMMT), told us that “HGVs may be one of the first elements of road transport that will take advantage of [CAV] technologies because ... if you are a road haulage operator, you are very interested in what your pence per mile rate is [and] you can have a benefit in fuel economy by platooning”.⁹⁹
90. However, Charlie Henderson, Partner at PA Consulting Group, told us that he believes there are business model challenges for platooning because it still requires there to be a driver in vehicle: “The business model is, as a fleet operator, you still have a driver sitting in the vehicle, so you are still paying for the driver. Do you pay them less because they are not driving a chunk?”¹⁰⁰
91. Mr Wilson also highlighted potential challenges relating to road maintenance: “[I]f all of these vehicles are travelling in a single wheel path, they could have a bigger impact on the integrity of the road pavement itself ... that part of the road will suffer the greater loads and is likely to need maintenance first.”¹⁰¹
92. ***Our evidence indicates that platooning of trucks could be an early example of CAV deployment on roads and the Government should***

95 Written evidence from Ageas (UK) Limited (AUV0042). See also written evidence from Dr Tom Cohen and Dr Clemence Cavoli, UCL (AUV0070)

96 The SARTRE project: <http://www.sartre-project.eu/> [accessed 16 December 2016]

97 Q 21 (Mike Hawes) and written evidence from the RAC Foundation (AUV0024), Atkins (AUV0047), the SMMT (AUV0058), CIHT (AUV0082) and the RoSPA (AUV0025)

98 Q 49 (Mike Wilson)

99 Q 21 (Mike Hawes)

100 Q 49 (Charlie Henderson)

101 Q 49 (Mike Wilson)

ensure that it carries out an early evaluation of the potential applications of connected and autonomous larger vehicles used for freight and logistics. The Government must ensure that a clear business case for platooning—and indeed for any CAV application—has been made before significant investment is made.

Reduced congestion

93. Many witnesses told us that CAV for the roads sector are expected to improve traffic conditions and reduce congestion.¹⁰² Mr Capes said that there was an “obvious benefit in network optimisation”, with CAV “being able to smooth out the way in which vehicles drive”.¹⁰³ As a result, he said this would “allow vehicles potentially to drive more closely together and allow capacity in the current highway network to be increased”.¹⁰⁴
94. We also heard how the use of data collected by CAV could have a positive impact on reducing congestion.¹⁰⁵ Mr Capes told us that CAV would provide authorities such as York with much bigger data sets, allowing them to do things such as “configure the way urban traffic control works better”.¹⁰⁶ He added that York was involved in a Government-funded trial to see how large data sets could potentially help “influence the way we manage traffic signals in the city and the way we manage congestion”; he described this as “probably a very early win” in the move towards autonomy.¹⁰⁷
95. In its report, *How autonomous vehicles could relieve or worsen traffic congestion*—more detail of which is summarised in Appendix 7—HERE (a business which provides mapping data, technologies and services to the automotive, consumer and enterprise sectors) describes the potential for CAV to help—or hinder—congestion in the short, medium and long term.¹⁰⁸ The type of impact will depend on the level of autonomy enabled and the level of adoption achieved. The report states that the longer-term outlook for CAV is “paradoxically easier to forecast than the medium-term”.¹⁰⁹ This is because, in the medium term, a mixed fleet of vehicles is likely to be operating on UK roads, including vehicles with no autonomous driving technology, vehicles with Advanced Driver Assistance Technology (ADAS) that are capable of autonomous travel in certain circumstances, and vehicles that are wholly autonomous.¹¹⁰
96. **The theoretical potential of CAV to reduce traffic congestion varies depending on the level of vehicle autonomy and the penetration rate. While we cannot say with any certainty what the impact on congestion will be, it is possible to imagine a situation of total gridlock as CAV**

102 Q 22 (Dr Hermann Meyer), Q 49 (Mike Wilson) and written evidence from the RAC (AUV0011), RAC Foundation (AUV0024), the RoSPA (AUV0025), Ageas (UK) Limited (AUV0042), Zurich Insurance plc (AUV0068) and Weightmans (AUV0080)

103 Q 41 (Darren Capes)

104 Q 41 (Darren Capes)

105 Q 54 (Mike Wilson)

106 Q 46 (Darren Capes)

107 Q 46 (Darren Capes)

108 HERE, *How autonomous vehicles could relieve or worsen traffic congestion* (2016): <https://www.acquirepublishing.nl/whitepapers/how-autonomous-vehicles-could-relieve-or-worsen-traffic-congestion.pdf> [accessed 28 December 2016]

109 HERE, *How autonomous vehicles could relieve or worsen traffic congestion* (2016): <https://www.acquirepublishing.nl/whitepapers/how-autonomous-vehicles-could-relieve-or-worsen-traffic-congestion.pdf> [accessed 28 December 2016]

110 Written evidence from Ageas (UK) Ltd (AUV0042)

crawl around city centres. It is important that the right policy decisions relating to CAV are made in order to reduce the likelihood of this occurring.

Economic benefits

97. We heard that CAV could offer a great market opportunity.¹¹¹ Mr Hawes said that the SMMT and KPMG had carried out research in 2015 that put the benefit to the UK economy “at £51 billion to GDP [gross domestic product] per annum”.¹¹² Mr Hawes qualified this figure by saying that only £1–2 billion of that would “naturally accrue to the automotive sector”, with the remaining £49 billion being “up for grabs, given the potential monetisation of connected vehicles, data and issues such as that”.¹¹³
98. Other witnesses provided similar figures. Transport Systems Catapult said that a conservative estimate for the current market opportunity in the UK was £4.8 billion per annum in 2016, rising to £50 billion by 2025.¹¹⁴ The Government’s evidence quoted an industry estimate, which suggested that if the UK could consolidate its early leadership position, “success could be worth up to £51bn annually in socio-economic benefits to the UK by 2030”.¹¹⁵ However, this £51 billion is not predicted to arise from direct financial benefits. The joint report from KPMG and the SMMT, *Connected and Autonomous Vehicles: The UK Economic Opportunity*, which calculated the figure explained:
- “Most of the benefits accrue to consumers who experience a transformation in the ease at which they can travel, which in turn generates wider economic benefits, such as fewer accidents, improved productivity and increased trade.”¹¹⁶
99. Rolls-Royce said that the greater use of autonomous marine vessels could save the global marine industry up to £80 billion per annum by “potential reductions in capital costs, manning costs and fuel costs”.¹¹⁷
100. There was some scepticism about the possible market opportunity. While acknowledging that several “reputable organisations” had offered “fairly firm predictions of future market sizes”, ITS United Kingdom said that there were “too many unknowns”.¹¹⁸ As a consequence, it said it was not possible “to make any firm predictions in monetary terms” and that the figures provided so far “should at most be taken as a very rough guide”.¹¹⁹

111 Written evidence from Ageas (UK) Limited ([AUV0042](#)), CIHT ([AUV0082](#)) and SmarterUK ([AUV0089](#))

112 [Q 21](#) (Mike Hawes)

113 [Q 21](#) (Mike Hawes)

114 Written evidence from Transport Systems Catapult ([AUV0071](#))

115 Written evidence from HM Government ([AUV0084](#))

116 KPMG and the SMMT, *Connected and Autonomous Vehicles: The UK Economic Opportunity* (March 2015): <https://www.smmt.co.uk/wp-content/uploads/sites/2/CRT036586F-Connected-and-Autonomous-Vehicles-%E2%80%93-The-UK-Economic-Opportu...1.pdf> [accessed 12 January 2017]

117 Written evidence from Rolls-Royce ([AUV0083](#))

118 Written evidence from ITS United Kingdom ([AUV0036](#))

119 Written evidence from ITS United Kingdom ([AUV0036](#)). See also written evidence from CIHT ([AUV0082](#)): “However we believe that the scale of the market would depend on the depreciation of current fleet and cost of replacing conventional cars with the technology and the provision of appropriate support infrastructure. It is envisaged that these vehicles will cost more than conventional vehicles as manufactures add the electronic functionality and other complexities needed to operate them therefore impacting on affordability.”

101. While we did receive some evidence on the potential economic disadvantages of CAV, this was minimal and not substantiated. In the main, this evidence suggested that CAV could result in job losses (see paragraph 107).¹²⁰
102. **Whilst some of our evidence has suggested that CAV could have huge economic benefits, we are not convinced that the statistics provided have been properly substantiated.**
103. *We recommend that the Government should commission a detailed cost-benefit analysis to provide a realistic indication of the economic benefits CAV could provide in all sectors, differentiating clearly between the different applications of CAV, actual monetary gains from deployment, estimated job creation and social benefits. This will help the Government decide where the focus of its efforts should be.*
104. One possible economic and social benefit of CAV may be job creation. The SMMT said it estimated up to 320,000 new jobs being created in the UK. Of these new jobs, 25,000 would be created in automotive manufacturing, with the remaining jobs created across adjacent sectors, including the tech sector and telecommunications.¹²¹ It will be important that people have the necessary skills in order to do these new jobs, which may be problematic given the current shortage of key engineering and digital skills (see paragraphs 82–87).
105. When we challenged the SMMT on its estimate of 320,000 new jobs, Mr Hawes explained that it was necessary to distinguish between connected vehicles and autonomous vehicles. He said that while the former would create new jobs, the latter would lead to a shift in jobs.¹²²
106. John Hayes MP expressed a similar view that there would be job shifting. He told us that while he did not think there would be a reduction in employment in net terms, “we may well see change”.¹²³
107. Other witnesses told us that autonomous vehicles would lead to job losses. Enders Analysis said: “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.”¹²⁴
108. ***It is unclear whether CAV will lead to job creation or job losses overall. The cost-benefit analysis that we have recommended should include detailed consideration of the impact of CAV on jobs; specifically whether this will include job losses, job creation or job shifts.***

