1. Introduction

1.1 The RAC Foundation\(^1\) is an independent transport policy and research organisation which explores the economic, mobility, safety and environmental issues relating to roads and their users. The Foundation carries out independent and authoritative research with which it promotes informed debate and advocates policy in the interests of responsible road users.

1.2 The Foundation welcomes the opportunity to give evidence on this important topic. Our comments relate specifically to road transport – including both the use of autonomous vehicles for road transport and the use of other types of autonomous vehicles that could have implications for road transport. We have set out some key considerations below before offering answers to the specific questions the Committee has posed.

1.3 The use of autonomous vehicles in the UK’s demanding traffic environment is one of the most challenging of potential applications. Less challenging but still relevant applications for autonomous vehicles might include:

- environments hostile to human life and wellbeing;
- open environments which are easily navigated by robotic devices;
- tightly controlled environments where external intrusions are eliminated;
- environments which are too small to accommodate a human presence; and
- routine and repetitive operations not requiring a high level of operating skill.

1.4 Whilst driving a car on the public road might be regarded as engaging in a hostile environment, the arguments about convenience and efficiency are weighing at least as heavily as those for improving road safety in the debate about autonomous road vehicles thus far.

1.5 Meantime, the concept of the self-driving car has caught the public imagination and is attracting vast investment in the development of autonomous technology from traditional auto manufacturers and from technology companies. Given our success in attracting inward investment in the auto sector of late, it makes perfect sense for the Government to seek to attract this research and development activity to the UK as part of its broader industrial strategy.

2. The Foundation’s general position on autonomous and driverless vehicles

2.1 The Foundation supports the introduction of aids to driving road vehicles where they:

- enable enhanced mobility, especially for those least well served by existing systems;
- reduce the risks of collisions between road vehicles and other vehicles, pedestrians and physical infrastructure;
- help to reduce fuel consumption, emissions and environmental nuisance;
- increase the effective capacity and reliability of the road system; and

\(^1\) For further information about the Foundation see [http://www.racfoundation.org/](http://www.racfoundation.org/).
Thus the Foundation sees the increased automation of road vehicle operation not as an end in itself - but as a means to increasing the safety, economy, efficiency and amenity of road transport. To achieve these benefits, we need to resolve a number of issues including the transition to autonomy and the nature of the business model (or models) under which autonomous vehicles will be made available.

Background

2.2 Over the last half century many innovations in automotive technology have improved the safety and economy of road vehicles\(^2\) from servo assistance to anti-lock braking, electronic stability control and autonomous emergency braking. Engine and drive train efficiency has also improved substantially with small, often turbocharged, units supplanting larger engines without sacrificing performance yet sharply reducing fuel consumption and emissions. Often these are ‘optional extras’ in their early stages but soon become standard to the point that many drivers are not aware of their existence.

2.3 More recently technological innovations have been introduced which, to varying extents, change the driving task itself, (adaptive) cruise control, lane departure warning systems, (dynamic) GPS routing and intelligent parking assist are four examples. These mean that some tasks that had to be carried out by the driver are reduced or replaced. It is here that we see a potential ‘fault-line’ opening up in the path to full autonomy.

2.4 Whilst the developers of autonomous systems are making ambitious claims for the point at which their products will come to market, it is possible that the complexities of operating safely and efficiently in all traffic environments are such that operation without human control may only be possible in less demanding traffic environments such as on limited access roads, or on ‘closed’ elements of the network, such as motorways. The challenge then becomes one of managing the transition:

- between driverless vehicles and other traffic – with nearly 40 million driven vehicles on our roads (including bicycles) in this country alone driverless vehicles will need to be able to operate alongside driven vehicles for a considerable time as the vehicle park turns over.
- between the driver and the vehicle – who is in control? And can control be passed back and forth (as is the case in an aircraft autopilot system)?

System and commercial architecture

2.5 For the autonomous car to be brought into general use a number of issues will need to be satisfactorily addressed, many as set out in the Foundation’s response to the recent Centre for Connected and Autonomous Vehicles consultation on the Pathway to Driverless Cars: Proposals to support advanced driver assistance systems and automated vehicle technologies\(^3\) including:

\(^2\) Bayliss 2008.
\(^3\) RACF 2016.
eliminating ambiguity of responsibility for vehicle control especially in transition between manual and autonomous operation;

- clarity of liability for damage caused by autonomous vehicles given the variety and complexity of detection, communication and control systems likely to be employed in their operation;
- how the interactions between autonomous vehicles and the general traffic stream will be managed;
- how autonomous vehicles will perform in complex traffic environments. Whilst platoon operation on motorways may well improve efficiency and capacity conservative autonomous vehicle operations in congested multi-purpose environments could result in sharp degradations of service levels and effective capacity;
- ethical questions about safety priorities in the event of a prospective collision; and
- robustness to IT failures and security risks such as ‘hacking’.

