HOUSES OF PARLIAMENT
PARLIAMENTARY OFFICE OF SCIENCE & TECHNOLOGY

POSTNOTE

Number 443 September 2013

Autonomous Road Vehicles

Vehicles capable of driving without human intervention are rapidly moving up the policy agenda. Legislation in Nevada, California and Florida now means that they are being tested on public roads for the first time. This POSTnote reviews recent technological and policy developments in this area. It looks at how road safety, the environment and congestion could be affected, and examines barriers to adoption.

Overview

- Autonomous vehicles could improve road safety and reduce congestion and emissions. However this is an emerging area of technology and it is uncertain to what extent the potential benefits will be realised.
- How autonomous vehicles could interact safely with other road users, and how they would communicate with each other, are the focus of ongoing research.
- There is no UK legislation governing autonomous vehicles and there are no EU standards.
- The main policy challenges are verifying the safety and reliability of autonomous road vehicles and creating a legal framework to allow their testing and deployment on public roads.

Background

Autonomous vehicles have existed as prototypes and demonstration vehicles since the 1970s. A fully autonomous vehicle capable of completing an entire journey on public roads without any human input is still some way from being realised. However, recent high profile demonstrations by automobile manufacturers and university research groups, and by Google, have intensified interest in the technology. In July 2013 the Minister for Science and Universities announced a £6 million investment in autonomous vehicle technology. The Department for Transport (DfT) has indicated that trials of autonomous vehicles on UK public roads will be underway during 2013.[1]

Autonomous vehicles (whether cars, buses or trucks) have the potential to improve road safety, increase fuel efficiency and reduce congestion. However, there are many technological and policy barriers to be overcome. This note summarises:

- recent policy developments in the UK and overseas
- technology and research efforts in the UK
- how road safety, traffic management and the environment could be affected
- barriers to adoption of autonomous vehicles.

Recent policy developments

DfT announced in July 2013 that it “will work to encourage the development and introduction of autonomous vehicles”.[1] The Automotive Council, chaired by the Business Secretary, sees autonomous vehicles as an important technology for the UK, especially given the strength of UK based automotive research and development, and wishes to promote UK based expertise.[2]

There are several EU funded programmes of research on both the technology and policy implications of autonomous vehicles. The European Commission has a working group on automation in road transport, which is cooperating with the US and Japanese departments of transport to develop research strategies and international standards. DfT is involved in these international negotiations. Three US states (Nevada, California and Florida) have enacted legislation to allow autonomous vehicles to be tested on public roads. The US National Highway Traffic Safety Administration (NHTSA) has issued preliminary guidance for states considering similar legislation.[3] Spain, Italy, Finland and Greece all have some degree of legislation governing their use but at present there is no specific UK legislation.

The main policy challenges involve verifying safety and reliability, and creating a legal framework to allow their testing and deployment.

Technology

Levels of Autonomy

Increasing degrees of automation are already being added to vehicles to improve road safety, reduce the number of tasks for the driver and improve fuel efficiency. Autonomy can be seen as a spectrum: from a fully manual vehicle to one where all functions are controlled by computer, as illustrated in Box 1.

The terms ‘connected’ or ‘co-operative’ are used to describe vehicles which can communicate in real time with other vehicles and with roadside infrastructure. ‘Autonomous’ vehicles do not have to be ‘connected’ though some argue that if they were, there could be benefits in areas such as traffic management. Similarly, connected vehicles do not necessarily have to be autonomous. There are different technological challenges associated with autonomous and connected vehicles, for example in the communications infrastructure required (see pages 3 and 4).

Fully Autonomous Vehicles

The majority of the technologies required to create a fully autonomous vehicle already exist. The challenge is to combine existing automated functions with control, sensing and communications systems, to allow the vehicle to operate autonomously and safely. There are various aspects to this:

- The vehicle needs to be able to navigate: to know where it is and how to get where it needs to go.
- It also needs to be aware of its surroundings, in order to obey local traffic laws and interact safely with other vehicles and pedestrians.
- The transfer of control between the human driver and the vehicle needs to be carried out safely.
- It needs to be able to perform basic functions such as braking, acceleration and steering. These tasks will be performed by an onboard computer.
- The vehicle must be able to gather and exchange data, such as maps. This exchange does not have to be in real time.