Lack of evidence for potential benefits

109. The Chartered Institution of Highways & Transportation (CIHT) highlighted that:

“There is relatively little data available to substantiate the listed potential benefits and there [may be] unintended consequences that could provide dis-benefits.”¹²⁵

120 Q 26 (Claire Depré)

121 Written evidence from the SMMT ([AUV0058](#))

122 Q 26 (Mike Hawes)

123 Q 73 (John Hayes CBE MP)

124 Written evidence from Enders Analysis ([AUV0085](#))

125 Written evidence from the CIHT ([AUV0082](#))

110. **There is little hard evidence to substantiate the potential benefits and disadvantages of CAV because most of them are at a prototype or testing stage. Furthermore, as with any new technology or advancements, there may be unforeseen benefits or disadvantages that have not yet presented themselves.**
111. **Nonetheless, the UK's ambition should be to take the lead with CAV in areas where a business case can be made which shows a clear early advantage accruing to the UK.**

CHAPTER 4: FURTHER RESEARCH

112. Whilst connected and autonomous vehicles (CAV) represent an opportunity in many sectors, the Government's strategy to date has largely concentrated on the roads sector. In this Chapter we set out what research and development (R&D), commissioned by the Government and others, needs to be carried out over the short and medium term to ensure the benefits of the deployment of CAV are maximised and potential drawbacks minimised across the roads and other sectors, including agriculture and marine, where the potential benefits of CAV technology are considerable.
113. As far as road transport is concerned, there are two concurrent streams of development—one of connected vehicles and one of fully autonomous vehicles. It is likely that connected vehicles will be seen on UK roads in the short term (the European Commission strategy is working to a three year timeframe, see paragraphs 159–161) whereas fully autonomous vehicles will take much longer to appear.
114. **In considering the necessary future research it is important that the Government plays to the UK's strengths and that the research is not carried out, commissioned or funded by the Government where it is better carried out by industry or other stakeholders. *The Government should not need to invest or take the lead in development of autonomous cars—this is best left to industry. However, the Government should continue to invest in the fundamental scientific research in robotics and information technology that underpins autonomous cars and other CAV, and also the social, human factors and network management problems that must be understood for deployment.***

Testing facilities

115. We heard evidence about the three CAV road trials currently underway, part funded by the Government through Innovate UK (see Box 1), and the A2/M2 connected corridor trial run by the DfT in partnership with Highways England, Kent County Council and Transport for London. The Committee also visited the GATEway project in Greenwich and observed testing of the new autonomous pod vehicle.
116. Professor Nick Reed, Academy Director at the Transport Research Laboratory (TRL), and speaking on behalf of GATEway, stressed the importance of real-world testing environments for CAV, such as those used by the GATEway project.¹²⁶ John McCarthy, Technical Director at Atkins' Intelligent Mobility, and speaking on behalf of the Bristol driverless cars project, told us that there was an opportunity for the UK to “sell capability to the rest of the world” by bringing together a unified offering of test facilities and research projects.¹²⁷
117. The Society of Motor Manufacturers and Traders (SMMT) said that more could be done to expand and improve the UK's demonstration facilities and that the creation of a CAV testing facility would “help promote the UK as a world leader on [the CAV] agenda”.¹²⁸ Furthermore, SmarterUK pointed

126 Q 34 (Prof Nick Reed)

127 Q 33 (John McCarthy)

128 Written evidence from the SMMT (AUV0058)

out that current testing was focussed on urban centres and there was also a need for testing in suburban and rural areas.¹²⁹

118. In July 2015 the Council for Science and Technology, in a letter about capturing value in the CAV industry, recommended to the then Prime Minister, the Rt Hon David Cameron, that the Government should work with business to create the world's first testing facility in a real world environment in a busy UK town where CAV and their networks could be tested. The Council urged the Government to act quickly before the UK is overtaken by its global competitors.¹³⁰
119. We note that the Government announced a prize fund for a town or city to develop a test site for testing of CAV in the Autumn Statement 2013.¹³¹ The Government then consulted on a proposal for a flagship test facility in June and July 2016 and in the Industrial Strategy Green Paper stated that it would publish its proposals in spring 2017.¹³²
120. **We are disappointed that the Government has delayed making a decision on a new flagship test facility. A delay is particularly damaging because CAV development is a fast moving area.**
121. *The Government must put together a comprehensive testing and research offer for CAV to attract manufacturers and academics to the UK immediately. This should include one or more large scale testing environments covering real world urban and rural environments.*

Human factors—better understanding needed

122. Understanding how CAV will affect the behaviour of drivers, pedestrians, cyclists and other road-users will be important in developing both the technology that will underpin CAV and the policy for their deployment. The changes in human behaviour needed to interact with CAV could be significant. The evidence shows that there is still much work to be done in this area and that current knowledge is limited. The Government commissioned a scoping study to understand the main social and behavioural questions relating to CAV. This identified nearly 400 open questions and concluded that behavioural aspects of CAV have been under-researched.¹³³
123. Professor Natasha Merat, from the Institute for Transport Studies at the University of Leeds, told us that, until recently, pedestrians' understanding of CAV had been largely ignored because it is a very complicated topic—cultural and regional differences in pedestrian and cyclists' behaviour are complex for human drivers to understand, let alone the sensors and cameras of a CAV.¹³⁴ Professor Sarah Sharples, Associate Faculty Pro-Vice-Chancellor

129 Written evidence from SmarterUK ([AUV0089](#))

130 Council for Science and Technology, Letter to the Prime Minister 'Capturing value in the Autonomous and Connected vehicles industry: an ambitious plan for the UK', (23 July 2015): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/459521/cst-15-1-driverless-vehicles.pdf [accessed 5 January 2017]

131 HM Treasury, *Autumn Statement 2013*, Cm 8747, December 2013: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/263942/35062_Autumn_Statement_2013.pdf [accessed 9 February 2017]

132 BEIS and Innovate UK, *Driverless vehicle testing facilities: call for evidence* (26 May 2016): <https://www.gov.uk/government/consultations/driverless-vehicle-testing-facilities-call-for-evidence> [accessed 5 January 2017]

133 Supplementary written evidence from HM Government ([AUV0095](#))

134 Supplementary written evidence from Prof Natasha Merat ([AUV0092](#))

for Research & Knowledge Exchange and Professor of Human Factors at the University of Nottingham, pointed out that risks to CAV users' safety may arise as a consequence of other road users adapting their behaviour in response to CAV being on the road.¹³⁵ The TRL said that “pedestrians, cyclists, sensory impaired groups and other road users may also need to adapt their behaviour and expectations to accommodate the conduct of the various types of automated vehicle”.¹³⁶ For example, it could be the case that pedestrians would become complacent and assume that CAV would avoid them, thereby crossing roads at any point.¹³⁷

124. Level 3 autonomy (see Figure 1) may require CAV to hand back control of the vehicle to the driver when it is unable to deal with a certain situation. We received evidence suggesting that handing back in this way to a potentially unprepared driver could be very dangerous.¹³⁸ Professor Neville Stanton explained:

“As vehicles become fully autonomous, even the most observant human driver’s attention will begin to wane. Their mind will wander ... This is particularly true if they are engaging in other activities such as reading, answering emails, engaged in conversations with passengers, watching movies or surfing the internet.”¹³⁹

125. Steve Gooding, Director of the RAC Foundation, expressed a concern that “at some point ... the driver is not driving enough to be properly in control of the vehicle”. He said that he was concerned that a vehicle could hand back control to the driver who, for example, “might well be asleep at the time”.¹⁴⁰ He went on to say that the risks inherent in a handover could be managed by skipping this level of automation altogether and requiring that an autonomous vehicle has to be capable of coping with any circumstances it encounters before being allowed on the road.¹⁴¹ Mr Wilson added that the handover is “a significant challenge ... it is certainly a question we will need to answer before [the trials on the strategic road network] go live.”¹⁴²
126. Professor Stanton told us that research had found that drivers of automated vehicles were generally not as effective in emergencies as drivers of manual vehicles. In simulated emergencies, up to a third of drivers of automated vehicles did not recover the situation, whereas almost all drivers of manual vehicles in the same situation were able to do so. In addition, research showed that drivers of automated vehicles took, on average, six times longer to respond to emergency braking of other vehicles compared to manual drivers.¹⁴³
127. Professor Sharples said her research had found similar results.¹⁴⁴ She said that it was important to understand the implications of increased autonomy

135 Written evidence from Prof Sarah Sharples and colleagues, University of Nottingham ([AUV0049](#))

136 Written evidence from the TRL ([AUV0039](#))

137 [Q 6](#) (Ian Yarnold) and written evidence from Prof Sarah Sharples and colleagues, University of Nottingham ([AUV0049](#))

138 Written evidence from Prof Sarah Sharples and colleagues, University of Nottingham ([AUV0049](#))

139 Written evidence from Prof Neville Stanton, University of Southampton ([AUV0029](#))

140 [Q 48](#) (Steve Gooding)

141 [Q 49](#) (Steve Gooding)

142 [Q 49](#) (Mike Wilson)

143 Written evidence from Prof Neville Stanton, University of Southampton ([AUV0029](#))

144 [Q 57](#) (Prof Sarah Sharples)

on the capability of humans to maintain vigilance and attention in order to be able to respond to an emergency situation.¹⁴⁵