2.6 There are also unresolved questions about the overall architecture of a general autonomous regime. The present prototypes rely mainly on a combination of various ‘in vehicle’ detection systems along with GPS and GSM links. As numbers grow the viability and benefits of more advanced vehicle to infrastructure (V↔I) and vehicle to vehicle (V↔V) are likely to improve.

2.7 A current example of the former would be traffic signals advising approaching vehicles of imminent green time to allow speeds to be regulated to avoid stopping; and of the second virtual linkages between platoons of trucks on motorways. Potentially more efficient architectures incorporating these facilities would require some measure of co-operation between vehicle manufacturers, telecoms providers, regulators and road operators. As yet there is little sign of this taking place and, variations in organisations’ objectives and commercial rivalries are likely to mean this would not be achieved overnight.

2.8 There are also questions about the commercial architecture of the autonomous vehicle market. Most of the descriptions of a future world of autonomous vehicles providing convenient, safe, efficient mobility for us all, without the need to worry about parking, are silent on the question of who, exactly will own and ‘operate’ the vehicle. Several models are possible, from an extension of the current, widely popular, leasehold contracts, under which a vehicle has a dedicated registered keeper, through to a form of minicab service, where users cease to own vehicles, instead booking them – and paying for them – by trip. Recognising that a variety of approaches might operate in parallel, it is hard, today, to be clear about the product that the individual motorist will be offered, and hence to form a view on the likely cost and affordability for individuals.

The pathway to autonomy

2.9 There can be little doubt that the pathway towards automated road vehicles will involve progressive introduction of driver assistance systems. Initially these have been passive (e.g. Anti-lock Braking Systems, Traction Control Systems and Electronic Stability

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4 This has led to the use of Connected Autonomous Vehicle (CAV) rather than Autonomous Vehicle.
Controls), subsequently there has been a mushrooming of driver information systems (e.g. motorway Variable Message Signs, Satellite Navigation and Traffic Alerts) and now a range of active/semi-active systems are being deployed (e.g. Autonomous Emergency Braking, Adaptive Cruise Control and Parking Assist). This process of innovation seems set to continue with new applications appearing first on high value premium models but quickly cascading down to middle and utilitarian ranges.

2.10 There should be considerable safety benefits from innovations designed to make the task of driving easier. It has been argued by some observers that Advanced Driver Assistance Systems (ADAS) could bring safety benefits sooner and at a lower cost than fully autonomous operations – especially in light of concerns about their congestion impacts and security. However their introduction will have to be carefully designed as the provision of information to the driver, even if intended to assist, can be distracting if not in the right form at the right time.

2.11 Furthermore, ambiguity over the extent of control required of the driver could, if not properly managed, introduce new forms of risks, in particular, where the driver is left with so little to do by way of controlling the vehicle that they are insufficiently alert when circumstances require the driver to take action. What is the driver realistically supposed to be doing on a motorway when the car is deciding for itself the speed to go at, when to brake, and when to turn the wheels to stay in lane? The less time a driver spends driving, the less we should expect them to feel in control.

2.12 The issue becomes starker as the borderline is crossed between driver-assistance into autonomous operation. The U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) has defined vehicle automation as having five levels, which have become widely recognised as a possible ‘road map’ toward full autonomy:

- **No-Automation (Level 0):** The driver is in complete and sole control of the primary vehicle controls – brake, steering, throttle, and motive power – at all times.
- **Function-specific Automation (Level 1):** Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.
- **Combined Function Automation (Level 2):** This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.
- **Limited Self-Driving Automation (Level 3):** Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The Google car is an example of limited self-driving automation.

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5 Sowman 2016.
**Full Self-Driving Automation (Level 4):** The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles.

2.13 We believe Level 3 is fraught with difficulty. The key is in defining what ‘sufficiently comfortable transition time’ means. Some descriptions of level 3 automation envisage the vehicle being able to cede control back to the driver where the circumstances it is encountering exceed its ability to interpret and manage them – potentially an imminent collision. But is it realistic to expect a driver to remain alert so as to regain control and act in the split seconds that count in such circumstances? A driver who has switched to autonomous mode and is catching up on e-mail or reading a book is unlikely to be able to re-take control. Indeed, many of the safety benefits claimed for autonomous operation stem from the ability of machines to sense and react more quickly than human drivers, as well as not being prone to human error.