The vehicle detects information about its surroundings via a range of sensors, including cameras, laser imaging, radar and ultrasound. This information is then compared to a detailed preloaded map for the purposes of both navigation and obstacle detection. This form of navigation requires that the route has previously been mapped by any vehicle with sensing technology, driving the route under human control, and that the map has been shared by the vehicle that made it. GPS can be used for route finding but is not suitable for fine control as it is only accurate to 20cm.

Autonomous vehicles will need to be able to monitor the behaviour of other road users and react safely. This will involve machine learning: vehicles will use data on how other road users behave, to improve their interactions with other road users. For example, an autonomous vehicle could learn to predict when a vehicle intends to turn off a road, even if it is not indicating, for example by analysing road position or braking patterns.

Adoption Pathways

There are many research efforts underway both in the UK and overseas, to develop the technology and assess the policy implications of vehicles becoming increasingly autonomous. Some examples of UK research are shown in Box 2. They illustrate three possible options for the adoption of autonomous vehicles:

- Low speed centrally controlled electric pods as public transport in urban areas.
- Vehicles capable of platooning (i.e. travelling in a group) on motorways.
- Individual vehicles capable of driving autonomously on certain roads.

A fully autonomous transport system would probably include all three options.

Box 1. Levels of Autonomy

	Levels of Autonomy	Existing Examples
Driver only	The vehicle is entirely under human control but may have some automated systems.	Cruise control, electronic stability control, anti-lock brakes
Driver assistance	The steering and/or acceleration are automated but the driver must control the other functions.	Adaptive cruise control: distance to car in front maintained. Parking assistant: steering is automated, driver controls accelerator and brakes.
Partial autonomy	The driver does not control steering or acceleration but is expected to attentive at all times and take back control instantaneously when required	Adaptive cruise control with lane keeping. Traffic jam assistance.
High autonomy	Vehicles are able to operate autonomously for some portions of the journey. Transfer of control back to the human driver happens with some warning.	Prototype vehicles.
Full autonomy	The vehicle is capable of driving unaided for the entire journey with no human intervention - potentially without a human in the car.	None

An example scale of autonomy combining elements of scales found in references 3 and 7

Box 2. Examples of UK Research and development

Personal Rapid Transport: Electric Pods - Ultra global PRT[4]
Ultra Global PRT, a spin-out company from the University of Bristol, has developed the 'Heathrow pods' - small electric vehicles which transport passengers between the business car park and Terminal 5. These pods run on a dedicated guideway and are computer controlled via wifi linked to a central control room. The vehicles log wheel revolutions and use lasers in conjunction with track markings to determine their position. The PRT system is seen as an alternative to other public transport systems. Advantages are reduced waiting times (typically down to 10-15 seconds), and a personalised service. However, pods can only run on dedicated tracks and in this case cannot detect obstacles. The company is planning to expand the system at Heathrow and install a much larger system in Amritsar, India, to transfer passengers between bus and rail terminals and a religious site.

Platoons of Vehicles - Ricardo[5]
Ricardo is a UK based engineering consultancy which led the European project 'Safer Road Trains for the Environment' (SARTRE). Vehicles follow automatically behind a lead vehicle which is driven manually. The vehicles use existing vehicle- to-vehicle communication technology, commercial or near-market cruise control, and emergency braking systems, with some software enhancements, to control the position in the lanes and the spacing between the vehicles. This method of automation is of particular interest to the freight industry. It increases fuel efficiency as the vehicles can be more closely spaced, hence reducing drag. There is also the potential for drivers in the following vehicles to count hours in the platoon as 'rest' although at present this is not possible, as drivers must remain alert to comply with traffic regulation.

Autonomous Private Cars – University of Oxford [6]
The RobotCarUK project at the University of Oxford aims to create an inexpensive system using off the shelf technology to automate a standard car. It has developed the sensing and control technology to allow a Nissan Leaf to drive autonomously on routes which have previously been mapped by human drivers. To increase automation, the cars will also collect data on how other road users behave allowing the car to learn to recognise situations and act accordingly. The group aim to license the technology to automobile manufacturers.

