About TRL

TRL (the UK’s Transport Research Laboratory) is a centre of excellence for research into all aspects of surface transportation. Founded in 1933, it was privatised in 1996 and is owned by a non-profit distributing organisation. TRL has contributed research to many of the most significant transport safety developments in the UK and internationally including the rules around drink driving, seatbelt use, mobile phone use and the EuroNCAP vehicle collision standards. It has been working on vehicle automation since the 1950s and has a growing and varied programme of research into the development and implications of connected and automated vehicles.

Summary

0.1 Connected and automated vehicles (CAVs) are developing along two converging paths. Fully automated vehicles operating in increasingly sophisticated environments and road vehicles in which automated systems take responsibility for greater parts of the driving task. The applications for CAVs are as broad as any situation in which people, goods or services need to be moved representing an enormous market opportunity.

0.2 Potential benefits include improved safety, accessibility, emissions performance and asset use but these must be weighed against potential disadvantages including user confusion, changes in opportunities for employment and threats to equitable transport provision.

0.3 The commercial benefits of truck platooning may result in this emerging as one of the early applications of vehicle automation technology with upcoming UK trials providing insights to its viability.

0.4 Questionnaire surveys to date have been dependent on respondents imagining what the future may be like using automated vehicles. This may be subject to inherent biases that do not accurately represent the true picture. Current UK trials of automated vehicles will provide additional evidence on public perceptions based on real world experience of the technology.

0.5 The UK government approach to date has delivered regulatory guidance, a dedicated policy unit (CCAV) and research funding to support developments of automated vehicle technology. This has enabled significant international impact, the development of interesting collaborations and support for developing SMEs in this space but the UK is lacking an equivalent to Silicon Valley in terms of investment, community and risk-taking approach.
0.6 To maximise UK impact in this area, it is vital that the key organisations working in this area are provided with an environment in which they can successfully achieve international ambitions from a domestic base.

0.7 Automated vehicles will be developed regardless of changes to digital or physical infrastructure. However, the deployment of automated vehicles may be significantly enhanced by having supporting digital and physical infrastructure available.

0.8 The key objective in progressing towards higher levels of deployment of automated vehicles is that safety, security, privacy and network performance are not unacceptably compromised by their deployment.

0.9 Insurance is a critical enabler for our road transport system. Regulation may be required to compel vehicle manufacturers to make data relating to incidents occurring in automated driving modes accessible. These data would need to be of sufficient scope, resolution and validity to allow an insurer to form a view on their liability for an incident.

0.10 Ethical dilemmas faced by automated vehicles make interesting thought experiments but will not present as big an issue as it is sometimes perceived to be.

0.11 It will be important to ensure the public are engaged in the increasing adoption of automated vehicles to maximise their likely uptake and deployment benefits.

0.12 The most challenging outcome of Brexit would be the loss of the UK’s ability to type approve vehicles for sale in Europe.

Full response to the inquiry

Impacts and benefits

1 What are the potential applications for autonomous vehicles?

1.1 There is a huge range of potential applications for connected and automated vehicles (CAVs). It is important to recognise two convergent trends in the development of automated vehicles. On one path, regular cars are being fitted with increasingly sophisticated driver assistance systems that are gradually automating more and more aspects of the driving task. Although other manufacturers have technology that may be more sophisticated, the vehicle maker that has had the greatest market prominence with driving assistance systems is Tesla through the deployment of its ‘AutoPilot’ system. This system supervises the vehicle on suitable roads (typically highways), including the ability to overtake slower moving traffic on multi-lane roads when instructed by driver (using the indicator stalk). It is important to recognise that the AutoPilot system requires the driver to be alert and attentive at all times should they be required to resume control at short notice.

1.2 The other path towards automated vehicles is the development of highly automated vehicles that are designed not to have a human operator. Many such vehicles are already in service (e.g. Docklands Light Railway, Heathrow Ultra PRT). By the application of advanced sensors and software, the scale and scope for the use of such vehicles is growing rapidly. It
is this approach that we are testing in our project in Greenwich called GATEway, that is co-funded by Innovate UK and commercial partners.

1.3 The applications for CAVs are as broad as any situation in which people, goods or services need to be moved. There are two important considerations that should be borne in mind. Firstly, it is vital to remember that the way a service can be delivered may be dramatically different if a human operator (often a significant cost in a vehicle service operation) is not required. Secondly, many of the benefits of automation can be accrued on both of the pathways described above before we reach the situation where vehicles are capable of driving in an automated mode all of the time.