2.14 Even outside emergency situations it is possible to envisage circumstances where a driver who has been reading or even sleeping for an extended period of motorway driving is not sufficiently awake and alert safely to retake control despite wishing to do so. Should the vehicle have the ability to deny the driver, possibly by reference to monitoring of the driver’s biometrics? Or should we only think of the control ‘baton’ being passed when a vehicle is stationary, thus the motorway driver wishing to retake control would need to instruct the vehicle to pull into a rest area and stop first?

2.15 In short, are we ready for a machine in which we are travelling not just to follow instructions, but to decide its own without the scope for a manual override?

3. **Responses to Specific Questions**

**What are the potential applications for autonomous vehicles?**

3.1 The environments where autonomous vehicles are most obviously suitable for deployment are briefly described in paragraph 1.2. But the full range of potential application is vast depending on the pace of development, sophistication and cost of the products coming to market.

**What are the potential user benefits and disadvantages from the deployment of autonomous vehicles?**

3.2 Generally the potential benefits include:
- substituting machines for human beings in dangerous environments;
- accessing sites beyond the reach of human operated machines e.g. ‘silo’ parking;
- making vehicle operation safer by removing human error;
- enabling all vehicle occupants to engage in non-driving activities so releasing time for more productive uses and expanding the availability of personal mobility;
- increasing infrastructure capacity e.g. by reducing headways;
• better matching the supply of services to the demand for them; and
• reducing the dependence on costly and sometimes unreliable human operation.

3.3 These potential benefits will not automatically materialise:
• high levels of automation can be costly;
• there are many environments where the limited capabilities of autonomous operation are such that it will not be worth their development and deployment.

A critical issue for promoters of autonomous vehicles is to establish a clearer picture of how they could perform, at scale, in real world environments and what the economic, social and environmental consequences would be as well as how the technical problems would be dealt with. This is less about disadvantage and more about uncertainty.

How much is known about the potential impact of deploying autonomous vehicles in different sectors?

3.4 There has been interest in self driving passenger vehicles for some time and in 2004 the US Defence Advanced Research Projects Agency launched a competition for off road vehicles\(^6\). More recently there is a growing commercial interest in the prospect of an autonomous vehicle market with tremendous interest and investment from some of the largest technology and auto manufacturing companies\(^7\), with a reported 33 major companies working on autonomous road vehicles at present\(^8\). It appears that the design and development of autonomous road vehicles has already become a major civilian R&D activity\(^9\).

3.5 Real life trials of CAVs have been limited so far. Google has operated its autonomous cars for over 1½ million miles in a number of US cities\(^10\) and the first stage of an automated taxi trial (6 vehicles in a 2½ mile radius zone) is underway in Singapore\(^11\). TESLA has been supplying its ‘autopilot’ technology in its cars since October 2014. This enables the driver to allow the car to ‘drive’ itself in certain traffic environments. The system steers, changes lane and controls speeds and braking and allows the driver to go ‘hands free’ whilst operational. This has not been without incident with at least two crashes and is almost certainly not yet suitable for operating in the wide range of conditions experienced in much everyday driving\(^12\). Here in the UK the Transport Catapult LUTZ project has recently demonstrated self-driving car operations (one vehicle) in Milton Keynes\(^13\).

3.6 Truck platooning has been trialled in a European project\(^14\) involving six manufacturers and twelve vehicle travelling on three motorway routes in northern Europe. This trial

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\(^6\) DARPA 2008.
\(^8\) CB Insights 2016, OICA 2016.
\(^9\) ERTRAC 2015.
\(^10\) Google 2016.
\(^11\) The Verge 2016.
\(^12\) Fortune 2016 see also Silver 2016.
\(^13\) Moran 2016.
\(^14\) SARTRE 2013.
appears to have gone well and lessons are being learned for future development/deployment of this technology\textsuperscript{15}. In the 2016 budget\textsuperscript{16} the Chancellor of the Exchequer proposed that the UK Government will:

- conduct trials of driverless cars on the strategic road network by 2017;
- consult this summer on sweeping away regulatory barriers within this Parliament to enable autonomous vehicles on England’s major roads;
- establish a £15 million ‘connected corridor’ from London to Dover to enable vehicles to communicate wirelessly with infrastructure and potentially other vehicles;
- carry out trials of truck platooning on the strategic road network; and
- start trials of comparative fuel price signs on the M5 between Bristol and Exeter by spring 2016 to drive fuel price competition and help motorists save money.

3.7 The M5 trial is underway\textsuperscript{17} and the London to Dover ‘connected corridor’ is planned to start pilot operation in the summer of 2017\textsuperscript{18}.

3.8 Whilst there is a great deal of activity in the development of Advanced Driver Assistance Systems (ADAS) and CAVs to date deployment has been very limited and mostly on a trial basis. Assessments of the impacts is therefore largely at a theoretical stage and there is no clear consensus of what these will be. Table 1 sets out one set of the potential impacts by Litman who is a respected transport analysts and without ant commercial interest in the technology.