Impact of Autonomous Vehicles
Proponents of autonomous vehicles say such vehicles could improve road safety, reduce congestion and emissions. This section discusses the predicted impact of the technology and explores the feasibility of these claims.

Safety
Some researchers suggest that autonomous vehicles would increase road safety. The majority of road accidents are caused by human error, with only 5% due solely to technical failure. However, the safety benefits are not clear cut, because although fewer accidents will be caused by human error there may be new categories of accidents, for example between autonomous vehicles and other road users. Autonomous vehicles must interact safely with each other as well as with pedestrians, cyclists and manually driven vehicles. Research into the interaction between autonomous and manual vehicles is ongoing, using computer modelling and driving simulators as well as testing on public roads.

Transferring control
Vehicles also need to be able to transfer control to their human drivers. There is no consensus on how this should be done, especially if the transfer is expected to occur whilst the vehicle is in motion. This transfer has legal implications, as detailed on page 4. In the event of the automated system failing the vehicle needs to remain safe. Systems to verify that the human driver is alert and capable of taking over are in development. Another approach is to adopt a system with many backups, similar to that used by the aviation industry. Drivers would need to be trained to understand how automated systems work and driving tests would need to be adapted.

Congestion and Traffic Management
Proponents of autonomous vehicles suggest that automation could help relieve congestion in two ways. Firstly, wirelessly linking autonomous vehicles to form platoons (Box 2) reduces the road space required per vehicle, as the stopping distances are shorter. However, with a mixture of autonomous and manual vehicles on the road, this is not straightforward. Autonomous vehicles would need to be able to coexist safely with manual vehicles. The spacing of vehicles, both within and between platoons, would need to be carefully tuned to ensure that these platoons did not prevent other vehicles from using the lane. Transport researchers say that many of Britain's roads are close to capacity, so there is not space to dedicate separate lanes to autonomous vehicles.

Co-operation
When vehicles are not connected, autonomy mainly gives benefits to the individual driver, for example by freeing up their time to perform other tasks. Reports by the Automotive Council and the EU working group stress that to obtain the greatest benefits from autonomous vehicles, co-operation between vehicles is necessary. A co-operative system of vehicles and other modes of transport could have benefits, such as enabling traffic management to relieve congestion.

Environmental Impact
The environmental implications of autonomous vehicles are subtle. On the one hand, smoother driving with less acceleration and braking, results in lower carbon dioxide and particulate emissions.[7] Autonomy could also mean that more that more journeys were made in low emission vehicles, for example electric pods for short urban journeys. Reduced congestion would also reduce emissions. On the other hand, if autonomous vehicles do increase road capacity, this could lead to more vehicles on our roads, thereby increasing emissions. Also, autonomous vehicles may lead to more car sharing explain why, as cars could travel independently between users. There is limited research on the effect this would have, but some research suggests that car sharing could increase the number of journeys made by car, in preference to other modes of transport.[8]

Barriers to Adoption
Fully autonomous vehicles are a longer term goal of both policy makers and manufacturers, with EU and UK technology roadmaps predicting they will be on sale from 2025 and Google predicting 2017. However, there are

issues to address with the technology, with public perception and with the regulatory framework. These will have a major influence on how soon the technology can be adopted.

Communication Infrastructure

Autonomous vehicle prototypes, such as those being developed by the University of Oxford (Box 2) and by Google, function without real time communication between vehicles, as the infrastructure is not available. If the infrastructure were available, there could be benefits to safety, the environment and traffic management, as described in the previous section. However, a number of issues first need to be addressed. One of these is network coverage. Another is standards, which still need to be established. The standards for short range Vehicle-to-Vehicle (V2V) and Vehicle to Infrastructure communication are an active area of research and are still under discussion at an EU and global level. Further issues with machine to machine communication are discussed in POSTnote 423.[9] Currently V2V communication systems are being developed on an ad-hoc basis. These proprietary systems risk being incompatible, which means the development of vehicle cooperation could be hampered. The Society of Motor Manufacturers and Traders (SMMT) says that rapid deployment of this technology would be aided by clear standards to encourage compatibility between systems.