128. Behavioural studies form part of the three CAV road trials outlined earlier (see Box 1), in particular the VENTURER trial in Bristol, Mr McCarthy told us was “looking to focus on the individuals, on understanding the behaviours and the relationship between people and autonomous vehicles, while not neglecting the need to understand the technology aspect of it”.¹⁴⁶
129. Professor Reed told the Committee that as part of the GATEway project in Greenwich (see Box 1), his team were using a driving simulator to investigate the behaviour of drivers of manual vehicles in the presence of CAV.¹⁴⁷ Furthermore, Professor Sharples advocated the use of simulation facilities, saying they were “critically important for both research and technology development. They have a very strong role in enabling researchers and companies to understand user behaviour and develop autonomous vehicles that are appropriate for use”.¹⁴⁸ We had the opportunity to experience a driving simulator first hand during our visit to the GATEway project in Greenwich.
130. Professor Merat told us that it will be important to think about driver licencing for CAV and whether there will be a need for driver training, including for those drivers who already have licences for conventional vehicles.¹⁴⁹ Furthermore, Professor Sharples said “we need to ... maintain the understanding that people have an appropriate level of competence through a driving test. Even with fully automated vehicles we need to build in for the contingency that the driver will need to take control”.¹⁵⁰ Professor Sharples also told us that there is a need to consider that a driving test may need to test an understanding of how a CAV will behave and not just control of a vehicle.¹⁵¹
131. **CAV could have negative implications for drivers’ competence, making drivers complacent and overly reliant on technology. This is of particular concern in emergency situations, where a driver may react slowly to taking back control of a vehicle. It may be the case that for Level 3 vehicles the risks will be too great to tolerate. The risk of complacency also extends to other road-users who will interact with CAV, such as pedestrians and cyclists. Further research is necessary to understand these risks, including possible measures to address them.**
132. *We recommend that the Government should give priority to commissioning work to understand the main social and behavioural questions relating to CAV, in particular answering those questions identified by its own scoping study. This work should build on international research in this area. Furthermore Innovate UK and Government departments should ensure that studying behavioural aspects is an integral part of trials they fund, including access to simulation facilities if necessary.*

145 [Q 56](#) (Prof Sarah Sharples)

146 [Q 32](#) (John McCarthy)

147 [Q 32](#) (Prof Nick Reed)

148 Written evidence from Prof Sarah Sharples and colleagues, University of Nottingham ([AUV0049](#))

149 [Q 60](#) (Prof Natasha Merat)

150 [Q 60](#) (Prof Sarah Sharples)

151 [Q 60](#) (Prof Sarah Sharples)

Modelling of a mixed fleet

133. The impact of a mixed fleet on the UK road network, including the effect on congestion, needs to be understood. This understanding could be developed through the modelling of various scenarios, including different levels of penetration of CAV and variations in the degree of cautious or assertive behaviour by CAV, building on the modelling work carried out by Atkins for the Government in the January 2017 report *Research on the Impacts of Connected and Autonomous Vehicles (CAV) on Traffic Flow*. This would stand alongside the work done in real-life trials of autonomous vehicles (see Box 1).
134. The Atkins report concluded that the likely tipping point for the proportion of CAV to produce major traffic flow benefits may be between 50% and 75%.¹⁵² The Government told us that the research had shown that “CAV offer major potential to reduce delays, improve journey times and improve journey reliability on strategic and urban road networks”. However, the findings also highlighted that “these benefits are not a given”, and depended heavily “on the proportion of CAV in the fleet”.¹⁵³ The report also concluded that initially, early models of CAV would act more cautiously and that the result could be a “potential decrease in effective capacity”.¹⁵⁴
135. Mr Capes highlighted why this kind of modelling work is important, saying that “most local authorities ... have very little understanding of how a mixed fleet could operate on the UK road network”.¹⁵⁵ Dr Hermann Meyer, Chief Executive Officer of ERTICO-ITS Europe, indicated a need to think carefully about a mixed fleet transition period and to develop a clear strategy for it.¹⁵⁶
136. We asked a number of our witnesses, including Mr Wilson, Mr Capes and Mr Hurwitz, about modelling, but they did not mention any specific work in this area in the UK or the work on micro-scale modelling carried out by Atkins on behalf of the Government.¹⁵⁷ Mr Forbes told us that the Centre for Connected and Autonomous Vehicles (CCAV) had done some modelling, but it was still at a very early stage. He went on to say that CCAV are keen to develop that work in the future and to build the evidence base over time.¹⁵⁸
137. **We welcome the modelling work commissioned by the Government. This should be a starting point for further work on mixed fleet modelling to inform policy development. *This work should help to counter the possible disadvantages and negative effects of managing a mixed fleet of autonomous and non-autonomous vehicles. The research on human factors must feed in to the modelling work so that as more is understood about human interactions with CAV, the modelling work can be refined to give more accurate results.***

152 DfT, *Research on the Impacts of Connected and Autonomous Vehicles (CAVs) on Traffic Flow: Summary Report* (May 2016): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/530091/impacts-of-connected-and-autonomous-vehicles-on-traffic-flow-summary-report.pdf [accessed 9 January 2017]

153 Supplementary written evidence from HM Government (AUV0095)

154 BBC, ‘Driverless cars ‘to increase congestion’ says government’, (accessed 6 January 2017): <http://www.bbc.co.uk/news/uk-38533517> [accessed 9 January 2017]

155 Q 41 (Darren Capes)

156 Q 21 (Dr Hermann Meyer)

157 Q 53 (Mike Wilson) and Q 45 (Darren Capes)

158 Q 2 (Iain Forbes)

138. *We were surprised that the work the Government has commissioned on micro-scale modelling was not more widely known by our witnesses. The Government should take steps to ensure future work in this area is more prominently planned and shared with stakeholders including LTAs.*

Agriculture sector

139. Professor Blackmore told us that CAV could lead to changes in how farming is carried out in the UK, with the benefit of making the crop production system significantly more efficient.¹⁵⁹ Professor Newman gave the example of a vehicle that can ‘see’ and apply herbicide to just the weeds and not to the crop.¹⁶⁰ SmarterUK told us: “Advances in this technology have the potential to make agriculture significantly more efficient.”¹⁶¹ Professor Blackmore also told us that CAV have the potential to make smaller farms more economical because agricultural CAV are likely to be much smaller than current farm machinery.¹⁶²
140. In 2013 the Government launched a long term agri-tech strategy with initial funding of £160 million for R&D.¹⁶³ Further funding has since been made available through the strategy. However, Professor Blackmore told us that he was concerned that the funding under the strategy is diminishing and that there will not be enough research funding available in the agriculture sector to realise the potential benefits of CAV for the agriculture sector.¹⁶⁴ He told us that he would like to see agri-tech as a named area for research within the Industrial Strategy, “because the opportunity for British agriculture is so huge. If the funding were to slow down or stop then a lot of this innovation would slow down and we would not overcome the disruption [to agriculture]”.¹⁶⁵
141. *The potential for improved crop production and reduced adverse impacts on the environment by the use of CAV in agriculture is considerable. The Government should fund appropriate R&D once a business case is made which demonstrates the advantages which will accrue.*

159 Written evidence from Prof Simon Blackmore, Harper Adams University (AUV0034)

160 Written evidence from Prof Paul Newman, University of Oxford (AUV0041)

161 Written evidence from SmarterUK (AUV0089)

162 Q 19 (Prof Simon Blackmore)

163 HM Government, *A UK Strategy for Agricultural Technologies* (July 2013): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/227259/9643-BIS-UK_Agri_Tech_Strategy_Accessible.pdf [accessed 12 January 2017]

164 Written evidence from Prof Simon Blackmore, Harper Adams University (AUV0034)

165 Q 14 (Prof Simon Blackmore)

CHAPTER 5: INTERNATIONAL COOPERATION, REGULATION AND STANDARDS

142. Many of the issues which need to be addressed in order for the UK to gain full benefit from connected and autonomous vehicles (CAV) will require action within the UK. But CAV are being tested and deployed in countries around the world, and so globally agreed regulations and standards will be required to help address these issues and allow the full benefits of CAV to be realised. We consider these issues in this Chapter.

Cybersecurity

143. We were told that CAV could be susceptible to hacking and used for malicious purposes. CAVT Ltd said that CAV could be used for criminal or terrorist purposes, “such as delivering drugs, firearms or explosives as a car bomb, kidnapping [or] driving into crowds of people”.¹⁶⁶ Of course conventional vehicles can and are used for all of these activities, however, there is a risk that it will be easier to use a CAV because—at the risk of stating the obvious—they do not require a driver.
144. The insurance specialist law firm Weighmans used the analogy of cars “morphing into mobile computers with wheels and an engine”.¹⁶⁷ There have already been examples of CAV being vulnerable to cybersecurity risks. In September 2016, there were reports that a team of hackers were able to take remote control of a Tesla Model S from a distance of 12 miles away. The hack involved “interfering with the car’s brakes, door locks, dashboard computer screen and other electronically controlled features”.¹⁶⁸
145. As noted by Weighmans, Tesla was fortunate in this instance, “as this was a so called ‘ethical hack’ where the hackers were looking for holes in the IT security system of the car and immediately reported their findings to Tesla”.¹⁶⁹ However, such cases highlight a real risk in using CAV. Weighmans summarised this concern:
- “[T]hey [CAV] are vulnerable to the same cyber attacks as our home computers ... It is not difficult to envisage hackers causing a multi vehicle accident by hijacking the connected cars.”¹⁷⁰
146. A number of witnesses stressed the importance of the Government taking a strong coordinating role with regard to cybersecurity, and emphasised the importance of communicating with the relevant stakeholders and industry experts.¹⁷¹
147. Transport for West Midlands said that the Government was “the only body that can take a central coordinating role”¹⁷² and that decisions “cannot be left to the industry, EU and international standards coordination or the devolved

166 Written evidence from CAVT Ltd (AUV0061)

167 Written evidence from Weighmans (AUV0080)

168 ‘Team of hackers take remote control of Tesla Model S from 12 miles away’, *The Guardian* (20 September 2016): <https://www.theguardian.com/technology/2016/sep/20/tesla-model-s-chinese-hack-remote-control-brakes> [accessed 29 December 2016]

169 Written evidence from Weighmans (AUV0080)

170 Written evidence from Weighmans (AUV0080)

171 Written evidence from Starship Technologies Ltd (AUV0072) and Transport for West Midlands (AUV0075)

172 Written evidence from Transport for West Midlands (AUV0075)

local highway authorities alone”.¹⁷³ A similar collaborative approach was advocated by Transport for Greater Manchester (TfGM).¹⁷⁴