3.9 The assessment assumes that the technologies will function adequately in a wide range of traffic conditions and any cost premia will not be so high as to prevent widespread take up of CAVs.

<table>
<thead>
<tr>
<th>BENEFITS</th>
<th>COSTS/PROBLEMS</th>
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<tr>
<td>Reduced driver stress. Reduce the stress of driving and allow motorists to rest and work while traveling.</td>
<td>Increases costs. Requires additional vehicle equipment, services and maintenance, and possibly roadway infrastructure.</td>
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<tr>
<td>Reduced driver costs. Reduce costs of paid drivers for taxis and commercial transport.</td>
<td>Additional risks. May introduce new risks, such as system failures, be less safe under certain conditions, and encourage road users to take additional risks (offsetting behaviour).</td>
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<tr>
<td>Mobility for non-drivers. Provide independent mobility for non-drivers, and therefore reduce the need for motorists to chauffeur non-drivers, and to subsidize public transit.</td>
<td>Security and Privacy concerns. May be used for criminal and terrorist activities (such as bomb delivery), vulnerable to information abuse (hacking), and features such as GPS tracking and data sharing may raise privacy concerns.</td>
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\textsuperscript{15} European Truck Platooning 2016, \textsuperscript{16} HM Treasury 2016, \textsuperscript{17} Highways England 2016, \textsuperscript{18} DfT 2016a.
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<tr>
<th><strong>Increased safety.</strong> May reduce many common accident risks and therefore crash costs and insurance premiums. May reduce high-risk driving, such as when impaired.</th>
<th><strong>Induced vehicle travel and increased external costs.</strong> By increasing travel convenience and affordability, autonomous vehicles may induce additional vehicle travel, increasing external costs of parking, crashes and pollution.</th>
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<td><strong>Increased road capacity, reduced costs.</strong> May allow platooning (vehicle groups traveling close together), narrower lanes, and reduced intersection stops, reducing congestion and roadway costs.</td>
<td><strong>Social equity concerns.</strong> May have unfair impacts, for example, by reducing other modes’ convenience and safety.</td>
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<tr>
<td><strong>More efficient parking, reduced costs.</strong> Can drop off passengers and find a parking space, increasing motorist convenience and reducing total parking costs.</td>
<td><strong>Reduced employment and business activity.</strong> Jobs for drivers should decline, and there may be less demand for vehicle repairs due to reduced crash rates.</td>
</tr>
<tr>
<td><strong>Increase fuel efficiency and reduce pollution.</strong> May increase fuel efficiency and reduce pollution emissions.</td>
<td><strong>Misplaced planning emphasis.</strong> Focusing on autonomous vehicle solutions may discourage communities from implementing conventional but cost-effective transport projects such as pedestrian and transit improvements, pricing reforms and other demand management strategies.</td>
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<tr>
<td><strong>Supports shared vehicles.</strong> Could facilitate car-sharing (vehicle rental services that substitute for personal vehicle ownership), which can provide various savings.</td>
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*Figure 1: Autonomous Vehicle Potential Benefits and Costs*

**Source; Litman 2015.**

**How much is known about public attitudes to autonomous vehicles?**

3.10 There have been a number of surveys of public attitudes towards driverless cars. However any findings must be subject to the caveat that few respondents have any direct experience of autonomous operation, and many will have little idea of how they would perform in practice. Subject to this qualification, these conclusions can be drawn from a number of recent surveys\(^\text{19}\) some of which are of UK citizens whilst others include both UK and other people:

- a substantial proportion of respondents believe they would not want to use driverless cars as they enjoy driving;
- there is a widespread feeling that autonomous road transport could significantly enhance the mobility and independence of those who were unable to drive (e.g. elderly, disabled and visually impaired people);

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driverless cars were seen by many as being potentially safer than manually driven cars although there were real concerns about hacking and others forms of abuse; there are social aspects to driving which driverless cars would not be able to integrate into; autonomous operation could reduce some costs e.g. for public transport operation by removing the need for professional drivers, but the picture was less clear for personal use – would there be a cost premium over ordinary road vehicles? Environmental impact could be reduced by automation but the availability of driverless vehicles could damage public transport services and prompt unwelcome lifestyle and land use patterns; some respondents thought that driverless cars should have segregated facilities to separate them for general traffic; some respondents did not see the development of driverless cars as a priority for the automotive industry.

A summary of the key points from these surveys is set out in Annex A.

What is the scale of the market opportunity for autonomous vehicles?