Under proposed EU legislation, all new cars are expected to have an inbuilt SIM card from 2015/16 onwards. The legislation is aimed at allowing cars to transmit and receive data over the mobile phone network following an accident. This can be seen as an initial step towards allowing cars to communicate routinely via the mobile phone network.

Cyber Security and Privacy

Communication systems would need to be robust and fail safely in case of corruption or cyber attack. Multiple backup systems would be required in order for autonomous vehicles to function safely in the event of communication systems being jammed or simply not available. Autonomous private cars such as those developed by Google and the University of Oxford, are reliant on data generated by other vehicles. There are privacy concerns over who would have access to this data and how it might be used. The University of Oxford has argued that the data acquired by the vehicles could be exploited for research and/or commercial purposes.

Public Attitudes

Very few people have ever travelled in an autonomous vehicle. In a recent survey of AA members, 65% of respondents agreed with the statement that ‘I enjoy driving too much to want a driverless car’. Respondents were divided as to whether advances in technology would allow such cars to be as safe as humans. It is reasonable to assume that few, if any, of these survey respondents, had ever driven in an autonomous vehicle. Customer satisfaction with the Heathrow pods is high and reports from journalists who used the SARTRE platooning system were positive. The Technology Strategy Board and the EU see demonstration projects as a way of introducing autonomous vehicles to the public and increasing acceptance.

Policy and Legislation

There is no explicit legislation which governs autonomous vehicles on UK roads. UK traffic regulations are based on the Vienna Convention on Road Traffic (1968) which requires the driver be in control of his or her vehicle at all times. The UK has signed but not ratified this convention. When testing prototypes of autonomous vehicles, a human is always present in the driving seat in order to take over in case of fault, so the systems remain in compliance. If the driver is engaged with other tasks, then handover of control is not instantaneous and this would not comply with the convention. This raises questions as to how autonomous vehicles could be best regulated to operate safely given the current absence of international standards.

At present there is no published strategy for the adoption of autonomous vehicles in the UK. The Technology Strategy Board feels that this lack of guidance is hampering technological progress. DfT is commissioning a scoping study to look at the barriers to implementation.

Safety Certification

Automated systems are becoming a safety requirement in consumer rating programmes for new cars: Automated emergency braking in response to other vehicles will be necessary from 2015. Without this, the highest (5*) safety rating will not be obtainable. As autonomous vehicles develop, systems will be increasingly interlinked, controlling brakes, accelerator and steering. Regulatory systems currently designed to test each system separately may need to be revised. New standards capable of verifying the reliability of autonomous control software will also need to be devised.

Liability and Insurance

There is ongoing discussion about liability in the event of an accident involving a vehicle which was being driven autonomously. With the current prototype systems, liability will probably be decided on a case by case basis in the courts, but this would not be suitable for wide scale deployment. The insurance industry would also need to update their processes as current risk modelling is based on the behaviour of a human driver. The SMMT suggests that increasing levels of automation will need to be supported by developments within the insurance and legal sectors.

Endnotes

1 DfT, 2013. *Action for Roads: A network for the 21st century*
2 UK Automotive Council, 2011. *Intelligent Mobility: a national need?*
3 NHTSA, 2013. *Automated Vehicles Policy*
4 www.ultraglobalprt.com/
5 www.sartre-project.eu/
6 http://mrg.robots.ox.ac.uk/robotcar/
7 EU Automated Vehicles Working Group, 2013. *Automation in Road Transport Road Map*
8 S. Le Vine, 2011. Strategies for personal mobility: *A study of consumer acceptance of subscription drive-it-yourself car services*.
9 POSTnote 423, 2012, *Machine-to-Machine Communication*.

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POST is grateful to Anne Pawsey for researching this briefing, to the Engineering and Physical Sciences Research Council for funding her parliamentary fellowship, and to all contributors and reviewers. For further information, please contact the co-author, Dr Chandrika Nath.