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

2.1 There are many potential user benefits of automated vehicle technology. One benefit is safety – 1.25 million people die on roads around the world each year and our own research has demonstrated that in the majority of these collisions, human error is the cause. Automation is addressing this driver error as a cause of road collisions. Two caveats – firstly, although we anticipate many fewer collisions with the advent of automated vehicles, we can also envisage new categories of collision that are caused directly by the use of automated systems and so we must be prepared to provide evidence and reasoning as to why the use of automated systems is of overall benefit from an ethical perspective. Secondly, whilst the number of casualties is too high, driving represents a remarkably safe system when one considers the quantity of driving that is undertaken. In terms of fatalities, if one uses the UK Department for Transport statistics to divide the number of vehicle miles driven per year with the number of fatalities per year, we find that there is around 180 million miles driven per fatality – which, if driven at a constant 60mph, would require more than 340 years of continuous driving (24 hours per day, 365 days per year) per fatality. This sets a very high bar achieving absolute proof that automated vehicles are safer than human drivers.

2.2 A second benefit is accessibility – we have a growing, ageing and increasingly urbanised population with existing transport service provision already under pressure. Automated vehicles may offer new ways in which to achieve mobility across a city in a manner that is complementary to existing modes, may help to improve road network performance and could support active travel policies. In addition, automated vehicles can open up independent mobility for elderly and disabled travellers to help them achieve better health, social and economic outcomes.

2.3 A further benefit relates to emissions and asset use. Automated vehicles make the development of car-sharing and/or ride-sharing services increasingly viable. This means that individuals can use vehicles that best suit their individual journey needs rather than the situation today in which a vehicle user selects a vehicle that best suits the majority of their mobility needs – resulting in many large family cars and SUVs being driven with single occupants (i.e. the driver) on many journeys. The ability to optimise vehicle choice against journey purpose raises the prospect of smaller, cleaner vehicles being used for short journeys whilst larger vehicles could be used more sparingly for longer and/or group trips.
2.4 A disadvantage of automated vehicles relates to the long period over which we will see non-automated, partially automated, highly automated and (eventually) fully automated vehicles co-existing on our roads. This may present a confusing situation for vehicle users. A driver must always be aware of the extent to which their attention and input is required to maintain safe control of the vehicle as a function of the level of automation available. A mismatch between user expectations and system capabilities can be seen to have contributed to a recent high profile fatal collision involving the Tesla ‘AutoPilot’ system. Such issues (extensively studied in aviation in relation to automation of the flying task) are likely to emerge with drivers, especially since, as a population, they are typically less well trained, regulated, motivated or rewarded in comparison to pilots. In a similar way, 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.

2.5 It is often the case that emerging technologies change the employment market. Whilst a new system may make workers redundant (e.g. the use of heavy machinery in agriculture), it also creates opportunities in new areas. This can be expected with the growth of automated vehicles and their potential to replace driving jobs across the transport sector. This may eventually include delivery drivers, taxi drivers, lorry drivers, forklift truck drivers and public transport (bus, train, tube) drivers. However, the transition will not happen overnight. Many of the processes around goods deliveries and vehicle operations depend upon human operators for tasks other than driving at varying points in the chain and organisations employing drivers will have time to adjust, retrain and redeploy employees where possible.

2.6 Numerous organisations have for many years claimed that some form of usage based road pricing would provide the best mechanism for managing congestion. The use of connected automated vehicles as a service would provide their operators (and regulators) with the means to apply dynamic charges for road usage with minimal additional infrastructure costs (i.e. identification, usage and charging can all be managed through app-based data). Charging may be varied according to a number of parameters including congestion, air quality, time of day, urgency of trip, route selection willingness to be shown adverts and total vehicle occupancy. There is a hugely significant role for national and/or regional authorities in regulating the delivery of transport services by such mechanisms to ensure that our roads provide adequate mobility for the broadest section of society. A city criss-crossed by so-called ‘Lexus lanes’ – routes where only the highest earners can achieve easy, free flowing transportation may benefit a minority but these must be weighed against potential adverse consequences to broader mobility across the city.