3.11 At any point in time the current car parc is a legacy of a history of introductions of new vehicles over many years. Looking at the market in Great Britain, taking the age distribution of the 2015 parc\textsuperscript{20} it would take 7½ years for half the parc to be replaced with post 2015 vehicles, 11½ years for three quarters to be replaced by post 2015 vehicles and 14 years for 90% of the existing parc to be retired.

3.12 Figure 2 shows three hypothetical scenarios for the growth of Autonomous Cars (ACs) between now and 2050. In scenario A ACs start to appear in numbers in 2020 and develop rapidly such that by 2028 all new cars are autonomous. In scenario B ACs start to appear in numbers in 2022 and penetration builds up more slowly over the next thirteen years to 2035 when all new cars are autonomous. In scenario C AC growth starts in 2024 and builds up over 18 years. All three scenarios assume that eventually all cars will be capable of autonomous operation. In practice, unless excluded from their use on public roads, some drivers may choose to drive only partially autonomous vehicles and, even if all vehicles were capable of fully autonomous operation, some drivers my choose, if permitted, to drive them manually for part of the time. If only two out of three new cars were to be autonomous then the saturation level in figure 2 would be correspondingly lower (see feint dashed blue line).

\textsuperscript{20} DfT 2016c.
Figure 2: Illustrative autonomous car growth scenarios

3.13 Whilst these growth profiles are purely illustrative they serve to show that on very bold assumptions about the penetration of autonomous cars into the market it would be 2030 before they became the dominant form of car transport and on more pessimistic/realistic assumptions (gradual take by only two thirds of drivers) this would not occur till 2042. There are other more or less optimistic projections with one forecaster estimating 5½ million new CAVs globally in 2019\(^\text{21}\) – equivalent to 7% of total car production and another, more sober prediction, giving between 40% and 45% CAV representation (globally) by 2050\(^\text{22}\).

3.14 But the automotive marketplace is a global business. If autonomous vehicles can be developed which do not rely on sophisticated state-run system architecture and pin-point accurate mapping, and can be produced at the right price, then the global market in developing economies could potentially be huge.

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

3.15 The trials and demonstrations of ADACs and CAVs is presently shared between a range of actors with the large automotive and technology companies playing the major part. We welcome the establishment of the Centre for Connected and Autonomous Vehicles to

\(^{21}\) Business Insider UK 2015, see also Lux 2014.

\(^{22}\) Litman 2015
span the policy interests of the Department for Transport and the Department for Business, Energy and Industrial Strategy and provide a single point of contact for Government interest in this issue. The CCAV framework to support the testing of automated vehicles on Britain’s roads\textsuperscript{23} has been recognised as a world-leading approach to describing and defining the framework that will need to be adopted, and to evolve over time, to allow for the development and deployment of autonomous vehicles on public roads.

3.16 The UK Government is also reasonably active in:
- part funding three trials to demonstrate autonomous road vehicles\textsuperscript{24};
- promoting lorry platooning trials; and
- providing tens of millions of pounds to research and develop new connected and autonomous vehicle technologies\textsuperscript{25}.

3.17 The fact is that tens of millions of pounds of Government research funding has to be seen in the context of the hundreds of millions being invested directly by the automotive and technology companies. Where Government might usefully turn its R&D thinking towards are the areas of:
- exploring alternative system architectures for autonomous road vehicle operations in which $V\leftrightarrow V$ and $V\leftrightarrow I$ communications figure as well as the mainly vehicle-based systems that are presently receiving so much attention; and
- exploring the traffic performance of ‘mixed’ systems with manual, ADAS and CAV operations in different types of road environments from motorways to busy mixed use urban streets.

3.18 As this is a rapidly developing field it is essential that the Government keeps abreast of developments as they emerge and has the capacity to assess their public policy implications of these in a timely fashion. It should also regularly review the support it gives to industry and keep an open door to new collaborative and worthwhile funding opportunities.

*How effective are Innovate UK and the CCAV in this area?*

3.19 Innovate UK and the CCAV are together responsible for a number of activities in the field of autonomous road transport but at this early stage it is difficult to give an informed assessment of their effectiveness. It is welcome that the Government has established CCAV as a focal point and single ‘portal’ for those wishing to engage with Government, and to take the lead on those issues which fall to Government, such as amending the statutory framework to allow for safe autonomous operation. It will be important for CCAV to retain the overarching policy responsibility.

