Impact and benefits

1. What are the potential applications for autonomous vehicles?

2. The term autonomous vehicles could cover a range of instances; truly autonomous, remote operated, or even semi-autonomous. The term ‘Autonomous’ itself suggests no human involvement at all. In some applications, this state will arise eventually but there will be a number of stages, with different levels of autonomy prior to this.

3. Application could be far reaching, and we have outlined possible applications below:

   - **Air**: parcel delivery e.g. Amazon’s UAVs. Airline piloting may also be autonomous in the longer term; this is already to some extent but pilots are highly trained in order to monitor the status of the system so that they can respond to emergency situations.

   - **Maritime**: freight/container ships and shipping, especially in open waters, but more critical in narrow and busy channels such as the English channel. It is likely this application would be seen sooner due to fewer issues than some application areas, such as aviation.

   - **Public roads**: cars and buses, however, as above there will be different levels of autonomy. Truly self-driving cars will not be operational in the near future on public roads due to the challenges in the aspects of technology, policy, behaviour and business models; different levels of autonomy will be required in different settings. This will cover both consumer products such as privately owned vehicles as well as public transport such as buses, taxi’s and freight. Application in freight is where the strongest cost benefit arguments exist such as platooning of trucks.

   - **Space**: this is effectively already happening, for example, space craft that dock with the International Space Station as supply vessels.

   - **Military**: a number of applications are already utilised by the military, such as truck platooning and remotely piloted UAVs. Bomb disposal activities are currently semi-autonomous.

   - **Warehousing**: use of specific tracks for transport of goods around the warehouse.

   - **Metro and rail**: cab driving applications (to some extent again, this is already present with the Docklands Light Railway and the planned refurbishment of the Metro system in Glasgow).

   - **Ambulance services**: truly autonomous vehicles will start to play a role in emergency care; whether by design or not passengers will arrive at A&E unconscious; better that we plan for this.

   - **Precision Agriculture**: this application is already well developed and is set to expand.
4. Looking at application to privately owned vehicles, truly empty cars with no people, or completely “hands-off”, are unlikely to be seen on public roads for 20-30 years. They will however be seen sooner in constrained environments such as pedestrianised areas or theme parks. In the next few years future application of degrees of autonomy in consumer cars will be present on public roads. ‘Drivers’ will be present but with only occasional involvement required.

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

5. We envisage the key benefits to be as follows:
   - Safety and efficiency or productivity; both economic and environmental – these will be key drivers across all applications. For example, practices such as platooning reduce fuel costs, automated cars are more fuel economic than manual driving. In the future where high levels of autonomy are present, this will replace the need to employ drivers or even it will allow drivers the time to undertake additional tasks. This is the same for application in freight, marine and aircraft.
   - Autonomy will also stimulate the economy and therefore indirectly benefit users through the development of new products.
   - Benefits may accrue from incentives or subsidies that may be offered to users to encourage uptake of the technologies e.g. subsidies for purchasing autonomous vehicles - this could provide economic benefit.

6. Disadvantages:
   - Increase in unemployment as driver roles become replaced by autonomous vehicles.
   - Users begin to rely on technology; complacency and over trust begins to develop. For privately owned/consumer products there is a higher potential for over reliance with users assuming 100% reliance which can result in accidents e.g. the recent Tesla incident.
   - Pedestrians might also become complacent assuming that autonomous vehicles would avoid them and therefore they cross roads at any point. This raises a number of issues around the behaviour of vulnerable road users on public roads.
   - Cyber security threats: the more reliant users are on these systems the more vulnerable they are especially when opening out communication between systems (connected vehicles). For example, car companies are steering away from hosting content on the cloud due to security fears.
   - Safety risk to users may arise as a secondary impact due to adaptation of behaviour by others. Research exists that shows other vehicles change their behaviour in response to autonomous vehicles being on the road such as changing to shorter headways making the new norm in the traffic flow different. For example, autonomous vehicles break differently, they are highly conservative and this will unconsciously change the way that manual drivers respond.
   - As noted from aircraft incidents, a problem can become a disaster when switching from autopilot to manual driving in emergencies, much more work is needed to understand this.

7. Benefit/disadvantage depending on perspective:
   The role of the user will change in autonomous vehicles. They will go from being a
controller of the vehicle to a monitor of the status of the vehicle. This will have implications on driver training and may necessitate new types of training.

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

8. Very little and the impacts will be highly distributed. For example, fully autonomous vehicles would enable elderly non-drivers to choose to live in rural areas, which could radically change housing and infrastructure demand.