148. Dr Meyer told us that cybersecurity would be a major and ongoing challenge.¹⁷⁵ Our evidence highlighted the role of manufacturers in cybersecurity.¹⁷⁶ RazorSecure Limited said that hardware and software manufacturers and operators should be required to put in place “a multi-layered approach featuring techniques such as firewall, encryption, intrusion detection and active response even when not connected”.¹⁷⁷
149. In the *National Cyber Security Strategy 2016–2021* the Government stated that further research into cybersecurity for autonomous systems may be funded through the upcoming Cyber Science and Technology Strategy.¹⁷⁸
150. *We recommend that funding is allocated for cybersecurity of CAV through the upcoming Cyber Science and Technology Strategy. Cybersecurity should also form an integral part of the Government’s review of the regulatory framework for CAV.*
151. *The Centre for Connected and Autonomous Vehicles (CCAV) is well placed to take a coordinating role with regard to cybersecurity for CAV. It should involve the newly established National Cyber Security Centre in this work as well as external stakeholders and experts.*
152. *An international effort is necessary to tackle the risks associated with cybersecurity, which are likely to rise—especially on a global scale—as the use of CAV increases. The Government could lead on this, in order to facilitate the establishment of global standards.*

Infrastructure

153. We were told that realising the full benefits of CAV is likely to require new road and communications infrastructure. But CAV technology is not yet sufficiently developed to enable a precise description of these changes.
154. Nonetheless, we were told that consideration should be given now to the types of infrastructure required to avoid expensive retro-fitting of infrastructure in the short to medium term. The Transport Systems Catapult said that “infrastructure that is being imagined, designed, and built now, needs to have capability for future compatibility and functionality built-in from the get go”.¹⁷⁹ A similar point was made by PA Consulting.¹⁸⁰
155. Professor Newman said that infrastructure changes should not be seen as a precursor to autonomy and any useful infrastructure changes would be driven by the market and not by the Government. Others, however, including CAVT Ltd, pointed to a requirement for a large investment in standardisation of the UK roads infrastructure:

173 Written evidence from Transport for West Midlands (AUV0075)

174 Written evidence from TfGM (AUV0027)

175 Q 26 (Dr Hermann Meyer)

176 Written evidence from the RoSPA (AUV0025)

177 Written evidence from RazorSecure Limited (AUV0018)

178 HM Government, *National Cyber Security Strategy 2016–2021* (2016): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/567242/national_cyber_security_strategy_2016.pdf [accessed 18 January 2017]

179 Written evidence from Transport Systems Catapult (AUV0071)

180 Written evidence from PA Consulting Group (AUV0008)

“[M]ore needs to be spent on upgrading all classes of road and communications, including standardisation of road layouts, traffic control, etc. in urban canyons, tunnels and remote rural areas.”¹⁸¹

156. Mobile coverage on UK roads will need to be improved to take full advantage of the possibilities of connected vehicles. In December 2016 Ofcom published its report, *Connected Nations 2016*, which stated that in 2016 6% of UK A and B roads did not have mobile voice coverage and 20% of UK A and B roads did not have 4G mobile data coverage—although this has improved from 10% and 47%, respectively, in 2015.¹⁸² The Society of Motor Manufacturers and Traders (SMMT) told us that only 48% of British roads have full 3G coverage and 18% have full 4G coverage.¹⁸³
157. The Rt Hon John Hayes MP told us that those areas that have poor mobile and broadband coverage could potentially become more isolated in the future if CAV relied on those technologies. He went on to say “I am very determined to make sure that does not happen by the steps the Government can take.”¹⁸⁴

European Commission strategy

158. On 14 April 2016 the Transport Ministers of all 28 EU member states signed the Amsterdam Declaration on Cooperation in the field of connected and automated driving.¹⁸⁵ The declaration contained an agreement to work towards a coherent European framework for the deployment of interoperable connected and automated vehicles; it also recognised the need for Europe-wide cooperation in order to maximise the potential benefits of the technology and ensure compatibility across borders.
159. The declaration was followed by the publication of a strategy by the European Commission, *A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility*, on 30 November 2016.¹⁸⁶ The aim of the strategy is to allow for the deployment of connected vehicles that communicate with each other and on-road infrastructure in Europe by 2019. An appropriate EU level legal framework will be adopted by 2018.¹⁸⁷
160. The strategy states that a hybrid mix of communication technologies is needed to support connected vehicles and the current most promising mix is existing mobile networks and ETSI ITS-G5. ETSI ITS-G5 is a European standard for wireless vehicle to vehicle and vehicle to roadside infrastructure communication.¹⁸⁸

181 Written evidence from CAVT Ltd (AUV0061)

182 Ofcom, *Connected Nations 2016* (16 December 2016): https://www.ofcom.org.uk/_data/assets/pdf_file/0035/95876/CN-Report-2016.pdf [accessed 9 January 2017]

183 Written evidence from the SMMT (AUV0058)

184 Q 71 (John Hayes CBE MP)

185 The Netherlands EU Presidency 2016, *Declaration of Amsterdam: Cooperation in the field of connected and automated driving* (14 April 2016): <https://english.eu2016.nl/documents/publications/2016/04/14/declaration-of-amsterdam> [accessed 10 January 2017]

186 Communication from the Commission on A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected and automated mobility, COM(2016) 766

187 European Commission, ‘Intelligent transport systems: Commission presents a Strategy towards cooperative, connected and automated mobility’ (30 November 2016): http://ec.europa.eu/transport/themes/its/news/2016-11-30-c-its-strategy_en [accessed 5 January 2017]

188 European Commission, ‘Intelligent transport systems: Commission presents a Strategy towards cooperative, connected and automated mobility’ (30 November 2016): http://ec.europa.eu/transport/themes/its/news/2016-11-30-c-its-strategy_en [accessed 5 January 2017]

161. Ms Depré told us that connected vehicles will be an essential step to realising the benefits of automation and this is why the Commission has developed a strategy for deployment of connected vehicles by 2019.¹⁸⁹ It remains to be seen what impact, if any, Brexit will have on this.
162. *Highways England and Local Transport Authorities should jointly engage with the industry to examine the potential for ensuring that new infrastructure can be future-proofed and does not need expensive retro-fitting.*
163. *The Government must take action with Highways England to improve digital connectivity, removing ‘not-spots’ on British roads—in particular on the strategic road network—in order to realise the benefits of connected vehicles, which, according to the European Commission, are likely to become available in the next three years. This can be done through the Digital Economy Bill and the implementation of the Universal Service Obligation to create a ubiquitous digital network. It will also require work at an international level to ensure the development of international standards relating to connected vehicles.*

Data governance and use

164. A large amount of data is already collected from vehicles—for example location data from satellite navigation systems—and this is likely to grow as CAV become more widely available.¹⁹⁰ We received evidence that exploiting such data could lead to a number of benefits for transport authorities and road users—such as monitoring infrastructure condition or improving traffic signal performance¹⁹¹—but the use of this data also raises a number of issues around privacy and data protection.
165. The Information Commissioner’s Office (ICO) is responsible for enforcing the Data Protection Act 1998, which governs the use of personal data. The ICO plans to issue a call for evidence on CAV to develop understanding of public attitudes towards the technology and to find out what steps vehicle manufacturers and technology providers are taking to address data protection concerns.¹⁹²
166. The ICO said that if the personal data of vehicle drivers and users such as in the case of geolocation data was processed inappropriately, there was “a heightened risk of intrusion into individuals’ work and private lives”. It therefore advocated that the Government and technology providers adopt a “privacy by design approach” and “ensure that privacy protections are built in to the design and development of new products and services”.¹⁹³
167. The ICO told us that it would “welcome the opportunity to engage with the Government, the Department for Transport and CCAV to help ensure the [data protection] issues identified are adequately addressed”.¹⁹⁴ Similarly, the Government’s response to the House of Commons Transport Committee report, *Motoring of the future*, said that the Government would liaise with

189 Q 22 (Clare Depré)

190 Supplementary written evidence from White Willow Consulting (Andy Graham) (AUV0094)

191 Supplementary written evidence from White Willow Consulting (Andy Graham) (AUV0094)

192 Written Evidence from the ICO (AUV0066)

193 Written evidence from the ICO (AUV0066)

194 Written Evidence from the ICO (AUV0066)

the ICO to ensure that consumers can be confident that data are being used appropriately.¹⁹⁵

168. The legal framework for data protection will change with the implementation of the EU General Data Protection Regulation (GDPR) from 2018. It is as yet unclear what impact Brexit will have on the continued implementation of the EU GDPR. However, any replacement is likely to require international cooperation and agreements with both the EU and other countries because of the global nature of data usage and storage.
169. **It is essential that any data gathered from CAV are used in accordance with data protection law. We welcome the fact that the Information Commissioner's Office (ICO) has undertaken initial work with vehicle manufacturers, and is launching its own call for evidence.**
170. **However, the meaning of personal data is unclear in the context of CAV. It will be important to achieve privacy for individuals and communities, while using data to achieve efficiency and safety of CAV operations. Data relating to an individual's CAV in terms of position, speed and performance on the road cannot be regarded as entirely personal—such data is needed for public benefit if a CAV system is to operate as a whole. Good data governance will therefore be needed to secure appropriate protection of personal information while safely using and linking open and non-sensitive data. Distinctions will need to be made between commercially sensitive data owned by technology providers and open data.**
171. *We recommend that the Government liaise with the ICO, automotive manufacturers and other interested parties, including international partners, to ensure that CAV and the data they produce comply with the relevant privacy and data protection legislation and that this legislation is appropriate and workable, and keeps pace with the technology.*
172. It is likely that insurance companies and the Police will need access to data when CAV are involved in an accident in order to ascertain what happened, and who (or what) was at fault, as highlighted in evidence from the Association of British Insurers.¹⁹⁶
173. We heard from Ian Yarnold, Head of International Vehicle Standards Division at the DfT, that international discussions at the UN Economic Commission for Europe are at an early stage, but that he expected standards for data storage to emerge in the short term.¹⁹⁷
174. We were also told about the importance of the Police being able to interrogate stored data in the event of an accident.¹⁹⁸ Mr Gooding told us that he did not think that the software was sufficiently user-friendly as to enable the Police to get answers to the type of questions they may ask after an accident.¹⁹⁹