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

3.1 It is unclear to us how much is known about the impact of deploying automated vehicles in different sectors. Clearly, there has been much press coverage about the potential for deploying automated vehicles on roads (and the partnerships that have emerged between large industry players to develop the vehicles). Although the market is gradually seeing lower levels of vehicle automation that bring some driver comfort and safety benefits, the technology to achieve road vehicle automation that does not require at
least some input from a driver is not yet mature. At that stage, some of the more significant and transformative impacts are likely to occur.

3.2 One likely early use case of vehicle automation (and connectivity) is truck platooning – the concept in which a lead truck can be followed at very short range by one (or more) other truck(s) forming a ‘platoon’, resulting in aerodynamic efficiencies and significant fuel savings for all participating vehicles. In a low margin industry where fuel costs represent a large proportion of costs, the commercial case for platooning is strong. The government is about to commission trials of platooning to understand the extent to which fuel savings achieved in technical demonstrations are achievable safely on the public roads with real trucks, real loads and real drivers.

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

4.1 Many questionnaire surveys have been undertaken and the impression that they give is that the public is broadly in favour of the safety benefits that automated vehicles may bring, particularly where the ability to operate a vehicle in an automated mode is an option over which they have full control over when, where and the extent to which the vehicle is automated. Surveys also suggest a less positive response towards vehicles that are fully automated with no opportunity for driver intervention.

4.2 However, whether these surveys measure true public attitudes to autonomous vehicles is questionable. Firstly, they tend to be produced by organisations that have established interests in existing transport systems and so the questions may not be pitched in ways that are truly objective. Secondly, it is difficult to say whether the survey results give an accurate reflection of real attitudes to automated vehicles when none of the respondents to such surveys have experienced travel in an automated vehicle. This underpins the purpose of the TRL-led GATEway project in Greenwich. By giving members of the public the opportunity to ride in an automated vehicle and see them operating as a service in an urban environment, they may be able to access a truer perspective on how such vehicles could play a significant role in future transport.

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

5.1 The market opportunity for automated vehicles is no less than every motorised surface transportation system and indeed, many of the technologies developed for automated road vehicles such as artificial intelligence and computer vision are applicable to aerial and marine vehicles as well. The market is therefore sufficiently large to make accurate estimates of its size challenging. That should not discourage the UK from taking a prominent role in the technology that will deliver vehicle automation. In doing so, care is required to ensure that UK-based pioneers of the technology do not automatically seek for their company to be bought out by international corporations but that the environment in the UK is sufficiently connected and appealing to ensure that they can achieve their international ambitions from a domestic base.

Creating an enabling environment

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

6.1 Based on attending many international meetings, symposia and conferences related to CAVs over the last five years, the UK’s current position on CAVs is one that is admired and indeed has been imitated by other nations. It has been established by three precepts; firstly, the government undertook an extensive review of regulations around the testing of automated vehicles and subsequently produced a code of practice for testing automated vehicles that provides straightforward guidance for organisations wishing to test automated vehicles on UK roads. Secondly, the creation of the Centre for Connected and Autonomous Vehicles (CCAV) has provided a focal point for the development of policy, regulation and research on CAVs in the UK and a conduit for international outreach, encouraging overseas organisations to bring their R&D, investment and jobs to the UK. Thirdly, it has provided seed funding for research through Innovate UK and CCAV to enable tests to get under way and to build momentum and capability in the UK for research and development in this area.

6.2 The programme of research that has emerged from this work has broadened in scope and ambition as organisations within the UK have become energised towards this agenda. The initial three projects (including GATEway) focused on the automated vehicles in the urban environment. This distinguished the UK’s innovation activities from those of many other countries. Following funding calls have provided broader scope for connected and automated vehicle research and development. It should be noted that whilst the investment from government (matched by industry) is very welcome, it is dwarfed by the research and development budgets of the major vehicle manufacturers and technology providers working in this space. A critical next step therefore is to attract major CAV research investment in the UK that complements and augments the developing indigenous capabilities in this space.

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?

7.1 Relative to other international governments, the coordinated actions described above indicate that the UK government is doing a good job to support research and development on autonomous vehicles. There is always more that could be done and there are two factors that are missing compared to other nations. Firstly, we do not have an equivalent of Silicon Valley – a region (and community/culture) in which technology start-up businesses can access huge sources of funding – some will fail (and fail fast) while a small proportion achieve exponential growth and become nationally and globally relevant.