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

9. The UAV / Drone Industry is an excellent place to look. There has been a technological and market revolution over the past 10 to 15 years. The public and regulatory debate and response has been intense and is on-going. Research can easily include the growing body of academic work, but there is also real-world material from government regulatory authorities (FAA, CASA, CAA etc), drone industry lobby groups, drone amateur enthusiast lobby groups, Anti-drone lobby groups, legal and insurers etc. Drones are probably the autonomous vehicle system which has had one of the greatest general public space proliferation and penetration of any to emerge in recent times. Highly regulated aerospace automation in human inhabited air vehicles is ongoing, but is also the subject of heated debate within the confines of the industry.

10. Outside of drones, very little accurate knowledge on public attitude exists. Lots of surveys have been published about trust and driverless cars but these are not useful for informing acceptance of a future technology. To truly understand attitudes, the public need to experience the vehicles first hand through full scale demonstrators rather than respond on a conceptual basis. Testing facilities and programmes are critical in this in this. The University of Nottingham has itself undertaken studies on user behaviour when commuting for a week using driverless vehicles. User behaviour changed from day one to day five to show an increase in trust. There is a concern in the academic community that surveys are not accurate and as such should not be used to influence policy or governmental decisions.

5. **What is the scale of the market opportunity for autonomous vehicles? Creating an enabling environment Research and development**

Creating an enabling environment

Research and development

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

11. Simulation facilities are critically important for both research and technology development. They have a very strong role in enabling researchers and companies to understand user behaviour and develop autonomous vehicles that are appropriate for use. In addition, they provide excellent training facilities as we move towards a new way of driving – much in the same way pilots will use simulators, these will allow us to develop safe driving practices on public roads.
12. Overall, the existing facilities are adequate but there is an opportunity to supplement this through advanced simulation where you can test things that you wouldn’t on public roads where it is not safe.

13. There is a concern that some demonstration facilities and initiatives are unconnected. There are a number of test facilities such as MIRA that are available alongside a number of facilities located across different universities and geographies but there is also investigation into the development of a holistic test site that may well duplicate what is already present. Some demonstrator projects exist that need be joined up to make the most of innovations. In addition, there are rafts of European projects looking to demonstrate autonomous developments. Whilst there is breadth the lack of connectivity makes it difficult to judge the sum of these parts.

14. Again, the drone industry has significant numbers which are easy to find. There is also a good body of research in the field of Personal Air Vehicles (PAV) which will rely on automation to succeed. An excellent case study to highlight the fact that society issues far outweigh technological capability in implementing these systems.

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?

15. Funding for research and development is being provided though, for example, the EPSRC. Indeed, autonomous vehicles directly align to the EPSRC focus on a connected and resilient nation and there is a need for fundamental research funding; continued significant investment into bodies such as EPSRC are essential.

16. Current funding has some effectiveness. It is important however that it continues alongside the important investment in infrastructure in the UK. We note that there has been a recent agreement between the Transport Systems Catapult, the Future Cities Catapult, the Satellite Applications Catapult and the Digital Catapult to collaborate around these issues and we fully support this move.

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

17. One challenge to accessing support from Innovate UK is that there is only really one major car company in the UK that is active in research and they are not a big player when it comes to automated driving. The academic and research community needs methods to collaborate with international car companies and draw down Research and Development funding; a number have manufacturing bases in the UK but no research base.

18. We support there being a number of avenues for funding such as Innovate, CCAV and the Research Councils in order to ensure it is not all through one body such as the automotive Council and allows for inclusivity. The peer review process of IUK and EPSRC is highly valuable.

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

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

19. Changes to both types of infrastructure can be foreseen. Looking at the digital infrastructure, if autonomous vehicles use GNSS or similar there may be issues of cyber security, jamming, spoofing and issues with signal reception in built up environments. There is currently no positioning system which can provide a backup to GPS or GNSS; and cyber security is a real issue. Both Europe and the US have recently shut down terrestrial back-up systems to GNSS (known as eLoran), although the US are set to reverse that decision. For companies such as Jaguar Land Rover, autonomous features are based on RADAR, LIDAR and cameras, but this is only a part of the provision – this may cause issues of reliability. Reliability issues come about where systems such as LIDAR and cameras may no longer operate or function as they are not able to recognise road features (e.g. deep snow, or a low sun angle and wet road with can distorts the vision of the road and impact capability). Sensors alone will not have an accurate vision so multiple digital infrastructure is needed. An ideal solution is an integrated system where GNSS is a part of the answer.