195 Transport Committee, *Motoring of the future: Government response to the Committee's Eighth Report of Session 2014–15* (Second Special Report, Session 2015–16, HC 349)

196 Written evidence from the ABI and Thatcham Research ([AUV0051](#))

197 [Q 9](#) (Ian Yarnold)

198 Written evidence from PA Consulting Group ([AUV0008](#)) and Keoghs LLP ([AUV0014](#))

199 [Q 54](#) (Steve Gooding)

175. *We welcome the Government’s work at an international level to draw up standards for data retention in the event of an accident involving CAV. These standards will ensure that manufacturers provide access to the necessary data in the case of an accident. The Government must also ensure that the Police and the wider criminal justice system have the necessary skills, tools and access to be able to appropriately interrogate the stored data.*

Ethical issues

176. We were told that the increase in the development and deployment of CAV would also raise ethical issues. The main ethical issue raised was the moral dilemma, in which a fatal collision is imminent and a CAV must, based on its prior programming, ‘choose’ who to save—often referred to as the ‘trolley problem’.²⁰⁰
177. In the context of CAV, the problem centres on whether an autonomous vehicle should act to protect the passengers, or external parties (such as pedestrians).
178. Consequently, there is a conundrum faced by car manufacturers, buyers and regulators. Professor Newman highlighted a recent paper, *The social dilemma of autonomous vehicles*, which found that “even though participants approve of autonomous vehicles that might sacrifice passengers to save others, respondents would prefer not to ride in such vehicles”.²⁰¹
179. There was a divergence of views amongst our witnesses regarding how these ethical issues should be addressed.
180. On the one hand, some of our witnesses said it was not only possible to programme CAV to be able to make these decisions, but that this could also be a good thing.²⁰² Ageas (UK) Limited said that CAV should be programmed “to avoid getting into situations in which a choice of this nature needs to be made”.²⁰³ They said that CAV could, for example, be prevented from driving faster than a speed that enables them to stop for or avoid an obstacle that might present itself in the road. This is called ‘defensive driving’.²⁰⁴
181. Several witnesses subsequently argued that there should be some form of code of practice or set of internationally recognised standards and norms.²⁰⁵ Professor David Lane told us:

“Engineers alone should not be left to programme behaviours into robots that cross ethical boundaries ... A culture of ethical concern should be encouraged across the international R&D [research and development]

200 [Q 34](#) (John McCarthy). The ‘trolley problem’ (or ‘trolley dilemma’) consists of a series of hypothetical scenarios developed by British philosopher Philippa Foot in 1967. The general form of the problem is this: there is a runaway trolley barrelling down the railway tracks. There are five people tied up ahead on the tracks and unable to move. The trolley is headed straight for them; you are standing some distance off, next to a lever. If you pull this lever, the trolley will switch to a different set of tracks. However, you notice that there is one person on the side track. You therefore have two options: (1) Do nothing, and the trolley kills the five people on the main track; or (2) Pull the lever, diverting the trolley onto the side track where it will kill one person. Which is the most ethical choice?

201 Written evidence from Prof Paul Newman, University of Oxford ([AUV0041](#))

202 Written evidence from Prof Paul Newman, University of Oxford ([AUV0041](#))

203 Written evidence from Ageas (UK) Limited ([AUV0042](#))

204 Written evidence from Ageas (UK) Limited ([AUV0042](#))

205 Written evidence from the BMF ([AUV0019](#)), Peak Power ([AUV0043](#)), the Royal Aeronautical Society ([AUV0077](#)) and SmarterUK ([AUV0089](#))

community. This requires an international effort and the evolution of ethical counsels to provide the reference guidelines and standards.”²⁰⁶

182. On the other hand, others disagreed and believed that such an approach was not achievable or desirable. The Institute and Faculty of Actuaries (IFoA) highlighted the challenge of pre-programming a decision for CAV, because “how can the so-called ‘lesser of two evils’ be determined?”²⁰⁷
183. This raises the question of whether there will be approved ethical processes to be checked as part of Type Approval and how after-market fitting of autonomous systems to existing vehicles can be regulated.²⁰⁸ Moreover, there would be questions over whether different countries might impose different ethical requirements for CAV to operate on their roads. This might cause difficulties when people take their vehicles abroad.
184. A number of witnesses expressed an entirely different view, believing that the ethical discussion surrounding CAV was over-emphasised and artificial.²⁰⁹ ITS United Kingdom said that there were “urban myths” in this area “about whether an AV [autonomous vehicle] will be programmed to kill a child or a pensioner, whether it will care about dogs, and so on”.²¹⁰
185. Other witnesses did not offer an opinion on the severity or means to address these ethical issues, but said further research was necessary. As noted by IAM RoadSmart, the debate on the moral issues around CAV “has only just started and needs to be much wider and more transparent”.²¹¹ Professor Sharples in her written evidence argued that “before deciding on such a philosophical definition of human judgement, we need research into what human drivers actually do in an emergency before judging algorithms”.²¹² We discussed human factors in more detail in Chapter 4 (paragraphs 122–132).
186. **The increased development and deployment of CAV raises ethical issues. The Government should keep this in mind as it takes forward its programme of regulatory reform for CAV, including taking a leading role in the development of international standards to address the ethical issues. These standards will need to ensure that companies are transparent about the way vehicles deal with these issues.**

Marine sector

187. In the marine sector, autonomous vehicles are being developed on several scales, from small remotely operated subsea gliders to unmanned cargo ships. Applications include commercial shipping, naval and defence, oil and gas and offshore renewables and marine science sectors.
188. IMarEST told us that regulation is the biggest challenge for autonomous marine vehicles.²¹³ Maritime regulations are agreed through the International Maritime Organisation. IMarEST went on to say that the UK is at “the forefront of this effort [to agree international regulation of autonomous

206 Written evidence from Prof David Lane CBE ([AUV0050](#))

207 Written evidence from the IFoA ([AUV0059](#))

208 Type Approval is the confirmation that production samples of a design will meet specified performance standards. The specification of the product is recorded and only that specification is approved.

209 Written evidence from Mills & Reeve LLP ([AUV0035](#)) and the SMMT ([AUV0058](#))

210 Written evidence from ITS United Kingdom ([AUV0036](#))

211 Written evidence from IAM RoadSmart ([AUV0022](#))

212 Written evidence from Prof Sarah Sharples and colleagues, University of Nottingham ([AUV0049](#))

213 Written evidence from the IMarEST ([AUV0064](#))

marine vehicles] through the work of the Maritime Autonomous Systems Regulatory Working Group, supported and driven by both the private sector and government agencies, in particular the Maritime & Coastguard Agency”.²¹⁴

189. *We welcome the UK’s leading role in the development of international regulation for marine autonomous vehicles and encourage the Government to continue to drive forward this initiative. There is potential for significant early benefit to accrue to the UK once a new international regulatory framework is in place.*

214 Written evidence from the IMarEST ([AUV0064](#))

APPENDIX 1: LIST OF MEMBERS AND DECLARATIONS OF INTEREST

Members

Lord Borwick
 Lord Cameron of Dillington
 Lord Fox
 Lord Hennessy of Nympsfield
 Lord Hunt of Chesterton
 Lord Mair
 Lord Maxton
 Baroness Morgan of Huyton
 Baroness Neville-Jones
 Lord Oxburgh
 Viscount Ridley
 Earl of Selborne (Chairman)
 Lord Vallance of Tummel
 Baroness Young of Old Scone

Declaration of Interests

Lord Borwick
Chairman, GATEway Project Advisory Group (Greenwich automated vehicle project) (non-financial interest)

Lord Cameron of Dillington
Part-owner of Dillington Estate, a mixed agricultural estate in Somerset

Lord Fox
Employed by GKN plc
Owns shares in GKN plc and Smiths Group plc

Lord Hennessy of Nympsfield
Fellow, British Academy

Lord Hunt of Chesterton
Fellow, Royal Society
Director of Cambridge Environmental Research Consultants (CERC) Ltd

Lord Mair
Professor of Civil Engineering, Cambridge University
Chair of the Department for Transport's Science Advisory Council
Fellow, Royal Academy of Engineering
Fellow, Royal Society
President-elect, Institution of Civil Engineers

Lord Maxton
No relevant interests declared

Baroness Morgan of Huyton
Vice Chair of Council, King's College, University of London

Baroness Neville-Jones
Member of the Engineering and Physical Sciences Research Council (EPSRC), which funds research into robotics and autonomous vehicles

Lord Oxburgh
No relevant interests declared

Viscount Ridley
Owner of Blagdon Farming Ltd (farming)
Speaking fee, Google, 2016, Dublin

Earl of Selborne

*Honorary Fellow, Institution of Engineering and Technology
Shareholder in Blackmoor Estate Ltd (farming)*

Lord Vallance of Tummel

No relevant interests declared

Baroness Young of Old Scone

Chancellor of Cranfield University which has a number of funded projects in the field of autonomous vehicles. Some of the funding comes from the Government.