7.2 Secondly, whilst there are major motor manufacturers that provide thousands of jobs in the UK, none are domestically owned. Even if the UK can create the software that underpins all automated vehicle operations, we are (at present) highly dependent on overseas companies to manufacture the vehicles that will operationalise software that UK organisations may create.

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

8.1 The Innovate UK competitions that are funding projects related to connected and automated vehicles seem to provide an appropriate balance between encouraging the
required research and delivering the required innovation to achieve significant return on investment. Importantly, they provide a forum in which academic, research and commercial organisations from related sectors (e.g. communications, insurance, energy etc.) can form new partnerships that will enable the most interesting and (commercially and academically) profitable projects to be delivered. The CCAV team have reached out across the UK and internationally to coordinate CAV activities with enormous energy, dedication and openness. There is much more work to do and their continued support by government is recommended.

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

9.1 The funding competitions run by Innovate UK and CCAV seem well positioned to support SME development. This is achieved in three ways; firstly, the gearing applied to the funding that enables SMEs to recover a higher proportion of their costs than larger organisations; secondly, the consortium building events that are coordinated by Innovate UK and CCAV provides fora in which SMEs can present their capabilities to a broad array of potential partners (and investors); and thirdly, the evaluation of Innovate UK funded project proposals can favour those that have well justified and commercially viable involvement from select SMEs. The ‘GREAT’ campaign and support from the Department for Business Energy and Industrial Strategy and the Department for International Trade also provides opportunities for SMEs to make connections they might otherwise miss.

9.2 As stated in the answer to question 7, we are missing a UK-based technology start-up/venture capitalist culture that can provide a real springboard to turn SMEs into large and highly profitable organisations creating hundreds and eventually thousands of technology related jobs.

Real world operation

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

10.1 Automated vehicles will be developed regardless of changes to digital or physical infrastructure. However, the deployment of automated vehicles may be significantly enhanced by having supporting digital and physical infrastructure available. This could enable the UK to achieve the predicted (societal, commercial, safety etc.) benefits sooner than other regions.

10.2 It must always be the case that automated vehicles, in the absence of any data connectivity, must be able to navigate safely. However, information gleaned from external sources (whether physical or digital) may improve their operation and management. Physical infrastructure is typically built with a lifespan of decades in mind making it impossible to construct in a manner that can accommodate future (unknown) technologies. For the foreseeable future, it will therefore be desirable simply for infrastructure to be constructed that is consistent with design guidance such that automated vehicles find the environment predictable.
10.3 Digital infrastructure – highly detailed 3D maps, annotated with important features of the operating environment – is likely to be a critical component of the deployment of automated vehicles, which will rely on having this as a reference map in which to localise itself, navigate the desired route and detect deviations which may represent potential hazards. Significant questions remain over who has responsibility for collecting and updating the map data, how this map is refreshed sufficiently frequently, at sufficient accuracy and how mapping information is communicated rapidly and effectively to millions of vehicles as required.

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?

11.1 The key objective in progressing towards higher levels of deployment of automated vehicles is that safety, security, privacy and network performance are not unacceptably compromised by their deployment. Provided this objective is met, there is a critical role for transport authorities to regulate public and privately operated automated transport services to optimise equality of mobility across all sectors of society.

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

12.1 The National Cyber Security Centre provides a good starting place for an integrated and coherent cyber security policy. The threats to connected and automated vehicles are technically similar to other cyber environments, though the consequences of successful penetration are unique. Hence the technical mitigation can easily be derived from existing guidance, and the threat analysis needs to be dedicated to the sector.

12.2 Wireless connections to connected vehicles provide the most likely attack vector into a vehicle, but automation provides a target which can be easily exploited by allowing the attacker to potentially take control of the vehicle. As mentioned earlier, while automated vehicles do not require connectivity, there are such significant advantages that it is almost certain that automated vehicles will also be connected.

12.3 TRL is supporting UK activity on the cyber-vulnerabilities of connected vehicles. In addition, there is a significant effort underway in the EC to address the cyber vulnerabilities of connected vehicles.

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

13.1 Insurance is a critical enabler for our road transport system in which the driver of a vehicle is insured against damages occurring as a result of their operation of the vehicle.

13.2 In an automated vehicle, or vehicle operating in an automated mode, the ‘driver’ or vehicle occupants may not have direct control of the vehicle at the time of an incident involving damage or loss.