*Is the environment for small and medium-sized enterprises (SMEs) working in this sector sufficiently enabling?*

\textsuperscript{23} DfT 2015a & 2015b, CACV 2016.
\textsuperscript{24} TSC 2014, Venturer 2016, Gateway 2016.
\textsuperscript{25} DBIS 2016 & DBEIS 2016
3.20 The questions about which technological mixes will prove successful, the presence of major players with deep pockets and the uncertainties of the regulatory environment mean that it is difficult for SMEs to take a solo lead in this area. However there are places for them in support of the Auto OEMs\textsuperscript{26} and Tech companies, especially where there are established relationships. As far as the UK Government is concerned the streams 2, 3 & 4 of the CCAV/Innovate UK will fund feasibility studies and industrial research and development projects ranging in size from total costs of £250,000 to £5 million with projects lasting between 12 and 30 months. This offers opportunities well suited to SMEs either on their own or as part of larger consortia. The LUTZ project involves the Oxford Robotics Group which is a small team of systems and software engineers with a commercial arm and a medium sized division of an established advanced engineering company (RDM). Whilst the commercial risks will limit early involvement of most SMEs the government’s involvement encourages SME participation.

*Will successful deployment of autonomous vehicles require changes to digital or physical infrastructure?*

3.21 This is an extremely difficult question to answer in any detail at this stage. Undoubtedly the general answer is ‘yes’, but ‘what’ and ‘how’ are much less clear. To some extent current autonomous systems rely on reading the features of their surrounding infrastructure; for example lane markings. If this continues then these will have to be maintained to a high standard and developed to cope with interference from adverse weather such as fog and snow. To the extent that CAVS and ADACs rely on reading road signs for their guidance then a consistent regime will be needed across the entire road system. Where there are large numbers of CAVs operating in close proximity there may be a need to increase the capacity and reliability of the mobile phone networks in the area. Similarly where GPS forms a part of a CAVs location/guidance system very high standards of reliability will be required.

3.22 If V↔V and V↔I communications figure in CAV operations then there will probably be a need to ‘smarten’ some aspects of the road infrastructure perhaps also replacing ANPR with electronic Automatic Vehicle Identification (AVI). The roles of these types of communication are, as yet, unknown and will depend of the overall systems architecture and protocols to be used for autonomous road transport operations.

3.23 The Foundation has commissioned research into the infrastructure implications arising from the introduction of autonomous vehicles which should be available in time to assist the Committee’s deliberations.

*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?*

3.24 The requirements for the widespread adoption of highly automated vehicles differ between ADAS and CAVs. Where the driver retains control – albeit with a substantial degree of assistance from the cars ADAS – the overriding issue is the safe capability of the

\textsuperscript{26} Original Equipment Manufacturers.
technology used. Where the requirement for manual control is removed other, more complex, issues arise. In this situation the highway operator/regulator will have to ensure that the CAV technology can operate safely, efficiently and with minimal environmental impacts in mixed traffic in defined traffic environments (e.g. motorways) or generally. This will require extensive proving of different types of CAV technology and evaluation of operations in a wide range of real life conditions. The trials so far are only early steps in this process.

3.25 Regulators will need to ensure that clear insurance arrangements are in place for CAVs and the rules of the road and CAV operation are consistent. If the introduction of CAV operations on a large scale require infrastructure changes then these will need to be introduced and this could costly and take time. The mix of responsibilities for highways and traffic means that a central lead will be required to ensure all highway and traffic authorities act in concert. Where CAV use crosses jurisdictions ideally they should be uniformity of autonomous operating regimes between these or at least a capacity for safe adaptation when switching between jurisdictions (e.g. minor adaptations of UK vehicles when travelling on Continental European roads).

3.26 For the UK government the immediate milestones to be reached are the successful completion of the lorry platooning trials and the recently started driverless car trials in Bristol, Milton Keynes and Greenwich. Again however these are first steps and the progressive development of a policy and regulatory context for autonomous road vehicle operation will be needed. A start has already been made but there is still a long way to go before a clear and comprehensive framework is achieved.

*Does the Government have an effective approach on data and cybersecurity in this sector?*

3.27 We do not have sight of Government activity in this area beyond noting that cybersecurity has been recognised as an important issue, but would expect cybersecurity to be explored directly and as an aspect of the trails that the Government is supporting.

*Are further revisions needed to insurance, regulation and legislation in the UK to create an enabling environment for autonomous vehicles?*

3.28 These issues have been recently consulted upon by the Centre for Connected and Autonomous Vehicles and the Foundation’s response is at Annex B (not published here).

*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?*

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27 Riccardo 2014.
28 Venturer 2016.
29 MKCitizen 2016.
30 DBIS 2016.
31 CACV 2016a.
32 CACV 2016b.
3.29 This issue is addressed in paragraph 2.12 of the Foundations response to ‘Pathway to Driverless Cars’.

What does the proposed Modern Transport Bill need to deliver?