A full list of Members' interests can be found in the Register of Lords' Interests: <http://www.parliament.uk/mps-lords-and-offices/standards-and-interests/register-of-lords-interests/>

Specialist Adviser

Professor Eric Sampson CBE, Visiting Professor at Newcastle University and City University London

In receipt of pension from the Department for Transport (DfT)

President of the International ITS Benefits/Costs Collaboration (IBEC)—

No remuneration of any sort

Global Ambassador of ITS (UK)—No remuneration of any sort

Adviser/organiser of ITS Congresses for ERTICO—ITS Europe—Monthly retainer plus reimbursement of actual travel and accommodation costs

Adviser to the European Commission; member of the Cooperative ITS Platform—No remuneration of any sort

Visiting Professor at Newcastle University, City University London and Westminster University—No remuneration of any sort

Adviser to Finland Government—Reimbursement of actual travel and accommodation costs.

APPENDIX 2: LIST OF WITNESSES

Evidence is published online at <http://www.parliament.uk/autonomous-vehicles> and available for inspection at the Parliamentary Archives (020 7219 3074).

Evidence received by the Committee is listed below in chronological order of oral evidence session and in alphabetical order. Those witnesses marked with ** gave both oral evidence and written evidence. Those marked with * gave oral evidence and did not submit any written evidence. All other witnesses submitted written evidence only.

Oral evidence in chronological order

- | | | |
|----|--|--------------------------|
| ** | Ian Yarnold, Head of International Vehicle Standards Division, Department for Transport (DfT) | QQ 1–10 |
| * | Iain Forbes, Head of the UK Government’s Centre for Connected and Autonomous Vehicles (CCAV), Department for Transport (DfT) | |
| ** | Dr Rob Buckingham FREng, Director, UK Atomic Energy Authority (UKAEA) | QQ 11–19 |
| ** | Professor Simon Blackmore, Head of Engineering, Harper Adams University | |
| * | Claire Depré, Head of Sustainable and Intelligent Transport Unit, DG MOVE, European Commission | QQ 20–30 |
| * | Dr Hermann Meyer, Chief Executive Officer, ERTICO—ITS Europe (Intelligent Transport Systems) | |
| ** | Mike Hawes, Chief Executive Officer, Society of Motor Manufacturers and Traders (SMMT) | |
| ** | Professor Nick Reed, Academy Director at TRL, on behalf of GATEway (Greenwich Automated Transport Environment) | QQ 31–39 |
| * | John McCarthy, Technical Director at Atkins’ Intelligent Mobility, on behalf of the Bristol driverless cars project | |
| * | Brian Matthews, Head of Transport Innovation, Milton Keynes Council | |
| ** | Michael Hurwitz, Director of Transport Innovation, Transport for London (TfL) | QQ 40–47 |
| ** | Darren Capes, Transport Systems Manager, City of York Council | |
| ** | Mike Wilson, Chief Highways Engineer, Highways England | QQ 48–54 |
| ** | Steve Gooding, Director, RAC Foundation | |
| ** | Charlie Henderson, Partner, PA Consulting Group | |

- ** Professor Sarah Sharples, Associate Faculty Pro-Vice-Chancellor for Research & Knowledge Exchange, Professor of Human Factors, Faculty of Engineering, University of Nottingham [QQ 55–62](#)
- ** Professor Natasha Merat, Professor in Human Factors of Transport Systems, Institute for Transport Studies, University of Leeds
- ** Andy Graham, Director of White Willow Consulting and Founding Chair of ITS (UK) Connected Vehicles Interest Group
- ** Rt Hon John Hayes CBE MP, Minister of State, Department for Transport (DfT) [QQ 63–74](#)
- ** Nick Hurd MP, Minister of State for Climate Change and Industry, Department for Business, Energy and Industrial Strategy (BEIS)

Alphabetical list of all witnesses

- Ageas (UK) [AUV0042](#)
- Association of British Insurers (ABI) [AUV0051](#)
- Association of Personal Injury Lawyers (APIL) [AUV0023](#)
- Atkins [AUV0047](#)
- AutoNaut Ltd [AUV0079](#)
- Aviva Insurance Ltd [AUV0026](#)
- AXA UK [AUV0017](#)
- Nicholas Bevan, University of Exeter [AUV0044](#)
- ** Professor Simon Blackmore, Harper Adams University ([QQ 11–19](#)) [AUV0034](#)
- * Bristol driverless cars project ([QQ 31–39](#))
- British Motorcyclists Federation (BMF) [AUV0019](#)
- British Parking Association (BPA) [AUV0038](#)
- British Standards Institution (BSI) [AUV0060](#)
- Dr Gary Burnett, University of Nottingham [AUV0049](#)
- ** Darren Capes, City of York Council ([QQ 40–47](#)) [AUV0093](#)
- Dr Clemence Cavoli, University College London [AUV0070](#)
- CAVT Ltd [AUV0061](#)
- * Centre for Connected and Autonomous Vehicles (CCAV) ([QQ 1–10](#))
- Chartered Institution Highways and Transportation (CIHT) [AUV0082](#)
- Dr Tom Cohen, University College London [AUV0070](#)
- Cranfield University [AUV0086](#)

	DAC Beachcroft LLP	AUV0067
	Deloitte LLP	AUV0045
**	Department for Business, Energy and Industrial Strategy (BEIS) (QQ 63–74)	AUV0084 AUV0095
**	Department for Transport (DfT) (QQ 1–10 ; QQ 63–74)	AUV0084 AUV0095
	Direct Line Group (DLG)	AUV0063
	Enders Analysis	AUV0085
*	ERTICO—ITS Europe (Intelligent Transport Systems) (QQ 20–30)	
*	European Commission (QQ 20–30)	
	Five AI Inc	AUV0013
	Forum of Insurance Lawyers (FOIL)	AUV0065
	Dr Michael Galea, University of Nottingham	AUV0049
*	GATEway (Greenwich Automated Transport Environment) (QQ 31–39)	
	John Gunn	AUV0006
	Robert Harcourt	AUV0001
	Heathrow Airport	AUV0076
**	Highways England (QQ 48–54)	AUV0090
	Dr Debbie Hopkins, University of Oxford	AUV0021
	IAM RoadSmart	AUV0022
	Information Commissioner’s Office (ICO)	AUV0066
	Innovate UK	AUV0037
	Institute and Faculty of Actuaries (IFoA)	AUV0059
	Institute of Marine Engineering, Science and Technology (IMarEST)	AUV0064
	The Institution of Engineering and Technology (IET)	AUV0069
	International Underwriting Association (IUA)	AUV0057
	ITS International Magazine	AUV0009
	ITS United Kingdom	AUV0036
	Kennedys	AUV0046
	Keoghs LLP	AUV0014
	Professor David Lane CBE FREng FRSE	AUV0050
	Eion MacDonald	AUV0002
	Maritime Autonomous Systems (MAS) Council of the Society of Maritime Industries	AUV0015
	Professor Derek McAuley, University of Nottingham	AUV0049

	Dr Xiaolin Meng, University of Nottingham	AUV0049
**	Professor Natasha Merat, ITS, University of Leeds (QQ 55–62)	AUV0092
	Professor Robert Merkin QC, University of Exeter	AUV0044
	Met Office	AUV0081
	Mills & Reeve LLP	AUV0035
*	Milton Keynes Council (QQ 31–39)	
	Professor Terry Moore, University of Nottingham	AUV0049
	Professor Herve Morvan, University of Nottingham	AUV0049
	Motorcycle Action Group (MAG)	AUV0073
	National Oceanography Centre (NOC)	AUV0056
	The Nautical Institute	AUV0020
	Professor Paul Newman, University of Oxford	AUV0041
	Dr Kyriaki Noussia, University of Exeter	AUV0044
	Orbit City Lab	AUV0003
**	PA Consulting Group (QQ 48–54)	AUV0008
	Peak Power	AUV0043
	John Philips	AUV0010
	Pinsent Masons and PETRAS	AUV0055
	Pupils 2 Parliament	AUV0016
	RAC	AUV0011
**	RAC Foundation (QQ 48–54)	AUV0024
	RazorSecure Limited	AUV0018
	Research Councils UK (RCUK)	AUV0053
	Road Safety Markings Association (RSMA)	AUV0012
	Rolls-Royce	AUV0083
	Royal Aeronautical Society	AUV0077
	Royal Society for the Prevention of Accidents (RoSPA)	AUV0025
	The Royal Society	AUV0052
	Professor James Scanlan, University of Southampton	AUV0030
	Associate Professor Tim Schwanen, University of Oxford	AUV0021
**	Professor Sarah Sharples, University of Nottingham (QQ 55–62)	AUV0049 AUV0091
	SmarterUK	AUV0089
	James Sneath	AUV0005
**	Society of Motor Manufacturers & Traders (SMMT) (QQ 20–30)	AUV0058

	Southampton Marine & Maritime Institute, University of Southampton	<u>AUV0028</u>
	Professor Benjamin K Sovacool, University of Sussex	<u>AUV0021</u>
	Professor Neville Stanton, University of Southampton	<u>AUV0029</u>
	Professor David Starkie, University of Applied Sciences, Bremen	<u>AUV0033</u>
	Starship Technologies Ltd	<u>AUV0072</u>
	Stewarts Law	<u>AUV0054</u>
	Thatcham Research	<u>AUV0051</u>
	Transport for Greater Manchester (TfGM)	<u>AUV0027</u>
**	Transport for London (TfL) (<u>QQ 40–47</u>)	<u>AUV0087</u>
	Transport for West Midlands	<u>AUV0075</u>
**	Transport Research Laboratory (TRL) (<u>QQ 31–39</u>)	<u>AUV0039</u>
	Transport Systems Catapult	<u>AUV0071</u>
	UK Space Agency	<u>AUV0074</u>
**	United Kingdom Atomic Energy Authority (UKAEA) and Remote Applications in Challenging Environments (RACE) (<u>QQ 11–19</u>)	<u>AUV0032</u>
	University of Southampton Insurance Law Research Group	<u>AUV0031</u>
	Weightmans	<u>AUV0080</u>
**	White Willow Consulting (Andy Graham) (<u>QQ 55–62</u>)	<u>AUV0094</u>
	Zurich Insurance plc	<u>AUV0068</u>

APPENDIX 3: CALL FOR EVIDENCE

The House of Lords Science and Technology Select Committee, under the Chairmanship of Lord Selborne, is conducting an inquiry into *Autonomous Vehicles*. The Committee invites interested individuals and organisations to submit evidence to this inquiry. The deadline for written evidence submissions is Wednesday 26 October 2016.