13.3 In such cases the owner or operator of the vehicle would need appropriate insurance for damages or loss from the event. It would be reasonable for existing motor insurers to
take on this role and this approach was suggested during the government’s recent consultation.

13.4 However, in taking on such a role insurers may find that access to data relating to
the operation of an automated vehicle system during an incident is controlled by a
manufacturer. If the insurer deems that the manufacturer may be at fault in an automated
vehicle incident then a conflict of interest may thus arise between manufacturers and
insurers.

13.5 To assist insurers in providing insurance services to operators of automated vehicles,
regulation may be required to compel vehicle manufacturers to make data relating to
incidents occurring in automated driving modes accessible. These data would need to be of
sufficient scope, resolution and validity to allow an insurer to form a view on their liability
for an incident and to initiate action to recover their costs against other parties where
appropriate.

13.6 Accessible event data of this type would also provide essential transparency with
respect to the real world performance automated driving systems which would be beneficial
from a policy development and public confidence perspective. Bi- or multi-lateral event
data sharing agreements between insurers and manufacturers without the opportunity for
independent oversight may not best serve the public benefit which these technologies
promise.

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?

14.1 The ethical dilemmas faced by automated vehicles make interesting thought
experiments and it is true that automated vehicles will encounter situations where a
collision is unavoidable and that choices made by the vehicle control system will influence
the casualties (individuals affected, severity of injury etc.) resulting from a collision.
However, there are two key reasons why this will not present as big an issue as it is
sometimes perceived to be.

14.2 Firstly, it can be anticipated that automated vehicles will be programmed to behave
in a manner that better estimates the extant collision risk and provides adequate response
time and space for the vehicle to respond in the event of emergency situations arising. As a
result, it will be many times less likely that an automated vehicle will encounter an
unavoidable collision scenario when compared to human drivers.

14.3 Secondly, an automated vehicle will have a range of sensor equipment recording the
driving situations that the vehicle encounters as well as recording the decisions applied by
software to operate the vehicle in response to the sensor data. In the event of a collision,
the recorded data will provide an evidence base from which liability in the crash can be
determined. This objective evidence can be also be used to determine whether the vehicle
behaved in a manner that could be considered most ethical. If an investigation or court
decides that this was not the case, it may be possible to apply software updates such that
vehicles using the same control system will behave more appropriately when encountering
the same situations in future (though care must be taken to ensure that adjusting vehicle
responses for a specific situation does not compromise vehicle performance in a range of other similar situations, resulting in an increased collision risk). Continually iterating this update loop in response to crash and near crash situations will enable vehicle control systems to achieve optimised ethical performance. Note that different nations and regions may vary in the conclusions they reach about what constitutes ethical vehicle behaviour and manufacturers must account for this in their vehicle control systems.

15.1 The Modern Transport Bill needs to provide the freedom that enables innovation to proceed such that UK businesses can outperform rivals but without compromising safety, security or privacy.

16.1 The education system is capable of delivering people with the right skills to enable the development of the automated vehicle sector. However, greater issues are how to deliver the numbers required to continue (and accelerate) the current pace of development and how to ensure domestic organisations can provide a work environment such that UK-trained engineers and scientists are not tempted by opportunities overseas.

17.1 In successive funding rounds, the awarded projects have broadened in scope and brought in expertise from adjacent sectors. Based on organisations showing interest in the latest funding round, this trend appears to be continuing. A possible shortcoming of the current strategy is the absence of a campaign to win over public ‘hearts and minds’ towards the use of automated vehicles. If the position is that they are genuinely going to play a critical role in our future transport systems, then a supporting case that aims to build momentum in their use could be helpful in achieving public trust and acceptance sooner.

18.1 The most challenging outcome of Brexit would be the loss of the UK’s ability to type approve vehicles for sale in Europe. The ability to test and validate the performance of automated vehicles (including physical and virtual testing) will be a vital step in certifying a vehicle as being capable of operating on real roads and mixing with real pedestrians, cyclists and vehicles. If an organisation wishing to access the European market could do so by bringing it for testing (and development) in the UK, achieving certification and then selling the vehicle in the 28 EU countries, this would represent a significant market opportunity (and failure to do so would be a significant lost opportunity).
The European Commission is indicating that significant investment is going to be made in automated vehicle research. Exclusion of UK organisations from large scale European research programmes on automated vehicles may result in a reduction in the level of influence that the UK has on future research directions and regulatory outcomes.

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