3.30 The Foundation has given its views in its response to the recent consultation on ‘Pathways to Driverless Cars’ set out in Annex B (not published here).

How effective is the UK’s education system in delivering people with the right skills to support the autonomous vehicles sector?

3.31 The UK has a long tradition of excellence in science, technology and engineering and has many remarkable achievements in these areas to its credit. This is reflected in the excellence of the relevant professional and institutions. However its record in commercial exploitation and applications is less impressive. This is due to a range of factors one of which is the shortage of sufficient skilled professionals and technicians in these areas.

3.32 The UKCES Employer Skills survey showed that the science, research, engineering and technology professionals’ category (SOC sub-major group 21) had the highest ratio of Skills Shortage Vacancies of any of the 25 occupational sub-major groups. A recent survey by the Confederation of British Industry (CBI) found that 44% of engineering, science and hi-tech firms reported difficulties in finding experienced recruits with the right STEM skills.

3.33 So the answer to this question must be ‘not effective enough’.

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?

3.34 In its review of the need to strengthen the nation’s engineering skill base the 2013 review by Professor John Perkins concluded that whilst a good deal was being done more was needed, in particular:

- the engineering community should work with Government to develop and promote new Level 2 and 3 qualifications that will create high-quality vocational routes for 16-19 year olds to enter engineering careers;
- the engineering community should work with employers to encourage and support provision of work experience for post-16 students, studying in colleges and schools.
- the engineering community, especially employers, should work with Government to develop additional Trailblazer Apprenticeships in engineering;
- Government should develop plans to boost diversity of engineering apprentices, building on the pilots and research commissioned by the Skills Funding Agency;

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33 RACF 2016.
34 Ibid.
35 UKCES 2016.
36 CBI 2016.
37 DBIS 2013.
• Government should build on the UTC experience and seek to develop elite vocational provision for adults so that our people have the opportunity to learn the very latest techniques and approaches in a vocational setting;
• engineering employers should encourage their staff to share their skills and knowledge, for example, by participating in the Education and Teaching Foundation’s Teach Too scheme;
• Government and the FE sector should encourage the application of learning technologies to extract maximum value from expert lecturers and the materials they produce, for example through Teach Too.

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?

3.35 Until the terms of the UK’s relationship with the European Union (EU), following its leaving, are clear and the new trading and co-operative relationships with other countries established it is very difficult to assess the implications for the automotive industry in the UK in general and its autonomous vehicle component in particular. In the short run these uncertainties are more likely to inhibit efforts by non-domestic players to promote the development of CAV activities in the UK than the reverse. In the long run there will be both opportunities and risks which will have to be carefully managed to ensure the UK realises its full potential in this area.

3.36 In the short term the Government must continue to play the positive roles it has already assumed in supporting the domestic development of autonomous vehicle technology and in creating a favourable environment for its safe and efficient introduction and deployment in the field. There are signs that the Government is alive to this issue and is seeking to ensure that the uncertainties of leaving the EU do not prejudice programmes by overseas based companies to develop autonomous road vehicle technology in the UK38.

3.37 UK representatives have long played a leading and influential role in the development of international vehicle standards e.g. in UN ECE committees, and it will help if this engagement is maintained and enhanced as new standards start to emerge for autonomous technologies.

25 October 2016

38 Nissan 2016b.
Sources


Nissan (2016b), *Comments from British Prime Minister Theresa May and Nissan Chairman and CEO Carlos Ghosn, following their meeting at No 10 Downing Street today*, 14th October 2016, http://newsroom.nissan-europe.com/uk/en-gb.

RAC Foundation (2016), *RAC Foundation’s Response to the Centre for Autonomous & Connected Vehicles Consultation on Pathway to Driverless Cars: Proposals to support advanced driver assistance systems and automated vehicle technologies*, RACF, London, September 2016. (attached)


ANNEX A- ATTITUDE POINTS

Catapult

39% would consider using driverless cars
Two thirds of progressive metropolites would consider using driverless cars
25% of petrolheads would consider using driverless cars

Sciencewise

Only 18% of those surveyed said they thought driverless technology was an important avenue for car manufacturers to pursue, with 41% deeming it unimportant.
Providing freedom of movement for the elderly and disabled
Comfort, convenience and increased productivity
Increased safety
Easing congestion
Decreased cost
Environmental benefits

but

The system is vulnerable to abuse
The degree of control big business and governments could gain over people’s lives
Safety.
Unwelcome changes to lifestyle
Waste of existing resources
Environmental concerns

RAC 2015

A majority of motorists (52%) believe that driverless cars will benefit older and disabled drivers. But only a quarter (27%) expect driverless vehicles to make road travel safer.

RAC 2016

There is widespread agreement that the driver-assistance technology used in existing vehicles is effective in making both cars and roads safer than in the past.