Background

“Autonomy” is defined as the ability to make decisions based on external events and internal goals that lead to different courses of action, even when faced with unexpected events and unknown environments.²¹⁵ The prospect of autonomous cars on the roads of the UK has captured the public imagination. But in addition to road transport there is a much wider array of possible applications for autonomous vehicles.

Cars present an obvious example of where autonomy could be useful, offering potential improvements in safety and freeing up the driver to perform other tasks. There are, however, also questions about how this will work in practice, how autonomous vehicles would interact with conventional road vehicles during a transition to a fully autonomous system and about consumer attitudes and behaviours. The arrival of autonomous cars and public transport will provide most people with their first experience of autonomous vehicles. Cars with some level of autonomy are already available and it is predicted that fully autonomous driving could be in widespread use as early as the 2020s.

Autonomous vehicles offer opportunities in a wide number of areas other than use on the road. There are potential advantages in removing the need for a driver in situations such as warehousing, deliveries or farming. Without the need for a driver, the use of new types of vehicle is possible—small aerial vehicles for deliveries or light weight farm vehicles. Autonomous vehicles can also be used to perform tasks in extreme environments, such as the deep sea, space or nuclear power stations.

The UK has the potential to become a world leader in developing, producing and deploying autonomous vehicles. The Government has identified robotics and autonomous systems as one of its eight great technologies.²¹⁶ Researchers and businesses working in this area have proactively engaged with Government. For example, in 2014 the Robotics and Autonomous Systems (RAS) special interest group of the Innovate UK network described a possible national strategy and associated recommendations.²¹⁷

The Government has been active in responding to the potential for the UK offered by autonomous vehicles. In 2015 it established a new joint policy unit, the Centre for Connected and Autonomous Vehicles (CCAV). In the 2015 Budget the Government announced a £100 million intelligent mobility research and development fund focusing on driverless car technology. It also published a review of existing legislation relating to road vehicles, which concluded that: “[the UK]

215 Special Interest Group: Robotics and Autonomous Systems, *RAS 2020 Robotics and Autonomous Systems* (July 2014): <https://connect.innovateuk.org/documents/2903012/16074728/RAS%20UK%20Strategy?version=1.0> [accessed 20 December 2016]

216 Rt Hon David Willetts, Speech on Eight great technologies, 24 January 2013: <https://www.gov.uk/government/speeches/eight-great-technologies> [accessed 10 January 2017]

217 Special Interest Group: Robotics and Autonomous Systems, *RAS 2020 Robotics and Autonomous Systems* (July 2014): <https://connect.innovateuk.org/documents/2903012/16074728/RAS%20UK%20Strategy?version=1.0> [accessed 20 December 2016]

legal and regulatory framework is not a barrier to the testing of automated vehicles on public roads”. In addition, it has published a code of practice for testing of driverless cars. In the 2016 Queen’s Speech, the Government announced that it would introduce a Modern Transport Bill to: “ensure the United Kingdom is at the forefront of technology for new forms of transport, including autonomous and electric vehicles”. CCAV held a call for evidence on the UK testing ecosystem for connected and autonomous vehicles, which closed in July 2016 and a call for evidence which sought views on proposals for people and businesses in the UK to use automated vehicle technologies and advanced driver assistance systems. This closed on 9 September 2016.

Scope

The Government aims to ensure that the UK is a world leader in developing, testing and deploying connected and autonomous vehicles and, as set out above, has been proactive in its response. This inquiry will examine whether the actions taken by the Government are appropriate, considering both the scale of economic opportunity and the potential public good benefits. The inquiry will collect evidence on the potential uses and benefits of autonomous vehicles. It will look at the transition path and the co-existence of autonomous and conventional road vehicles. Finally, it will consider connectivity and interactions with physical and digital infrastructure.

As cars, and other forms of public transport, will be at the forefront of the public’s experience of autonomous vehicles, many of the questions in this Call for Evidence refer to this type of vehicle. Evidence is, however, sought on autonomous vehicles across a whole range of possible applications.

Questions

The Committee invites submissions on the following points, with practical examples and other evidence where possible. You only need to answer questions of relevance to you. Please also do draw the Committee’s attention to any relevant issues not captured in the specific questions below:

Impacts and benefits

1. What are the potential applications for autonomous vehicles?
2. What are the potential user benefits and disadvantages from the deployment of autonomous vehicles?
3. How much is known about the potential impact of deploying autonomous vehicles in different sectors?
4. How much is known about public attitudes to autonomous vehicles?
5. What is the scale of the market opportunity for autonomous vehicles?

Creating an enabling environment

Research and development

6. Is the scale of current and planned demonstration facilities for autonomous vehicles sufficiently broad and ambitious?

7. Is the Government doing enough to fund research and development on autonomous vehicles, and to stimulate others to do so? Should it be doing more to coordinate UK actions?
8. How effective are Innovate UK and the CCAV in this area?
9. Is the environment for small and medium-sized enterprises (SMEs) working in this sector sufficiently enabling?

Real world operation

10. Will successful deployment of autonomous vehicles require changes to digital or physical infrastructure?
11. How might a move from current levels of highly automated vehicles to their extensive deployment best be managed? What do you see as the key milestones?
12. Does the Government have an effective approach on data and cybersecurity in this sector?
13. Are further revisions needed to insurance, regulation and legislation in the UK to create an enabling environment for autonomous vehicles?
14. What, if any, ethical issues need to be addressed in the substitution of human judgement in the control of vehicles by algorithms and Artificial Intelligence?

Wider governance

15. What does the proposed Modern Transport Bill need to deliver?
16. How effective is the UK's education system in delivering people with the right skills to support the autonomous vehicles sector?
17. Is the Government's strategy and work in this area sufficiently wide-reaching? Does it take into account the opportunities that autonomous vehicles offer in a wide range of areas, not just on the road?
18. What are the implications of exit from the European Union for research and development and the autonomous vehicle industry in the UK? Are specific actions from the Government needed to support or protect the autonomous vehicles sector in the short term or after the terms of Brexit have been negotiated?

15 September 2016

APPENDIX 4: SEMINAR HELD AT THE HOUSE OF LORDS ON 5 JULY 2016

Members of the Committee present were the Earl of Selborne (Chairman), Lord Borwick, Lord Cameron of Dillington, Lord Fox, Lord Hennessy of Nympsfield, Lord Hunt of Chesterton, Lord Mair, Lord Maxton, Baroness Morgan of Huyton, Baroness Neville-Jones, Lord Oxburgh, Viscount Ridley and Baroness Young of Old Scone.

Presentations were heard from:

- Roland Meister, Head of Transport, Innovate UK;
- Professor Paul Newman FREng, BP Professorial Fellow in Information Engineering, University of Oxford;
- Chris Turner, Director Advanced Technology Marketing, CPU Group, ARM; and
- Professor Simon Blackmore, Head of Engineering, Harper Adams University.

APPENDIX 5: ABBREVIATIONS, ACRONYMS AND TECHNICAL TERMS

ABI	Association of British Insurers
ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance Systems
AEB	Autonomous Emergency Braking
Autonaut	“Wavegliders” and “autonauts” are examples of unmanned surface vehicles powered by wave and solar energy. They are used for marine research and data collection.
Autonomous vehicles	‘Autonomous vehicles’ are those in which operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking and are designed so that the driver is not expected to monitor constantly the roadway while operating in self-driving mode.
AV	autonomous vehicle(s)
BEIS	Department for Business, Energy and Industrial Strategy
BMF	British Motorcyclists Federation
BPA	British Parking Association
CAV	Connected and autonomous vehicles. Some vehicles are both autonomous and connected whilst others are connected vehicles only and others are autonomous only.
CCAV	Centre for Connected and Autonomous Vehicles
CIHT	Chartered Institution of Highways & Transportation
Connected vehicles	‘Connected vehicles’ are vehicles that use any of a number of different communication technologies to communicate with the driver, other vehicles on the road (vehicle-to-vehicle [V2V]), roadside infrastructure (vehicle-to-infrastructure [V2I]), and the “Cloud.”
DCMS	Department for Culture, Media and Sport
Deeptrekker	Deeptrekkers are remotely operated vehicles—also called underwater drones—specifically designed and developed for underwater inspection.
DfT	Department for Transport
EPSRC	Engineering and Physical Sciences Research Council
HMG	Her Majesty’s Government
HMT	Her Majesty’s Treasury
HAU	Harper Adams University
ICO	Information Commissioner’s Office
IFoA	Institute and Faculty of Actuaries
IMarEST	Institute of Marine Engineering, Science & Technology
LTA	Local Transport Authorities

MoD	Ministry of Defence
Mixed fleet	A ‘mixed fleet’ is when both traditional vehicles and CAV use roads at the same time.
Platooning	‘Platooning’ is where one lorry leads and makes the decisions for those behind that are wirelessly connected to form a road-train.
R&D	research and development
RACE	Remote Applications in Challenging Environments
RAS	Robotics and Autonomous Systems
RCUK	Research Councils UK
RoSPA	Royal Society for the Prevention of Accidents
SAVI	Singapore Autonomous Vehicle Initiative
SIG	Special Interest Group
SMMT	Society of Motor Manufacturers and Traders
Strategic road network	The ‘strategic road network’ comprises approximately 4,300 miles of motorways and major ‘trunk’ A-roads in England, and it is managed by Highways England (successor to the Highways Agency), a company wholly owned by the Secretary of State for Transport.
TfGM	Transport for Greater Manchester
TRL	Transport Research Laboratory
Trolley problem	The ‘trolley problem’ (or ‘trolley dilemma’) consists of a series of hypothetical scenarios developed by British philosopher Philippa Foot in 1967. The general form of the problem is this: there is a runaway trolley barrelling down the railway tracks. There are five people tied up ahead on the tracks and unable to move. The trolley is headed straight for them; you are standing some distance off, next to a lever. If you pull this lever, the trolley will switch to a different set of tracks. However, you notice that there is one person on the side track. You therefore have two options: (1) Do nothing, and the trolley kills the five people on the main track; or (2) Pull the lever, diverting the trolley onto the side track where it will kill one person. Which is the most ethical choice? In the context of CAV, the problem centres on whether an autonomous vehicle should act to protect the passengers, or external parties (such as pedestrians).
Type Approval	Type Approval is the confirmation that production samples of a design will meet specified performance standards. The specification of the product is recorded and only that specification is approved.
UKAEA	UK Atomic Energy Authority
Waveglider	“Wavegliders” and “autonauts” are examples of unmanned surface vehicles powered by wave and solar energy. They are used for marine research and data collection.