20. Changes in physical infrastructure will also be required. If fully autonomous vehicles are used by the public they may need to be running on a separate road, parallel to manual drivers resulting in challenges around the required infrastructure and the costs of this. The UK is much less prepared for this than China for example.

21. When thinking about physical infrastructure changes, different road surfaces may need to be considered due to driving style, different design of vehicles also such as lights/indicators etc and looking at the most appropriate ways of communicating the different functioning of the autonomous vehicles.

22. There are many examples from Aerospace where much of the potential for modern systems is compromised or defeated by legacy. The aviation certification system makes change slow, lead times are usually in excess of technological development cycle times for instance in mobile telephony. However, some constraints such as lack of dependability of GPS leads to more robust systems development such as ‘Sensor Fusion’ and ‘Signals of Opportunity’. In these, any and all available sources of data are used. Example, TV / radio station transmitters, may be used for position fixing when combined with accurate data base of source location and characteristic. Lidar or radar sensors can locate position of electrical power distribution networks (power lines) or roads, again referencing data base knowledge of geometry etc.

11. How might a move from current levels of highly automated vehicles to their extensive deployment best be managed? What do you see as the key milestones?

12. Does the Government have an effective approach on data and cybersecurity in this sector?
13. Are further revisions needed to insurance, regulation and legislation in the UK to create an enabling environment for autonomous vehicles?

23. Costs and subsidies (financial or compliance/legislative) could be a big motivator for people to have an autonomous vehicle. If, for example costs are too high for a manual car and this enabling environment may arise naturally through cost incentive e.g. due to the driving style, autonomous cars have lower emissions and stay within a safety threshold therefore lowering the insurance and tax costs.

24. Whilst not necessarily ‘enabling’ revisions to insurance will need to occur in order to take account of the following:
   - a ‘danger’ algorithm.
   - Liability regime that is different to manual driving.
   - Premium models (if the cars no longer crash where do insurance companies make their money).

25. Legislative considerations will also need to be made, specifically with reference to understanding the status of the driver in any given state or situation. With highly automated driving there will be problems if the car doesn’t understand that status of the driver and adjust manual intervention times accordingly e.g. if the driver is sleeping it may take longer to intervene or they may have no capability to respond and take a decision/control.

14. What, if any, ethical issues need to be addressed in the substitution of human judgement in the control of vehicles by algorithms and Artificial Intelligence? Wider governance

26. A number of ethical issues arise here that will influence acceptance of autonomous vehicles. For example, if a car kills one person and not another there will be considerations of how to make decisions that favour one person over another.

27. As discussed previously, in aiming to understand issues of “human judgement”, it is necessary to measure and study humans, not ask them what they would do by survey – the latter is a philosophical thought experiment, which does not provide insight into human judgement in time critical situations. So before deciding on such a philosophical definition of human judgement, we need research into what human drivers actually do in an emergency before judging algorithms.

Wider governance

15. What does the proposed Modern Transport Bill need to deliver?

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

28. Skills that we believe are needed:
   - Computing
   - Institute of civil engineering (infrastructure)
   - HFRG ergonomics
• Engineering in general (electrical, mechanical – all fundamental technologies)
• Autonomous vehicles are alongside electrical

17. Is the Government’s strategy and work in this area sufficiently wide-reaching? Does it take into account the opportunities that autonomous vehicles offer in a wide range of areas, not just on the road?

18. What are the implications of exit from the European Union for research and development and the autonomous vehicle industry in the UK? Are specific actions from the Government needed to support or protect the autonomous vehicles sector in the short term or after the terms of Brexit have been negotiated?

29. We will wish to maintain the EU as a major export market and so we should ensure work focusses on common standards, indeed such standards should best if internationally agreed.

30. In common with all existing EU R&D collaborative programmes under Horizon 2020, if the UK government wishes to maintain its standing internationally, replacement funding sources will be required. However, while maintaining some R&D links with the EU will be important, replacement funding should encourage more widespread collaborations. Such mechanisms are coming into place with the Global Challenges Research Fund for OECD developing nations, but mechanisms for collaboration with, for example, non-EU G20 countries.

Other comments:
• Change acceptance will be more challenging for older more experienced drivers. If there is an insurance break for younger drivers, they will be more accepting and engage.
• We may see a move away from cars as a product I buy to a service. Especially if the pricing system works; fewer young people are buying cars and have drivers licenses. Extension of the Boris bike model.

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