AA

2016 – 72% said driverless cars have the potential to increase mobility and independence for those who otherwise may not be able to drive (elderly, blind, etc.)

2015 - Two thirds (65%) of respondents say that they ‘enjoy driving too much to ever want a driverless car’.

Over half agree that ‘driverless cars would have to be segregated’ (56%) and that they ‘wouldn’t trust assurances that driverless cars were safe’ (57%).
2013 - Two-thirds of AA members surveyed (65%) enjoy driving far too much to ever want a driverless car, and 56% wouldn't trust manufacturer or government assurances that driverless cars were safe.

12% of respondents can’t wait for the day when they can buy a car that will drive itself, and almost a third (31%) would like UK laws to be changed so that trials can happen on our roads. This could be problematic because over half of AA members (57%) would want driverless cars to be segregated and drive only on dedicated roads or lanes.

**Shoettle & Slivak**

The majority of respondents had previously heard of autonomous or self-driving vehicles, had a positive initial opinion of the technology, and had high expectations about the benefits of the technology.

However, the majority of respondents expressed high levels of concern about riding in self-driving vehicles, security issues related to self-driving vehicles, and self-driving vehicle not performing as well as actual drivers.

Respondents also expressed high levels of concern about vehicles without driver controls; self-driving vehicles moving while unoccupied; and self-driving commercial vehicles, busses, and taxis.

The majority of respondents expressed a desire to have this technology in their vehicle. However, a majority was also unwilling to pay extra for the technology; those who were willing to pay offered similar amounts in each country.

Females expressed higher levels of concern with self-driving vehicles than did males. Similarly, females were more cautious about their expectations concerning benefits from using self-driving vehicles.

**Kyriakidis et al**

Results showed that respondents, on average, found manual driving the most enjoyable mode of driving. Responses were diverse: 22% of the respondents did not want to pay more than $0 for a fully automated driving system, whereas 5% indicated they would be willing to pay more than $30,000, and 33% indicated that fully automated driving would be highly enjoyable. 69% of respondents estimated that fully automated driving will reach a 50% market share between now and 2050. Respondents were found to be most concerned about software hacking/misuse, and were also concerned about legal issues and safety.

**LSE/Goodyear**

This survey asked questions on ‘comfort’, ‘openness’, ‘familiarity’, ‘perception’ and ‘Technological Optimism & Driver Sociability’, from focus groups in four European countries and through a 12,000 respondent on line survey in eleven European countries including the UK.

*Comfort* - 26% of respondents describe themselves as comfortable (either totally, very, or quite) with the idea of using an AV and 29% for driving alongside one. Conversely, 44% feel
uncomfortable about using an AV, whilst 41% feel uncomfortable about driving alongside one.

**Openness** - Twice as many respondents agreed (43%) than disagreed (19%) that most accidents are caused by human error, so autonomous vehicles would be safer and machines don't have emotions so they might be better drivers than humans (37% v 21%) but 73% of respondents were concerned that autonomous vehicles could malfunction and that machines did not have the common sense needed to interact with human drivers.

**Familiarity** - When more thought was given to the comfort issue the respondents became more optimistic.

**Perception** - Respondents who already relied more on in-car technology are, on average, more open to AVs. So, while only 15% of respondents say that they regularly use cruise control, of these 61% are in the top half of the scale in terms of openness to AV. Nevertheless 70% thought that humans should be in control of their vehicles and 80% said it should have a steering wheel. 82% of respondents said they would probably or definitely prefer to keep aware of the road around them and only a few saying that they would sleep (19%) or watch a video (18%) if they didn’t have to pay attention to the road.

**Technological Optimism and Driver Sociability** – ‘Sociable’ drivers tend to be less open to AVs as they enjoy a level of social interaction with other drivers they would not get with AVs and these folk are less technologically optimistic. ‘Combative’ drivers on the other hand tend to be more technologically optimistic and see AVs as easier to deal with than other drivers.

This study concluded that the majority of respondents remain concerned at the prospect of AVs, even if over a quarter of respondents are open to the arrival of AVs on our roads. When considering current levels of knowledge and experience of AV technology, it is to be hoped that greater familiarity will allay some of the concern.

But this research identifies a number of deep-seated reservations – to the willingness to give up control, to the reliability of AV technology and to AVs’ ability to integrate in the “social space” that is the road. It is necessary to understand these reservations, rather than just assume that the public needs more information if AVs are to negotiate a place for themselves on the road.

Arguments that focus simply on promoting greater safety, lifestyle enhancements or economic efficiencies will not gain traction if AVs do not fit comfortably into the public’s picture of what the road should be like for them to drive on.