APPENDIX 6: EXAMPLES OF CURRENT CAV APPLICATIONS

Road applications

As a part of Project SAVI (Singapore Autonomous Vehicle Initiative), Singapore has designated an area in the city centre for testing autonomous vehicles in typical traffic conditions. The test space is composed of normal streets but it is extensively instrumented so that researchers can study vehicles' behaviour from outside as well as from inside the vehicle. There are static signs on the roadside to inform the public of the autonomous vehicles conducting trials in the area but there are no special markings on the road. In August 2016, select members of the public began hailing free rides, through their smartphones, in taxis operated by nuTonomy (an autonomous vehicle software start-up).

The ultimate goal is to have a fully self-driving taxi fleet in Singapore by 2018. Initially the taxis will only run in a 2.5-square-mile business and residential district called "one-north". Pick-ups and drop-offs are limited to specified locations. The cars (modified Renault Zoe and Mitsubishi i-MiEV electrics) have a driver in the front who is ready to take back the wheel and a researcher in the back who watches the car's computers. Each car is fitted with six sets of Lidar—a detection system that uses lasers to operate like radar—including one on the roof that constantly rotates to scan all directions. There are also two cameras on the dashboard to scan for obstacles and detect changes in traffic lights. It is estimated that autonomous taxis could reduce the number of cars on Singapore's roads from 900,000 to 300,000.²¹⁸

Aerial applications

The Royal Aeronautical Society said that there already existed "a wide range of automated capabilities within both civil and military aviation sectors".²¹⁹ These included automatic landing systems for use in poor weather, automated navigation, anti-collisions systems and engine controls. Furthermore, in the field of unmanned aircraft systems, automation was already underway in areas such as take-off and landing and navigation.²²⁰ Innovate UK said: "In civil Aerospace the technology already exists to fly point-to-point on Autopilot without the need for any human input, only monitoring."²²¹

Marine applications

Rolls-Royce highlighted the potential benefit to the UK of using autonomous vessels in naval applications, both surface and sub-surface:

"The Royal Navy, like most European navies, is preparing to introduce small (<12m) unmanned vessels deployed from existing platforms to conduct specialist tasks such as mine countermeasures, surveillance and fleet protection. 'Unmanned Warrior', a large scale, multi-environment, military demonstration of unmanned technology has just completed off the west coast of Scotland. It combined industry, academia and defence partners, including the US Navy, to explore the feasibility of increasing the use of unmanned and autonomous systems in delivering maritime capability. Modern combatant designs, such as the Royal Navy's

218 Bloomberg Technology, *World's First Self-Driving Taxis Debut in Singapore* (25 August 2016): <https://www.bloomberg.com/news/articles/2016-08-25/world-s-first-self-driving-taxis-debut-in-singapore> [accessed 20 December 2016]

219 Written evidence from the Royal Aeronautical Society (AUV0077)

220 Written evidence from the Royal Aeronautical Society (AUV0077)

221 Written evidence from Innovate UK (AUV0037)

planned Type 26 frigate, are increasingly including ‘mission bays’ to house and deploy such unmanned vessels. The US Navy is probably the most advanced in this area, they have commissioned a 40-metre proof-of-concept unmanned vessel, Sea Hunter, which is intended for anti-submarine and mine-hunting activities.”²²²

Energy sector applications

The Institute of Marine Engineering, Science & Technology (IMarEST) provided an example of how autonomous systems were used in the offshore oil and gas sector:

“Autonomy is used to reduce exposure to personnel, increase data return through the ability to obtain regular uploads of data from sub-surface instrumentation, improving the ability to perform baseline type measurements, enabling data acquisition in more severe sea-states, when manned vessels cannot operate and providing a multi-discipline (metocean, survey, Environmental Impact Assessment) platform.

“Oil major BP already employs a wide assortment of different marine autonomous systems, including wavegliders, autonauts²²³ and deeptrekkers²²⁴. The company states that it’s only in recent years, as technology has advanced and costs fallen, that these vehicles have become ready to take over underwater surveillance duties. It has partnered with manufacturer Oceanering for a large-scale AUV trial to survey pipelines and subsea infrastructure in the Gulf of Mexico, ahead of a full roll-out.”²²⁵

222 Written evidence from Rolls-Royce ([AUV0083](#))

223 “Wavegliders” and “autonauts” are examples of unmanned surface vehicles (USVs) powered by wave and solar energy. They are used for marine research and data collection.

224 Deeptrekkers are remotely operated vehicles—also called underwater drones—specifically designed and developed for underwater inspection.

225 Written evidence from the Institute of Marine Engineering, Science & Technology (IMarEST) ([AUV0064](#))

APPENDIX 7: CAV IMPACT ON CONGESTION IN THE SHORT, MEDIUM AND LONG TERM

This Appendix summarises HERE's description of the potential for connected and autonomous vehicles (CAV) to help—or hinder—congestion in the short, medium and long term.²²⁶

Short term (next 5 years)

There is already technology within cars that has been shown to offer benefits in terms of accident reduction and improvements in traffic efficiency (known as Advanced Driver Assistance Systems (ADAS)). The HERE report highlighted academic studies which analysed the benefits from the widespread adoption of existing Adaptive Cruise Control (ACC) systems, “showing how they can enable roads to operate at higher vehicle density and flow rates”. For example, in a study supported by Volkswagen, relatively low penetrations of ACC were found to “completely eliminate certain types of simulated traffic congestions”. However, other studies have been less optimistic, highlighting risks associated with mixed traffic scenarios where not all drivers are relying on ACC.

SBD Automotive forecast that by 2021, 17.5 million cars would be sold annually in the USA and Europe with applications like ACC and AEB, and that these would play a modest role in helping to alleviate traffic congestion.

Medium term (5–20 years)

The effect of the introduction of Level 4 autonomous vehicles on traffic congestion is much less predictable. In the medium term, there may be a number of possible negative effects on traffic congestion:

- Other drivers may be surprised by the different behaviour of autonomous cars, leading to more accidents.
- Owners of autonomous cars may become over-reliant on autonomy and fail to step in when necessary, with a similar effect as above.
- Slower acceleration and deceleration rates among autonomous cars may be required to enhance passenger comfort, but would lead to the overall flow of the road decreasing.
- People who are less likely to drive or own cars now, such as the elderly and young, may suddenly start buying cars leading to busier roads.
- There may be changes in the urbanisation trends, as people choose to move away from cities and their workplaces as they can use their journey time more effectively.

HERE notes that at this early stage “it is impossible to holistically quantify the positive or negative impact of highly autonomous cars”. The report also says that new vehicle ownership models and changing governmental policies “could play a role in counteracting some of these negative side-effects of congestion”. For example, car sharing “could become significantly easier when cars become more autonomous”, thereby possibly leading to a drop in vehicle ownership. Additionally, the Government could incentivise autonomy by setting up dedicated ‘Autonomous Lanes’, thereby “also preventing negative interactions with traditional cars and

226 HERE, *How autonomous vehicles could relieve or worsen traffic congestion* (2016): <https://www.acquirepublishing.nl/whitepapers/how-autonomous-vehicles-could-relieve-or-worsen-traffic-congestion.pdf> [accessed 28 December 2016]

encouraging those individuals who have invested in autonomous technology to enjoy the benefits and become more comfortable with the technology”.

For the medium term, HERE concludes:

“Further studies and trials will be required to assess the dozens of autonomous use cases, hundreds of variables and thousands of scenarios in order to fully understand how traffic congestion will change. However, policy makers and the industry should fully recognize the many potential impacts that could accompany the positive benefits of highly autonomous vehicles.”

Long term (20–50 years)

The longer-term outlook for CAV is described as “paradoxically easier to forecast than the medium-term”. At some stage in the distant future (likely to be due to Government regulation), CAV will become ubiquitous and manual driving will be restricted. At this stage, the central management of all vehicle movements will become feasible, with both traffic accidents and congestion expected to be eliminated. However, HERE’s report acknowledges that “the value of debating how and when this will happen is limited”. Instead, attention must be given to “overcoming the medium-term complexities of managing mixed fleets of autonomous and traditional vehicles”.

APPENDIX 8: COMMITTEE VISIT TO THE GREENWICH GATEWAY PROJECT ON 6 DECEMBER 2016

Members of the Committee present were the Earl of Selborne (Chairman), Lord Borwick, Lord Cameron of Dillington, Lord Hennessy of Nympsfield, Lord Hunt of Chesterton, Lord Mair, Lord Maxton, Baroness Neville-Jones, Lord Oxburgh, Viscount Ridley, Lord Vallance of Tummel and Baroness Young of Old Scone.

Presentations were heard from representatives of the Transport Research Laboratory and the Royal Borough of Greenwich.

Members viewed the GATEway shuttle operating autonomously, rode in Oxbotica's autonomous Geni vehicle and experienced the GATEway simulator trial in a mini driving simulator.